POLITICAL ECONOMY OF LATE INDUSTRIALIZATION IN HIGH TECH: POLITICS, POLICY, AND INNOVATION IN THE KOREAN AIRCRAFT MANUFACTURING SECTOR

By

Choi, Jung Hyuk

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A long crossing has finally come to an end. After six years of sleepless nights, stranded in a lonesome solitude of desperateness, while compelling sacrifice to the unrecoverable moments of destitute, have I laboriously delivered this transcript of resolution. Undoubtedly the achievements are never championed alone, by virtue of the given fortune I chose to eschew over the dubious expectations for gaining this higher grounds of wisdom. I am therefore deeply appreciative of the teachings provided from many who have assisted this endeavor throughout the bygone days of exertion. The historical materials and insightful knowledge shared from fellow colleagues who constantly yielded intriguing motivations in contriving the main reasoning of this thesis have invaluably contributed to bringing the final draft into fruition. My supervisor, Professor Park, Hun Joo, has counseled me far more than as an instructor, but furthermore as a teacher provoking intellectual enlightenment. The treasured guidance and recommendations from the distinguished members of my dissertation committee have augmented the limited perspectives of my interpretation towards sophisticating the core hypothesis of the central debate. My co-workers have willingly devoted their time and efforts in refining and broadening my narrow thoughts and parochial argument. However, to the greatest extent possible, I am deeply indebted with profound gratitude over the faithful devotion from my family – my mother's wholehearted prayers for my success and wellness, my father in-law and mother in-law's sincere encouragement, my sister and her family's stimulating support, my grandmother's unlimited confidence, and the thankful wishes goes on and on. But above all, I am most humbled and grateful to my children and wife. Younglin and Yehwon have been my muse and passion for continuing this venture in times of utmost anxiety and exhaustion. My long lasting companion, Minjung, has candidly rendered her unequivocal conviction in all respects of completing this task. Lastly, in remembrance of my late father's visionary inspiration towards education, the entirety of these elements constitute the golden pillars for preventing me from languishing into indolence. For these reasons, I hereby dedicate this manuscript to all who have embolden me to stand firm and finish this journey.

ABSTRACT

Political Economy of Late Industrialization in High Tech:
Politics, Policy, and Innovation in the Korean Aircraft Manufacturing Sector

The study intends to review the prospects of bolstering sectoral capacities in East Asian developmental states over the course of building institutional infrastructure in highly complex technological products with a focus on aircraft manufacturing. In the case of the late industrialization process of East Asian catch-up economies, theory revealed the astonishing economic performances that arouse from established institutional arrangements, which were engendered unique towards the country's idiosyncratic political attributions. Leaving behind the glorious economic achievements of late industrialization, however, East Asian developmental states have been struggling in its attempts of enhancing sectoral competitive capacities into intensely science based areas of highly advanced technological fields.

Industrial upgrading has been the talk of the town the past few decades in Korea, as the fast following sectors in technology catch-up started to foresee the stalling growth patterns emerging across its economic sphere. In order to grasp the growing economic potentials of high tech advanced products such as in aircraft-manufacturing, the national innovation systems of Korea attempted to accommodate emerging developmental challenges through established institutional arrangements in R&D, production, and industrial competition structures, which once proven its effectiveness during the earlier days of rapid industrialization. Over the process of industrially upgrading into these knowledge-based capital intensive sectors, the domestic institutional arrangements, in association with external international conditions, which facilitated achievements in fast economic catch-up, have turned cumbersome in terms of transitioning the country's innovation system adaptive enough to accommodate the more complex technological challenges. Vertical stovepipes streamlined towards state driven economic development policies have somewhat become obsolete as the institutional construct, shaped attune to the processes of late industrialization, has exhibited incompetence over regulating spontaneously grown sectoral firm based capacities and competitiveness in advanced technological manufacturing fields. Thus, the inherent developmental complexities unfolding in a highly technological Schumpeterian Mark II sector increasingly present convoluted challenges against established institutions of the national innovation systems. The situation materialized ostensibly evident in the Chaebol dominated industrial composition of the Korean aircraft-manufacturing sector where government competition policies did not perform well enough to fulfill the developmental aspirations of aircraft manufacturing. The proposed framework of analysis for this study attempts to accommodate relevant contemporary theories made known from a bundle of innovation studies, which include the theories of national innovation systems, varieties of capitalism, developmental state, and complex product systems. The theory illuminates the sectoral innovation systems demonstrated from the technological regimes of the Schumpeterian Mark II sectors, of which translates into the situation of the Korean aircraft-manufacturing sector. In this regard, the

proposed analytical framework developed from these point of views highlights the role of coordinative mechanisms that interconnects national-regional-sectoral levels of innovation over a chosen high technology sector. The absorptive capacities of key actors and diffusion mechanisms of established institutions constitute the major analytical point of this coordinative mechanism.

The main argument of the study asserts the need to effectively build cross sectoral coordinative mechanisms throughout the national, regional, and sectoral level of analysis, while exerting concerted efforts to overcome the multiple layers of hurdles against late entrants into technologically complex business areas. Consequently, regarding an attainable solution for Korea successful accession into highly technological sectors, the paper necessitates the transitional efforts of transforming a rigid state-led innovation system into a spontaneously integrated coordinative institutional structure, which accommodates a broad spectrum of absorptive capacities and diffusion mechanisms tailored for developing complex product systems.

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Chapter 1. Introduction

Jae was once a promising athlete in his college soccer team. Although he started the sport late in his high school year after being handpicked into the team by the school head coach, he rapidly improved his skills and performances based on the substantial support provided by the school and his team mates. Superior in physical conditions, standing nearly six feet tall with an exceptionally flexible and agile footwork, Jae dominated the high school division leagues, which earned him a soccer scholarship into college.

After leaving behind the accolades of his varsity team glories, Jae was drafted with a second overall pick into a renowned professional soccer team. His performances in the league, however, came in a little shy from the high expectations as a first class player. The game plan turned more complex than the college division leagues. After five years into professional soccer, he was compelled to understand the nature of the games the hard way in a sense that the professional leagues applied different rule sets and customary practices from amateur high school leagues. Jae noticed he did not obtain the requisite skills to dribble the ball against a sturdy defense line. He did not have the wide viewpoint of observing the field as to where to effectively pass the ball. Jae was used to playing comfortable games where he simply positioned himself nearby the goal while his team mates from college and high school laboriously passed him the ball to score goals. Jae could no longer rely on the old way of playing games he used to play, at which he now had to set the conditions of the game for his team mates and himself. Competition was intense, not only against adversary teams, but also within the team itself, contesting against multiple players over certain team positions. Hence, Jae was placed in a predicament in terms of adapting into the new set of governing norms and regulations of professional soccer. His late entrance into the sports and biased team tactics once given him the fame and glory in the lower leagues of the sport, but became no longer valid in the professional leagues. The earlier set of rules in high school and college shaped Jae's performing skills mediocre in rating compared to other players in the professional league, which mean he came to play the sport without possessing the basic preconditions of becoming a competent soccer player. And these skills are not what someone can build-up overnight. How can Jae overcome the quagmire of this transition and successfully establish his reputation in the league?

This is a situation commonly experienced by East Asian late industrializing countries at the moment of attempting to transition into higher value added technological sectors. The relative economic backwardness supported by a powerful state-influenced market economy has enabled Asian developmental states to rapidly catch-up technologically with its contemporary industrial competitors. The institutional composition of these countries, arranged in a way that uniquely reflected the respective national idiosyncrasies of its innovation system, have engendered the developmental engine to outpace its Western European and American forerunners in economic growth rates and technological achievements, primarily concentrated in consumer products and relatively low-profiled industrial commodities. The dazzling accomplishments in electronics, automobiles, shipbuilding, and so forth, exemplify the way how specific institutional compositions in government driven economic planning, associated with selective state-business relationships, assisted by the streams of international trade conditions, resulted in what the contemporaries label as the 'East Asian Miracle'. However, as the competitive circumstances change, triggered by the emergence of rapidly modernizing developmental states from other parts of the world, mainly China and the periphery Southeast Asian economies, have swiftly taken over the comparative advantages in the traditional sectors where East Asian developmental states performed strong influence in the global market. In this regard, countries like Korea and Taiwan have been striving to move up into the domain of high tech sectors such as biotechnology, aerospace, robotics and artificial intelligence, etc., where the platforms are connected into a cascade of interconnected systems that constitute a complex manufacturing structure of networked products. The gaming rules substantially differ from the playing grounds where East Asian developmental states excelled. This new domain demands a high degree of mastery over the distinctive characteristics of nonlinearity, intuitive regulations, adaptive behaviors, and feedback loops, at which the role of the state becomes marginalized and market mechanism strongly relies on the spontaneous order of the interconnected structure of the national innovation system. Respectfully, the once successful East Asian developmental states have shown difficulties in penetrating into this domain. The existing institutions that once celebrated success and prosperity have now turned obsolete. Thus the idea of innovating these customary industrial arrangements into a socio-economic structure effectively adaptive to the new technological challenges has presented a puzzling problem to these countries.

Innovation is a pervasive term that encompasses the ideas of progressiveness and change. The lifecycle of a firm, organization, or country is highly dependent on how these entities adequately respond to exogenous, if not endogenous, changes, hence institutional flexibility to adopt innovation. However, there are instances shown through history that represent certain characteristics of an institution showing favorable terms for innovative ideas. On the contrary there also exist elements that function as stumbling blocks in accepting the incoming waves of innovative changes. No one hardly imagined a half century ago that a war torn society like Korea with the world's highest illiteracy rates and lowest per capita income would become a rising global economic powerhouse that produces high-tech commercial products in addition to illustrious cultural fascinations. Nonetheless, history frequently shows the ebb and flow of these occasions which still continues even now. A number of evidence show that institutional factors contribute in large part to innovative changes.

Innovation is often used in mixed terms with inventions, whereby inventions are generally used as expressing "newness" of technology or other conceptual figures, whereas innovation is termed as expressing the "process" or "adaptive implementations" of inventions.[1] For instance, the idea of a helicopter that was first conceived by Leonardo Da Vinci in the medieval period was nothing less but an "idea" at that time; the lack of materials, engineering job skills, accumulated knowledge in

[1] Jan Fagerberg, "Innovation, a guide to the literature," in Fagerbrg, Mowey, and Nelson, Oxford Handbook of Innovation, p. 5

aerodynamics, power engines, etc., lingers the illusiveness of these images in the domain of imaginative fantasies. It was not until the modern era after the industrial revolution and the conceptual illustration of flying transformed into reality science in mainstream aeronautics and dynamics that enabled the engineering of the helicopter. In this regard, the appropriations of innovation are contingent upon the maturity of systems that supports the full implementation of these new innovative ideas into physically real figures. Here, we see the need to define the scope and role of the governing systems that materializes these new inventions into commercial commodities. The arrangement of these systems, or in other words institutions, normally come analogous with norms and values that are materialized in legal systems, informal rules, or common knowledge acquired by actors through history and culture of a group, society, and nation. The widely acclaimed institutions of the developed world are those that revolve around the market economy, hence different forms of capitalism showing different institutional tendencies toward innovation. In this aspect, different governance systems of market capitalism determine the various customs of innovation.

The case of the Korean aircraft-manufacturing sector is evidence to this line of thinking. The aircraft-manufacturing sector is commonly labeled as a high tech profession that incorporates a system of complexity, or complex product systems (CoPS), such as aeronautical dynamics, avionics and armaments, intricate networks of radio-navigation, and so forth. In this matter, the Korean aircraft-manufacturing sector is considered a wonderful subject to study the advantages and disadvantages of technological innovation regimes both in the public and private spectrum. The industry has been supported by various policy incentives and given preferential treatment under numerous government contracts, but the qualitative scale in technological development trends has remained slow, if not stagnant, after reviewing the achievements shown from the progression of major development programs. Instead of striving for a highly competitive stature through relentless efforts of innovation, the industry has become lopsided in a domestic cutthroat competition against each other. Nonetheless, the government continues to announce ambitious military projects with overly optimistic forecasts with hopefuls for accompanying substantial trickle down effects, aka spinoffs, into other business sectors, whereas the flagrant reality signifies unimpressive innovative accomplishments.

In a comparative point of view, the Korean aircraft industry has been placed far lower in competitiveness against its overseas contenders, coming 17th in place internationally behind Taiwan and Brazil. Already in the late 1980s and 1990s, both Taiwan and Brazil successfully accomplished indigenous production of its own fighters or commercial airliners, whereas the Korean aircraft industry to date has not been able to come in pair with the aircraft-manufacturing sectors of these two countries. Even compared to other domestic business sectors such as automobiles, shipbuilding, and consumer electronics, the accomplishments of the aircraft-manufacturing sector have not shown much impressive performances. Was the government policy wrong in the first place or was it the industry’s reluctance to adaptively transform into necessary competitive dispositions? Even now, though the sector is positioned in a critical juncture to replace its primary fighter jet, which appeared evident in the bidding process of the Air Force's Future Fighter Experiment (F-X) program and the Korea Fighter Experiment (KFX) program, spectators constantly witnessed the absence of a strategic vision and systematic efforts that synchronizes a construct for technological innovation. I had the opportunity to routinely deal with these challenges in the aircraft industry throughout my professional career and found it a pity to see honest and sincere developmental efforts and valuable resources, both national and corporate, became buried under the debris of domestic politics and sectoral inertial resistance. Thus, the landscape of the Korean aircraft manufacturing sector replicates the analogy of the gazelles from the 'Red Queen'.

The national innovation systems for late industrialized countries currently confront inherent challenges in sustained development and industrial upgrading. Especially for industrially fast following countries like Korea that went through a process of rapid economic catch-up and technological development, now finds its place on top of the S-shaped learning curve while faces sluggish growth rates in the midst of institutional hurdles when entering into the high tech domain of complex product systems. The country's institutional arrangements and organizational setting that were considered suitable for technology imitation during the fast-paced economic development phase have now turned obsolete and are in dire need of substantial repair and overhaul in order to keep up with rapidly transformative competitive circumstances in the course of sustaining innovation momentums experienced throughout all technological dimensions. Hence, the old Schumpeterian business cycles of 'creative destruction' for achieving 'technology innovation' for 'economic growth' come into being. However, the reform efforts, under the vernaculars of 'creative destruction', are hindered by stove-piped bureaucratic inefficiencies that obstruct the mechanisms of interagency coordination and technology innovation. State-business relations represented by crony capitalism that once generated the economic growth engine for some East Asian developmental states have grown out of proportion and demonstrated intrinsic limitations in integrating and exploiting innovative opportunities. Hence, the developmental state theory that once swept the literature of development economics and East Asian political economy requires some reconstruction work.

The challenges of national innovation systems in the aspects of state-business relations and national science and technology authorities appear obvious within the distributed architecture of defense acquisition systems. The defense industry and weapon system procurement apparatus are deeply influenced by government policies and bureaucratic dynamics. The South Korean aerospace and defense sector perfectly fits into this framework. The government nurtured the defense industry through large amounts of subsidies and technological assistance, which enabled the defense sector to grow in size and scope. As the defense sector reached its pinnacle in industrial catch-up, the issue of technologically upgrading the industrial capabilities to more complex weapon systems has become complicated. The state can no longer lead the way in industrial development and upgrading where at some point it became the obstacle in itself against innovation. Organizational inertia and restrictive bureaucracies have made it difficult to share critical knowledge and diffuse technology between major stakeholders throughout the total life cycle management system of defense products and systems. In this regard, the Korean integrated defense acquisition management architecture has come to a point where it is rated as a technical sector that marginally contributes to the domestic economy.

This study seeks to tackle some of the implicit restraints of state capitalism against late industrialized catch-up economies attempting to enter the high tech domain by using the Korean aircraft-manufacturing sector as a case study. The theme of this study derived from the following two elements.

1) Where does the theory of developmental states stand in the innovation discourse?
    - National Innovation Systems perspective
    - Varieties of Capitalism perspective
    - Firm based theories (CoPS) vs. Statist theories (Catch-up Economies)
2) What challenges confront developmental states in technology and industrial upgrading?
    - Domestic institutional factors
    - International systemic factors
    - Inherent technological factors

The study intends to critique and answer the research questions further developed from these two motivations in regards to the institutional aspects reflected in the given analytical framework. In this respect, this study intends to focus on the institutional elements of innovation, especially on the aspects of adopting new technological developments, and strives to answer the following questions; how technological innovation permeates institutions; what are the optimal conditions for institutions to become adaptive to technological innovation; How do these innovative elements in the micro-level become viral and evolve into the macro-level, henceforth the formulation of national systems of innovation. The main scope of innovation covered in this paper is limited to technology and the institutional aspects how these innovations occur within the national systems of innovation.

1) Evolution of the developmental state theory.
    - Shortcomings in technology upgrade
    - Changing role of the state in evolutionary aspects
2) Contributing dynamics of institutions to the diffusion of innovations.
    - Role of national innovation systems
    - Interactions with market mechanisms
3) Characteristics of Schumpeterian Mark II sectors in aerospace and defense.
    - Changing patterns of global aerospace and defense value chain
    - Adaptive transition for developmental states
4) Evolution of state-business relations and consequences to the innovative performances of the Korean aircraft-manufacturing sector.

- National R&D policy and technology commercialization
- Corporate strategies under the context of national strategic interests

5) Disruptive causes that impacted on the innovation trajectory of the Korean aircraft-manufacturing sector.
    - Domestic structure vs. international systemic

In chapter two, the study reviews the literature of state driven economic policies that include the typologies of national innovation systems, complex product systems, comparative studies of capitalist regimes, and the developmental state theory. It reviews two layers of analysis as part of supplementing the comparative debate between National Innovation Systems, Varieties of Capitalism, and Developmental State theory. One layer that adds to this debate is the general theory of innovation networks that reviews the connectivity between S&T capacities, market mechanism, institutions, and public policy. The second layer presents additional thoughts on the ever evolving high-tech sector and the correlative aspects towards existing institutions, which is represented by the analytics adopted from Complex Product Systems (CoPS).

The third chapter provides an overall review of the global aerospace and defense sector. The chapter mainly follows the analytic framework laid out in Chapter two, which covers the innovation mechanisms over industry implementation within a global settlement. It then compares the technologically advanced industrial countries and the technologically emerging countries represented in Tier One and Tier Two industries by introducing the trends of the international aerospace industry and technological idiosyncrasies between first-tiered and second-tiered countries in this field.

Chapter four surveys the national innovation systems of Korea, reviews the competitive elements in science and technology policies, and scrutinizes the critical linkages with the local industrial chain. It then extends this framework specifically into the defense sector and assesses the connectivity between the national S&T and defense S&T apparatus.

Chapter five further investigates the framework in terms of how state sponsored institutions formed what is now the current shape of the Korean aircraft-manufacturing sector. The chapter constitutes one of the four main entry points of the dissertation regarding the institutional components for catching-up in the Korean aircraft industry. It outlines the historical aspects of the industry followed by reviewing the national innovation systems in science and engineering that constructs the essentials of the technological catch-up process. The chapter attempts to identify the reason behind the sluggish development trajectory of the Korean aircraft-manufacturing sector by surveying national level institutions and anchor tenets that connects the national systems with subnational actors.

Chapter six reviews the regional level and sectoral level institutions within the national innovation construct of the aircraft-manufacturing sector. It attempts to survey connection points between regional capacity building efforts and national policy directives. It then proceeds into sectoral level innovation dynamics by illustrating the consolidation process of local aircraft-manufacturers in the aftermath of the Asian Financial Crisis, and further efforts to sustain sectoral development and growth.

The following two chapters are case studies of specific developmental trends in Korea’s effort in aircraft manufacturing. Chapter seven examines the thirty-year history of the fixed-wing sector by reviewing the chronologies of capacity building through domestic and international efforts. It then dives into the development case of the T-50 Golden Eagle Advanced Supersonic Jet Trainer and scrutinizes the success and limiting factors of the program based on the given analytical framework.

Chapter eight extends the analysis from the previous fixed-wing case study, and further researches the rotor-wing sector as a separate branch of aircraft manufacturing, by reviewing the efforts to build-up capacity in rotorcraft manufacturing from the past thirty years of industry experience. It then reviews the Korea Utility Helicopter-Surion as a case study under the purview of the given analytical framework of national innovation systems and the role of state capitalism.

The concluding chapter reviews the analytical framework and developmental history of the Korean aircraft-manufacturing sector and strives to pull out the theoretical limitations and the lessons learned in applying the framework into practical case studies.

Before entering into the details of this study, I personally find it important to illuminate the general terminologies used in the text. When addressing the Korean aircraft industry, I use the term ‘aircraft-manufacturing sector’ to avoid potential jargons of misinterpretation with other business sectors relevant to this line of business. The term ‘aircraft industry’ is often confused between the manufacturing business and the airborne transportation business. Some people use it interchangeably as a single comprehensive business area whereas others distinguish it with a clear definitive boundary. In the defense industrial area of expertise, the field is often termed as the aerospace and defense industry, that covers a wide range of industrial products involving the full spectrum of weapon systems development and manufacturing. Also within the advanced industrial countries, the field is referred to as the aerospace industry that covers both aircraft manufacturing and the space exploration enterprise. Whatsoever, neither of these terms fit well into second tiered catch-up economies, at which the main effort relies on engineering and manufacturing of aircraft products. In the case of Korea, domestic aircraft manufacturing efforts mostly fall under this category, where the field gives very limited accounts over the space exploration field. Also, the production of aircrafts considers a very narrowly focused domain that becomes troublesome terming it as an ‘industrial’ field. In this respect, this study entitles the domestic efforts in producing aircrafts as the ‘aircraft-manufacturing sector’, but will often refer to the area as the ‘aerospace industry’ when juxtaposing it with a global anecdote.

Chapter 2. Theory and Analytical Framework

The world was astounded by the robust developmental achievements of the East Asian economies during the 1960s, 70s, and 80s. Japan and the four East Asian Tigers have demonstrated unprecedented state led performances in technological catch-up and industrial upgrading, captured in double digit economic growth rates in both scale and scope. However, starting from the mid-1990s, the long heralded achievements of East Asian economic development have stumbled into a stalemate, experiencing sluggish growth rates while struggling against apparent institutional challenges towards technological innovation. Thus, after reaching its peak on the S-curve, the institutional setting of developmental states that nurtured the rapid technological catch-up and industrial upgrading has somewhat turned obsolete, and to a certain extent, started to obstruct the competitive basis of the country's national innovation systems.

The study of national innovation systems and its supporting institutions traces a long tradition of interdisciplinary and comparative research between socio-economic components and politico-economic activities. Most studies of different capitalist practices primarily focused on political compositions, therefore the way how institutions are arranged and the ensuing interaction with different entities of the society have constituted the focal point of the analysis. The socio-economic approach contributed by the rich literature of national innovation systems (NIS) accounts for the impact of varying national institutional constellations in the micro/macro level analysis onto divergent innovative effectiveness.[2] The politico-economic approach, highlighted by the advocates of the Varieties of Capitalism (VoC) discourse, supplements the shortcomings of NIS theorists regarding institutional establishments whereby it further facilitates the incorporation of traditional institutional theory in the macro level of innovation studies.[3] The intent of this chapter is to form an analytical framework in innovation studies through identifying a convergent point between the three main line of thinking, and attempts to apply this framework in a regionally focused undertaking on late industrialization and economic catch-up in East Asia.

2.1. East Asian Capitalism, the Developmental State, and its Place in the Innovation Debate

Innovation in late industrializing countries is considered more of a learning process, thus it is often termed industrial technology upgrading that follows the phased implementing sequences of learning-imitation-adoption-adaptation, further leading into innovation in relative mastery and maturity of the

[2] Edquist, Charles, Systems of Innovation: Perspectives and Challenges, in Fagerberg et. Al., The Oxford Handbook of Innovation, 2005, p. 188.
[3] Hollingsworth, J. Rogers, Doing Institutional Analysis: Implications for the Study of Innovations, Review of International Political Economy No. 7, 2000, p. 43.

subject area industrial field.[4] Under this context, East Asian developmental states, pioneered by the early industrialization of Japan followed by the East Asian Tigers such as South Korea, Taiwan, Hong Kong, and Singapore, have demonstrated an effective statist role in terms of strategic intervention into the market that enabled these economies to rapidly catch-up with the global standards of economic excellence.

In this respect, developmental state theory refers to a pattern of state-led macroeconomic planning, which is often cited as state development capitalism most notably salient in the four East Asian countries stated above. The theory illuminates the rapid economic achievements in industrial sectors strategically chosen by the government – such as in relative low-tech sectors in regards to consumer electronics, shipbuilding, automobiles, ICT, etc., where the countries successfully earned the title of fast followers in par with advanced industrialized countries. The vibrant and dynamic intraregional industrial networks allowed a fluid transfusion of foreign investment and technology transfer opportunities. Industrial tools such as tariff barriers, export driven policies, centralized financial system, R&D subsidies and infrastructure development, etc., were factors that contributed towards maximizing national productivity.[5] In a technological sense, the East Asian relative economic backwardness, driven by strong nationalistic sentiments with perceived public aspirations of rapid industrialization to catch-up with Western industrialized countries, has motivated and facilitated the adoption of new technology and promoted further diffusion and exploitation of the subject technological field into industrial upgrading. Nowadays, the East Asian developmental states are more than ever technologically accomplished countries with proven competitiveness in the global economy and R&D networks. Representative characteristics of developmental states are strong state-level intervention in the market through the implementation of extensive regulatory market policies and the execution of state-led economic planning.[6] These strong nationalistic motivations combined with aspirations to catch-up technologically are often coined as 'technonationalism', and was used as a slogan to solicit the backing of the public to support the country's development excursions. It is a national ideology that weds the ideals of 'rich nation strong army' into the technological innovation process of indigenization-diffusion-nurturance in order to become more self-reliant in its industrial setting as well as its national security establishments. Technonationalism initially promoted the diffusion of dual-use technology in terms of spin-off (conversion from military to commercial) or spin-on (from commercial to the military).[7]

The combination of state capitalism, or big leadership roles, and the external advantages of late development, or second-mover advantages, spared East Asian developmental states from the

[4] Eduardo B. Viotti, "National Learning Systems: A new approach on technical change in late industrializing economies and evidence from Brazil and South Korea," Science, Technology and Innovation Discussion Paper No. 12, Center for International Development, Harvard University, 2001

[5] World Bank, *The East Asian Miracle*, World Bank Policy Research Report, 1993, p. 46.

[6] Adrian Leftwich, "Developmental states, effective states, and poverty reduction: The primacy of politics," UNRISD Project on Poverty Reduction and Policy Regimes, 2008, p. 10.

[7] Richard J. Samuels, Rich Nation Strong Army

uncertainties and risks of first-order technological innovation, while facilitated the industrial technology upgrading process through effectively acquiring the requisite knowledge and skill base from its advanced industrial competitors. State-business relations were governed and controlled by elite technocrats in the government that were less subject to electoral politics under the guise of authoritarian leadership, thus the political system obtained relative liberty to plan and execute long-term economic policies with minimal disruption from other economic players such as corporations or labor unions.[8] The authoritarian regimes of East Asia have offered relative stability in domestic politics that empowered state technocrats with the political maneuvering capability necessary to execute state initiatives under a highly structured and competently staffed enforcement agency.[9] Consequently, the hierarchy of technocratic bureaucracy facilitated consensus building within the vertical and horizontal structures of the government and promoted efficiency in policy making.[10] Therefore, although most governments of East Asia had no ownership over private corporations, bureaucrats leveraged the market by strictly imposing control measures through ways of choosing and protecting national champions in selected industrial sectors with a focused export oriented policy supported by strong corporatist alliances between the state and corporate actors.[11] As such, East Asian countries were able to rapidly mobilize national resources with a vested interest in economic growth and development rather than on redistribution of public wealth, which resulted in the making of the East Asian economic miracle, but also placed developmental states into laggards of social welfare that eventually hindered the progress into an egalitarian society in furtherance of promoting technological innovation.

The financial institutions were mostly under strict regulatory control of the government, where state capital ultimately forced repressive policies in the finance sector to establish publically-imposed interest rates below market standards that supplied loans to industrial sectors specifically sponsored by state policy, i.e. getting the prices wrong.[12] In the case of Japan and South Korea, a collusive relationship between state and private businesses was formulated that engendered crony capitalism among widely diversified special business groups and state actors.[13] These strategically chosen industrial sectors gained momentum in catching up with other advanced contenders, which later formed large and diversified business conglomerates. On the other hand, state-business relations at Taiwan was more restrained and fragmented among the transplanted bureaucratic and military authorities that migrated from mainland China in conjunction with the indigenous businesses locally pre-established in the region. This created extra space for coexistence and evolution between state owned enterprises and smaller firms elsewhere, which formed the characteristics of Taiwanese economy relatively non-

[8] Adrian Leftwitch, , "Bringing politics back in: Towards a model of the developmental state," *Journal of Development Studies*, Vol. 31, Issue 3, 1995, p. 402

[9] Chalmers Johnson, MITI and the Japanese Miracle: The Growth of Industrial Policy, 1982, Stanford University Press.

[10] Joseph Wong, "The Adaptive Developmental State in East Asia," *Journal of East Asian Studies*, Vol. 4, No. 3, 2004, p. 351.

[11] Ibid., p. 408.

[12] World Bank, p. 9.

[13] David Kang, "Bad Loans to Good Friends: Money Politics and the Developmental State in South Korea," *International Organization*, Vol. 56, Issue 1, 2002, p. 191.

interventionist, leaning towards a more neoliberal stature. In the case of Singapore, the city-state has adequately leveraged its strategic location as a critical trading port, and has efficaciously accommodated foreign investments into its economy. Thus, the once small port city cornered in between the Malacca Strait has become the regional headquarter of a number of multinational corporations.[14]

In a technological sense, the developmental state demonstrated its effectiveness in coordinating national actors over an industrial path that has already been established by western advanced economies. The well-defined technological risks in the industrial sectors of steel, electronics, automotive, shipbuilding, and so forth, have reduced uncertainties in the business prospectus with maximized short-term returns, which allowed East Asian developmental states to fully exploit the given path and proven technology, with a comparative advantage in production costs realized through the availability of cheap labor.[15] In addition to the comparative advantage in costs and low risks factors in technology development, the unique geopolitical imperatives of the Cold-War situation in a historical context also provided opportunities for East Asian developmental states in the aspects of receiving substantial amounts of technological assistance from advanced western economies, notably the United States, in order to prevent the continued expansion of communist and socialist ideals in the region. Korea, Japan, and Taiwan were recipients of tremendous technology assistance in the commercial and military domains during this period, which allowed these countries to build-up its economy and military to a level in par against its impending security threats.[16]

However, after the East Asian Financial Crisis of 1997, the East Asian development model has confronted serious doubts with its adaptive capabilities and sustained effectiveness. The market mechanisms that supported the Developmental State Theorem, regarding the elements of manipulative exchange rates, repressive authoritarian regulatory powers against corporate decisions and labor policies, comparative advantage in low-skilled mass produced commodities accomplished through relatively cheap labor, unconditional technology transfers and assistance from advanced industrial countries, in addition to a myriad of other factors, were no longer available in the entering decades of the new millennium. This research will not go into detail regarding the cause and consequences of the East Asian Financial Crisis, but will elaborate on the transitional aspects of the East Asian developmental state model regarding the changes in its competitive advantages and the ensuing transition into a more diversified high tech industrial portfolio.

2.1.1. Challenges of the Developmental State: Domestic and International Systemic Factors

Despite the growing complexity of economic circumstances and industrial competition, the

[14] Joseph Wong, "The Adaptive Developmental State in East Asia," pp. 355-358.
[15] Peter Evans, "State Structures, Government-Business Relations, and Economic Transformation," in Sylvia Maxfield and Ben R. Schneider ed., Business and the State in Developing Countries, Cornell University Press, 1997, p. 67
[16] Henry Wai-chung Yeung, "Rethinking the East Asian Developmental State in its Historical Context" Finance, Geopolitics, and Bureaucracy," Area Development and Policy, Vol. 2, Issue 1, 2017, pp. 7-11.

developmental state theory has been criticized for its excessive reliance on the idea of defining the state as being internally cohesive and serving as a unitary actor, while neglecting the complex and dynamic working processes underlying the state structure.[17] The earlier focus of developmental states was in catching-up with the industrialization process by closing the gap in the technology divide and promoting capital accumulation between the developed and less developed countries. This is not to construe the prestige that glamorizes the theory and practice of the developmental state. There were apparent misjudgments by elite bureaucrats and subsequent system failures caused from strategic intervention and bad selection decisions in the market, represented by previous cases of MITI's role in establishing VCR standards or the long-term catastrophes of overseas construction and shipping in Korea.[18] In this aspect, this study intends to focus on the transitional points of these developmental patterns, where the epitomized strengths of state systems for economic catch-up later turned obsolete and started to hinder developmental progression of these rapidly growing economies. After technological catch-up and industrial upgrading were successfully achieved, benefits of economic backwardness were no longer effective for further progression. There were no established models to imitate, and state bureaucracies were unable to build a highly advanced S&T based industrial base in the magnitude competitive enough towards global standards. Currently, after accomplishing a notable mark in the catching-up process, the focus has now shifted to diversifying the industrial structure into a higher value added sector in conjunction with accelerating the upgrading process of technology. Developmental states can no longer take credit on the previous competitive advantages granted by low labor and manufacturing costs. Instead, the countries must now seek its vantage point in accumulating mental capital and reorganize its institutional settings suitable to compete in the higher technological sectors, also known as the Schumpeterian Mark II sectors. Nonetheless, apparent stumbling blocks exist that hampers the smooth transition of East Asian economies into the global standards of high-tech.

Firstly, East Asian authoritarianism in state practices has significantly dissipated in the 1980s with the proliferation of democratic ideals assimilated into the hearts and minds of the public. The spread of democratic norms instigated the general public to bring down authoritarian rule and introduce a more diverse and pluralistic political landscape in domestic policy making. Therefore, the implementation of state led economic planning has become intractable, at which point made troublesome the conventional practices of picking winners and supporting national champions in a selective industrial field. The electoral politics of presidential campaigns and parliamentary elections provided limited assurances for sustaining national research projects and industrial development initiatives that resulted in certain disconnects of sustained policy support on a number of critical science

[17] C.I. Moon and Rashemi Prasad, "Beyond the Developmental State: Networks, Politics, and Institutions," Governance: An International Journal of Policy and Administration, Vol. 7, No. 4, 1994, p. 364.
[18] Gregory Noble, "The Japanese Industrial Policy Debate," In S. Haggard and C.I. Moon eds, *Pacific Dynamics*, Westview Press, 1988.

based national and industrial programs.[19]

Secondly, the cooperative state-business relationship that once generated strong momentum in productivity growth and economic development has degenerated to a level of collusive rent-seeking that deteriorated entrepreneurship and innovation.[20] In the case of Japan, socio-economic institutions formed around social norms that promoted development and national autonomy started to cripple national competitiveness of once a global economic super power. Social norms that served for broader objectives of social stability, predictability, and order – represented by lifelong employment assurances, state regulated market mechanisms, seniority based wages, collusive industry groups, centralized credit based financial systems, etc. – hindered the injection of new entrants and practices into the economy and ruptured state capacities of innovation, which resulted in over twenty years of sluggish economic growth and deteriorated national competitiveness in higher technological sectors.

Thirdly, the pressures of economic globalization defy the protective privileges previously enjoyed by state industrial protectionism, while urges the domestic economy to become more integrated into international norms and regulations. The deepening of the global trade and financial regimes such as the World Trade Organization no longer provides preferential treatment to East Asian developmental states in the playing ground of the world economy. Exchange rates are now subject to close monitoring and scrutiny, therefore all players are required to get the prices right, which leaves very little leeway for governments to intervene in international monetary policies. In addition to international norms, in a sectoral perspective, the high-tech sectors represented in the Schumpeter Mark II category presented significant challenges over a multitude of impediments in terms of technology acquisition, program management, market entrance, and so forth. The global oligopolistic structure of these industrial sectors poses high entry barriers against firms intending to penetrate the market. In terms of norms and regulations alone, the high level of appropriability such as in intellectual proprietary rights, safety accreditations or other functionalities, and the overarching legal mechanisms to sustain these components arranged within the international setting present challenges to late industrialized countries for market entry. Especially in the value added high tech field of biotechnology, organic chemistry, precision machineries, and aerospace, where international technology standards are firmly set and legally binding regulations such as in safety, ethics, and proprietary rights are established, a more intensive degree of experience or accumulation in knowledge is required for new entrants to find a place in this sector and outperform its competitors.

In the institutional aspects of developmental states, the institutions from the past developmental trajectory turned obsolete and not fine-tuned to coordinate the growing complexities of industrial upgrading in a highly advanced technological sector. This idea asserts the complications of replicating an innovation system of complex products from an overseas source into a national construct,

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[19] Benjamin Reilly, "Parties, Electoral Systems, and Governance," in Diamond L., Plattner M., Chu Y., eds, *Democracy in East Asia: A New Century*, Johns Hopkins University Press, 2013, p. 20.
[20] Marie Anchordoguy, Reprogramming Japan, p. 15.

which demands substantial reshaping of pre-existing institutions and practices into a form adaptive to change.[21] Adopting a case study on biotech as an example, the technologically high exploratory risks and business uncertainties of the sector, compounded with established regulatory restrictions and safety protocols, have constrained decision makers from Korea, Taiwan, and Singapore to choose an industrial policy and institutional composition that once well functioned in the old developmental years. In comparison to the biotech sector, the IT sector, where the developmental state theorem performed adequately well, addresses the imposed risk factor through the coordinated actions between the state and industry in terms of trade protection, public subsidies, and reverse engineering efforts. In the highly innovative and complex field of biotech, under the auspices of state-led industrial policies, the three countries devoted substantial financial resources, adjusted domestic laws and regulations, and hand-picked selective companies in the industry to carry out the developmental aspirations in biotech. Countries like the United States or China, which have a vast domestic market, can afford to mitigate the developmental risks as the vastly spread market neutralizes the inherent liabilities by providing economies of scale and scope. On the other hand, small countries with limited resources, like the East Asian economies, have no choice but to strategically select companies and support the requisite efforts of building firm competencies. However, the old strategy of selective concentration, or 'picking-winners', over the course of attempting to devour an undefined technological sector, in a field of highly advanced complex products such as biotech, has resulted in producing an unimpressively disappointing economic outcome.[22] The difficulties of state bureaucracies were unable to make acute assessments of a strenuously evolving S&T based industrial sector. Thus, the incapacity of existing institutions to coordinate the demanding intricacies of a globally established high-tech field has left the developmental state theorem of state intervention mostly applicable to fast followers in the technologically lower profiled business sectors of the market. Whatsoever, the attempt to extend the traditional notion of the theory beyond the realm of East Asian industrial upgrading is restricted.[23] In this aspect, the vertically integrated state-business relations, illuminated as once the prominent pivot of the developmental state theory, have gradually transitioned to a more horizontally decentralized collaborative structure, where state capitalism mostly receded to a role of sowing seed money into the sector whereby letting the corporate players in the market to figure out the solution.[24]

In order to dive into a more in-depth analysis of state-led innovation in the systemic perspective, there is a need to review what the developmental theories lack. Thus, comparative perspectives given from other fields of studies should provide insights to these weaknesses. The following sections will highlight innovation studies under the perspectives of national innovation systems (NIS) and capitalist system (VoC: Varieties of Capitalism).

[21] Joseph Wong, Betting on Biotech: Innovation and the Limitation of Asia's Developmental State, Cornell University Press, 2011, p. 167.
[22] Ibid., p. 14.
[23] Ibid., p. 180.
[24] Ibid., p. 172.

2.2. National Innovation Systems (NIS)

2.2.1. Overview of the NIS Literature

The literature of National Innovation Systems (NIS) originates from a vast literature of technology innovation that advocates the characteristics of country-specificity, embedded skills, capabilities, and accumulation of knowledge.[25] The debate on the national innovation systems was first initiated in the late 19th Century by Friedrich List, a German economist that had contrasting views of the market against Adam Smith's, in which List illustrated his doctrine in the form of a nation perspective opposed to Smith's individual economics and cosmopolitan economics. The view was mostly in support of the economic rise of Germany as a late comer in the geopolitical landscape of Imperial Europe during the 19th Century, and the idea of nationalism (Pan-Germanism) to catch-up with its European forerunners such as the British and French. This concept was directly transferred to the mid-1970s after the world quietly monitored the two war-torn countries of the Second World War, Germany and Japan, ascending to the stature of a major economic power. The attention was highlighted in the role of national level institutions, which later became dubbed as "National Innovation Systems".[26]

The vast discussions on NIS were highlighted on the national institutions, its incentive structures, and competencies, that determine the rate and direction of technological learning or the volume and composition of activities generating change in a country[27] or the network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies.[28] The thesis generated from these scholarly debates, in association with the emergence of the world's new economic structure, crusaded over the initiative to launch an international study of National Innovation Systems at the OECD. The seminal work published on 1999 culminated in focused groups that encouraged the existence of innovative firm networks (France, Canada, Denmark), clusters (Netherlands), mobility of human resources (Norway, Sweden), organizational mapping (Belgium), and the economies of catching up (Korea). In the part of firms, the report concluded that innovation exists where there are frequent collaboration between firms and research institutes (universities, public/private laboratories) while also finding correlations in terms of firm size (larger the firm more frequent the collaboration).[29]

The next aspect of NIS accentuated on clusters and the policies that supports this concept. Clusters are engineering and manufacturing networks of highly interdependent firms linked to each other in a value-adding production chain, both connected in vertical and horizontal linkages. The key

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[25] Daniele Archibugi and Jonathan Michie, "Technology and Innovation: An Introduction," Cambridge Journal of Economics, Vol. 19, 1995, p. 3; Richard Nelson, Why do firms differ and how does it matter," Strategic Management Journal, Vol.12, 1991, p. 72.

[26] Christopher Freeman, "The National System of Innovation in Historical Perspective", Cambridge Journal of Economics, No. 19, 1995, p. 7.

[27] Patel, P. and Pavitt, K., "National Innovation Systems: Why they are Important, and how they might be Measured and Compared", Economics of Innovation and New Technology, No. 3, 1994, p. 81.

[28] Christopher Freeman, p. 5.

[29] Organization for Economic Cooperation and Development, Managing National Innovation Systems, 1999, pp. 15-18.

to this concept is diversity and scaled economy; diversity in a sense that assures access to new and complementary technology between dissimilar network positions; and scaled economies in terms of sustaining the economic drive of innovative findings. Such conditions incorporate the array of interrelated industries sharing common technology, skills, information, inputs, and customers. Under this context, most participants are not direct competitors but share common needs and constraints.[30] The notion is driven by the aspects of human resource mobility concentrated on the efficiency of knowledge transfers aggregated in certain physical locations that bolsters a vibrant business ecosystem for firms. Countries that showed higher rates of mobility in human resources, especially within the highly educated sector, demonstrated higher levels of innovation. This indicated the higher mobility rates preconditioned the fluent transfers of information and knowledge. On the contrary, the pattern differed in sectors in low-tech industries where the strong demand in skilled labor consequently induced low degrees of mobility, hence lower levels of innovation. Conclusively, government employment policies and incentives to different sectors exhibited positive impacts on the level of innovative performances.[31] Organizational mapping focused on countries like Belgium which had few domestic multinational firms are relatively active in basic research but less so in near market collaboration and private technology alliances. This indicates insufficient valuation of national R&D potential. In small countries of these kinds, firms are significantly more inclined to become partners of foreign actors than firms in large countries, and to rely on cross networking within the value chain in order to compensate for insufficient resources and the lack of appropriate partners available at home.[32]

The degree of innovation depends on the strong integration of science, technology, and business operations where institutions serve as the linchpin that lead to different patterns of innovative outcomes.[33] Innovation in a national framework is an aggregation of knowledge and institutional learning weaved in cultural ideologies inherent within the boundaries of a distinct political system.[34] It is this distinct political system that regulates the structural setting of industries, finance, R&D, and other elements more conducive to innovation. For instance, the communitarian heritage of the Japanese national ideology[35] and effective consensus building examined by MITI and other supporting institutions[36] highlight interactive and collective learning trends in a Japan-specific way that granted competitive advantage for the early success of the Japanese economy. Although similar in cultural heritage, different applications of institutional tools result in differed technological outcomes, as shown in the case of Dutch and Danish waste water treatment practices, at which the Dutch system relied more

[30] Ibid., p. 85.
[31] Ibid., p. 90.
[32] Ibid., p. 97.
[33] Richard Nelson, National Innovation Systems: A Comparative Analysis, Oxford University Press, 1993, p. 112.
[34] Lodge and Vogel, *Ideology and National Competitiveness*, Harvard Business School Press, 1987, p.87.
[35] Ibid. p. 89.
[36] Chalmer Johnson, Institutional Foundations of Japanese Industrial Policy, in Barfield and Schamrei eds. The Politics of Industrial Policy, American Enterprise Institute, 1986, p. 65.

on regulatory control whereas the Danish system focused on tax incentives.[37] Both practices were evidence of divergent innovative policy products.

Differing governance systems define the characteristics of institutions. In other aspects, however, innovation theory mainly extracts its ground of argument from the way of learning, or in other words, institutional education and research. The set of institutional learning is represented in the socio-economic impact of research and development, which characterizes innovation models into increasing complexity, bound with socioeconomic factors such as market linkage, matched up with available social infrastructure. In the 1950s, the growing demand in physical science, which was triggered by the competition among warring states during the Second World War in the development of the atom bomb, and the increasing democratization in education, coupled with the close linkages of university research on highly innovative government programs, generated the idea of 'technology push' of innovation. Simply saying, investment into universities for innovative research was the smart solution to create thought provoking radical products.[38] The technology-push model concentrated on subsidizing big firms or research institutes in order to create national champions. The efforts were extended into public institutions by building universities and government led research laboratories.

However, further developments and maturation of the free market, and the following growth of firms and the way how it immediately responded to market demands, led to the formulation of the market-push models of innovation, mainly advocating that market components (firms), while reacting to market (customer) requirements, attributes to the innovation drive. This line of thought continues to dominate mainstream theories in economics and business studies.[39] This model started observing the rise of market forces in the form of small and medium sized enterprises and the associated independent research and development activities that ensued. Here, the governments subsidized mostly in large scale national programs such as weapons development, but most of the subsidies to industry were phased out and was replaced as tax incentives instead in return of sustaining the commercial momentum in technological developments. In this period, research engines were created mostly from the commercial market, and a number of government led research labs became privatized, thus the portion of innovation has shifted to the private sector.[40] As the roles of institutions unraveled in the debate of innovation theories, the role of government policies in the macro level took part as another source of policy debate, which has given high attention to the national innovation systems.

The heuristic nature of NIS respects the idiosyncratic differences of nation specific innovation systems arranged in a systemic way that relates to international trade. Because of the 'nationalistic' connotations of the term, NIS might be treated as an obsolete phrase in an era of accelerating

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[37] Anderson E.S., "Techno-Economic Paradigms as Typical Interfaces Between Producers and Users," Journal of Evolutionary Economics, 1991, p. 13.

[38] Mansfield, E. 'Academic Research and Industrial Innovation' *Research Policy*, Vol. 20, 1991, p 12.

[39] Ibid., p. 14.

[40] Roy Rothwell, "Successful Industrial Innovation: Critical Factors for the 1990s," R&D Management, Vol. 22, Issue 3, 1992, p. 227.

globalization. However, refuting the arguments not necessarily defying the essentials of globalization, but augmenting the supporting elements existing in national borders, the NIS literature recognizes the importance of networking regional production systems and technology districts under a globalized settlement.[41] Previous studies based on intellectual property rights or patent statistics also supports the argument that national origins matters for multinational firms in terms of locating innovative performances.[42] However, encapsulating the NIS concept within the national borders of a country confines the scope of potential cross-border achievements in innovation. A narrower definition mostly focuses on established processes supporting scientific research and development. But a broader perspective embraces the dynamically moving components of a vibrant transnational economic structure including production and marketing systems, financial institutions, and training and education as subsystems.

The NIS literature distinguishes knowledge in two separate categories; tacit and codified knowledge. Codified knowledge literally defines officially recorded and visible features of codified information and knowhow that can be interpreted and diffused through formal education and training, whereas tacit knowledge represents the societal and un-codified features of knowledge more culturally embedded, which is absorbed through experience and social interaction. The focus on 'innovation' studies is mainly oriented towards the absorption and diffusion mechanism of these two knowledge categories in the process of 'learning' (Lundvall edit, 2010). The interactive nature of learning, which is basically a socially embedded process, has to be understood under the context of its established institutional settings. It is the system of these social components that brings together various elements for instigating the interaction of knowledge through socially established learning processes, which sustains the developmental dynamics within the borders of a nation state.

Innovation systems must be understood under the context of the firm, national borders, and global levels of a society. Through the interaction of these different activity levels, innovation promotes and further generates economic growth. In the national context, the increasing importance of interconnecting regional production systems, industrial districts, and technologically specialized zones have gained importance more than ever.[43] Innovation is a ubiquitous phenomenon that is reached through a gradual cumulative process. It occurs based on the combination of different accumulative achievements, hence in a Schumpeterian terminology, 'new combination' or a synergistic interaction of past experiences, resulting in a thesis-antithesis-synthesis paradigm. Such cumulative process is coined as routine activities "rooted in the prevailing economic structure" of the respective society where innovation emanates.[44] In terms of the intensity or degree of innovation, incremental innovation results from existing product bases, therefore the coordination between established design and technological

[41] Porter, Michael E., The Competitive Advantage of Nations, London, MacMilan, 1990, p. 21.
[42] Patel and Pavitt, "Is Western Europe Losing the Technological Race?," Research Policy, Vol. 16, 1987, p. 43.
[43] Porter, Michael E., The Competitive Advantage of Nations, 1990.
[44] Lundvall, B.-A, "Innovation as an Interactive Process," in Dosi, G. et al. Technical Change and Economic Theory, London, Printer Publishers.

features augmented by existing firms forms the basis of such changes. Radical innovation is achieved through a different game plan where a different set of technological principles creates new market opportunities for new entrants into the market.[45]

In the aspects of production systems and market specialization, the innovation literature generally agrees on four processes that constitute the system core of innovation; production systems, specialized home-markets, interactive learning processes, and the institutional arrangement that integrates all dimensions of the economic power house.[46] The life cycle approach on national systems stresses the relationship between production linkages and the learning process under the context of interaction between user sectors and production sectors.[47] It highlights stimulated learning processes generated through the information flow shared by user-producer relationship in backward linkages. An extended portrayal of the life cycle approach was depicted in the hierarchical classification of national innovation systems through the sectoral approach of asserting different economic sectors resulting in different outcomes of economic growth. In this regard, the vertically upstream hierarchy, such as in the machinery sector, constitutes the epitome of dynamic growth. In this respect, Freeman argues the importance of interaction between the stakeholders within a system and sub-system existing in an organizational setting. He asserts the way how R&D and production sections organized in a firm, inter-firm interactions, and state-business relationships, constitute the critical framework that nurtures innovation.[48] This relationship was described through the Japanese system of producing knowledge.

Nelson advocates a more in-depth review of the institutional attributions of innovation, which combines public and private sector technology, and emphasizes the role of universities and governments in the promotion of the respective technology.[49] This approach was focused on the U.S. innovation in a narrower sense. In terms of production relationships and its NIS linkages, vertical integration of firm structure facilitates learning within the integrated structure of the firm where technological know-how is shared. However, vertically integrated structures also introduce rigidities in the production system that in many instances disturbs responsiveness to change. Meanwhile, production units existing outside of the integrated structure become reluctant to share sensitive information imperative for continued advancement of the production process. Thus, interactive learning becomes specialized in a limited scope, in which a balanced number of propellant industries (autonomous innovators) and impelled industries (induced innovators) come to determine the development power of a nation.[50]

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45 Henderson, R.M. and Clark, K.B., "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms," Administrative Science Quarterly, No. 35, 1990, p. 23.

46 Lundvall B.-A. et al., "National systems of production, innovation, and competence building," Research Policy, Vol. 31, 2002, p. 55.

47 Andersen, E.S., "Approaching National Innovation Systems," in Lundvall, B.-A., Ed., National Innovation Systems, Pinter, London, 1992, p. 83.

48 Freeman, Christopher, Technology and Economic Performance: Lessons from Japan, London, Pinter Publishers, 1987, p. 43.

49 Nelson, Richard R., National Systems of Innovation: A Comparative Study, Oxford, Oxford University Press, 1992. P. 13.

50 Bengt-Ake Lundvall, "User-Producer Relationships, National Systems of Innovation, and Intrantionalisation," in Ludvall ed., National Innovation Systems: Toward a Theory of Innovation and Interactive Learning, Anthem Press, 2010, pp.48-51

2.2.2. Sectoral Systems of Innovation, Technological Regimes, and Patterns of Technological Catch-up

Innovation differs based on sectoral characteristics that appear evident in the comparison of the specific knowledge base, economic actors and interactive networks, and the institutional arrangement. Under the context of Schumpeterian patterns of innovation, technology related factors, in par with the significance of country specific innovation patterns, have substantial influence over innovative activities in sectoral organizations.[51] The Schumpeterian distinction of sectoral characteristics that focuses on the market structure and industrial dynamics is outlined by Schumpeter Mark I and Schumpeter Mark II patterns of the industry.[52] A Schumpeter Mark I pattern represents "widening" or "creative destruction" that introduces new entrepreneurial firms and practices with easy market access, mostly in the form of small and medium sized start-up companies, which is highly turbulent and technologically disruptive in terms of market competition. Widening indicates the nature of continued entries of innovative firms into the sector that continuously threaten to erode the competitive advantage of incumbent firms. The Schumpeterian Mark II pattern represents "deepening" or "creative accumulation" described by established large firms positioned in the core of the sector, built in with sector specific accumulated knowledge with the presence of high entry barriers into the market. Deepening relates to the prevalence of a few dominant firms in the sector that constantly innovates by iterative accumulation of technological knowledge. Such difference in sectoral patterns of innovation is explained in the learning domain, or in other words technological regimes, which synthesizes technological innovations in opportunities, appropriabilities, cumulativeness, and properties of knowledge.[53] The relationship between technological regimes and Schumpeterian patterns of innovation are as follows.

		Patterns of Innovation	
Type		Schumpeter Mark I	Schumpeter Mark II
Characteristics		widening (creative destruction)	deepening (creative accumulation)
Entry Barriers (market structure)		Low (Competitive) Small specialized firms	High (Oligopolistic) Multidivisional firms
Technological Regimes	**Opportunity**	High technological opportunities (Technologically less predictable)	Low technological opportunities (Technologically predictable)
	Appropriability	Low appropriabilities	High appropriabilities
	Cumulativeness	Low cumulativeness	High cumulativeness
	Properties of Knowledge	Generic Knowledge	Specific Knowledge
Industry Areas		Information Technology, Consumer Goods	Bio-tech, Aerospace,

Table 1. Relations between Technological Regimes and Patterns of Innovation
Source: Franco Malerba and Luigi Orsenigo, "The dynamics of evolution of industries," Industrial and Corporate Change, Vol. 5, Issue 1, 1996.

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[51] Stefano Breschi, Franco Malerba, and Luigi Orsenigo, "Technological Regimes and Schumpeterian Patterns of Innovation," *The Economic Journal*, 110 (April), pp. 388-389.
[52] Ibid., p. 340.
[53] The four categories are described as follows; technological opportunities consider innovative outputs generated from the amount of input; appropriability describes the chances of protecting innovative rights from imitation; cumulativeness relates to technical advances realized by a stream of gradually accumulated knowledge; properties of knowledge relate to the knowledge base belong under either generic or specific knowledge.

In regards to the innovative achievements being highly concentrated to incumbent contenders in the market in addition to the relatively low occurrence of technological breakthroughs, catching-up in the technological domain generally poses more challenges in Mark II sectors than in Mark I sectors.[54] This is because the competitive order of the Mark II sector carries established norms and institutional rules, which presents barriers for new entrants attempting to access the sector. Hence, significant challenges exist for new entrants into the competition. Technological catch-up, in a general sense of convergence studies, is achieved through the concerted efforts of investments in physical assets and the accumulation of technological capabilities. Depending on social capabilities, technologically backward countries with socially advanced institutions have the potential of generating rapid growth opportunities than that of more advanced countries through successfully exploiting acquired technologies that are already in use by technological leaders.[55] Historically, technological catch-up was associated with the adoption of existing techniques followed by the innovation of those techniques to improve productivity or induce new inventions. In pre-modern times, technological diffusion depended mostly on the migration of individual skilled workers because technology was embodied in persons, or was codified as 'tacit' information. However, the Industrial Revolution, signified by an era of codified engineering standards, created innovation in a more systemic way, which made the diffusion and absorption of technology comparatively transmittable than pre-modern times.[56] Thus, in a structural viewpoint, the technological catch-up process of Western Economies in the early 20th century, although shown in varying degrees, mostly relied on systems of innovation generated by market mechanisms, whereby resources provided through financial institutions constituted the essentials of industrial development. Contrastingly, the East Asian catching-up process showed a different pattern, in which rapid industrialization after the Second World War was feasible by government led market interventionist policies.

Accomplished catch-up economies have taken full advantage of inward technology transfers enabled through a national innovation system nurtured by firm-based absorptive capacities. This capacity is promoted by continued investments in science and technology education as well as in a competition driven domestic industrial policy, at which the effectiveness of state intervention in the strategic industries resulted in lesser importance compared to the earlier stages of the catch-up process for late industrializing countries.[57] The aspect of innovative catch-up regards to the manufacturing and branding strategies of the respective product. First countries choose to enter the market by acquiring low level production skills in the form of Original Equipment Manufacturer (OEM) entitlements, or in other terms called 'subcontracting' or 'licensing'. The industry matures by acquiring essential design

54 Breschi, Malerba, and Orsenigo, p. 341.
55 Moses Abramovitz, "Catching Up, Forging Ahead, and Falling Behind," The Journal of Economic History, Vol.46, no. 2, 1986, p. 390.
56 Jan Fagerberg and Manuel M. Godinho, "Innovation and Catching-Up," in Fagerberg et al., *The Oxford Handbook of Innovation*, Oxford University Press, 2011, p. 516.
57 David C. Mowery and Joanne E. Oxely, "Inward Technology Transfer and Competitiveness: The Role of National Innovation Systems," Cambridge Journal of Economics, Vol. 19, 1995, p. 67.

skill as an Original Design Manufacturer (ODM). And lastly, the industry establishes its reputation by creating extensive networks for marketing, distribution, and so forth by launching its own brand and technical reputation, hence becoming an Original Brand Manufacturer (OBM).[58] Nevertheless, this evolutionary process is not always the rule of thumb. Countries or firms, in some general technology or industrial sectors, do not necessarily follow the same evolutionary pathway (path-following) of what its foregone predecessors use to take, but instead skip certain stages of the evolutionary process (path-skipping), or create their own path (path-creating) that differs from the conventional norm in some other cases, henceforth achieving an innovative standing of "leapfrogging" in the catching-up process.[59] Although the institutional arrangements established during the early catch-up phases were proven effective, the educational and organizational setting of these countries being attuned to certain technological types in some cases started to constrain further potentials to advance into a higher competitive status. Catching up is mostly referred to a process of improving productivity in manufacturing and related services. Once the catching up process is finalized, the rationale for productivity improvement loses its basis, which makes the overall economic system supporting the incumbent production regime relatively obsolete and subject for replacement in the course of keeping up with the advances in technological competition. In this respect, the portion of market share in tandem with technological achievements becomes critical in sustaining the fruits of technological catch-up.

The cultural influence indeed weighs on heavily in determining the direction and performances of national innovation systems. A study performed on government polices of France and Germany in three industrial sectors – telecommunication, machine tools, and semiconductors – provides an assessment of the cultural impact on the outcomes of these state led policies. The knowledge group culture of each country is the starting point for the analysis, in which France adheres to a more centralized but closed elite based system whereas Germany relies on a more decentralized but open system with affluent human resource mobility. Therefore, the French model adheres more towards a state centric arrangement in a sense that the industrial policies are targeted to a small number of elites in the political as well as in the realm of science and technology, whereby following a top-down hierarchical structure. On the other hand, the German model conforms to a more opened arrangement in its sources of knowledge and technology, such that government policies are more attuned to allocating public subsidies in support of nurturing certain industrial sectors.[60] Furthermore, the differing educational policies of the two countries were essential in forming a unique knowledge bearing systems. The French policies created a highly selective group of knowledge bearing elites in the national level with creating highly controlled access to knowledge. In this aspect, the national technical expertise was largely a state function in which the elites tended to exist in a closed, self-replicating systems. To a large

[58] Keun Lee, "Making a Technoloical Catch-up: Barriers and Opportunities," Asian Journal of Technology Innovation, Vol. 13, No. 2, 2005, p. 101.
[59] Keun Lee and Chaisung Lim, "Technological regimes, catching-up, and leapfrogging: findings from the Korean industries," *Research Policy*, Vol. 30, p. 461.
[60] Nicholas Ziegler, Governing Ideas: Strategies for Innovation in France and Germany, p. 31.

degree, these elites were not only predominant in research and development but also in public policy as these trained elites became eligible to move directly from universities to public administration. Germany in contrast possessed an educational system focused on occupational skill training. Whereas French engineers stood at the top of the technical food chain while having little interaction with other non-knowledge bearing groups, the German knowledge bearing groups were cultivated in a more open fashion and possessed a culture more inclined to encourage collaboration among different groups.[61] These conditions resulted in different outputs in the three industrial sectors. If the selective French elite based structure was feasible in telecommunications, the German structure proved more efficient and innovative in machine tools. However, the national innovation systems of both countries was proven insufficient in coping with the new emergence of semiconductors, in which the French experienced huge losses whereas the Germans went through marginal gains but not much significant expansion into the new business field.

A similar but different account towards national innovation system was displayed in the Japanese case. In the studies of the recent demise of the Japanese economy, the pressure to liberalize the Japanese economy after its near collapse in the 1990s has been limited by the historical legacies of the main bank system, supplier-manufacturer loyalty, and the organization of industry through keiretsu networks. The economic turmoil that disrupted the Japanese economy in the 1990s deteriorated the traditional three pillared institutions that were believed to have driven the Japanese economic success – such as lifetime job security, banking system, close ties between government and industry, and the Keiretsu – came into serious scrutiny. These institutions were represented by the state-led economic policies in which the Japanese government played a central role in the overall governing aspects of the economy.[62] The first pillar, system of labor relations, was characterized by relative labor peace attributed by enterprise unionism and lifetime employment. The financial system, which formed the second pillar, was highlighted by banks serving as the principal source of corporate finance in often turns also monitoring firm performances. The third pillar, the corporate governance system, represented by circular corporate ownership through Keiretsu conglomerates, cultivated an extensive network with small suppliers who were highly dependent on these firms for technology, managerial expertise, and finance, which ensured strict pricing and quality standards.

However, the existing institutions were ruled inefficient to cope with the economic downturn, and government policies leaned towards de-regulation of these inefficient institutions by emulating the US modeled liberal market economies. In these aspects, Japan has taken a frenzied restructuring path; Japanese enterprises expanded merit based compensation, sold subsidiaries, and moved production abroad; Government modified the pension system, revised corporate law, removed substantial amounts of bad loans. However, these efforts were not translated into successful outcomes because the selected reform agendas by government officials and industry leaders failed to modify the existing institutions,

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61 Ibid., p. 50.
62 Steven Vogel, Japan Remodeled, p. 36.

sometimes even reinforcing the system, opposed to abandoning these malpractices. In terms of employments, Japanese firms were engaged in downsizing, but without severe layoffs because these firms believed that downsizing in the US did not have much positive effect on corporate financial performance as defined by profits, productivity, or stock price. The firms believed that companies with the longest job tenure had the highest profits, which highly advocated political leaders to choose a more incremental reform policy while preserving the core institutions of the Japanese economic model.[63] Transformation of the Japanese capitalist system to a structure more accommodating to the US system may become a difficult task than expected because Japan's culture discourages reforms that might undermine long-term relations with workers, financial institutions, and the government. As a result, the Japanese model has transformed into what is more selective in its alliances, more differentiated in its forms, and more open to foreigners and outsiders, while not undermining their networks of cooperative relationships with long-term partners, workers, banks, and suppliers.[64]

2.2.3. Diffusion of Innovation: From Adoption to Exploitation

Before indulging into systemic arrangements for innovation, it is imperative to understand the overall qualifications as prerequisites. In this regard, absorptive capacity is an element considered critical as a prerequisite mechanism to facilitate the diffusion of knowledge and practices in an organized fashion. It highlights the importance of prior knowledge and diversity of background in the relevant fields of interest that sets conditions for further expectations of innovation. In the seminal work of Cohen and Levinthal, absorptive capacity is a process of properly communicating the assimilation, accumulation, and exploitation of shared knowledge and expertise for fostering innovation opportunities.[65] The focal point of their reasoning was on the investment decisions of firms in R&D, which traces the cumulative nature of absorptive capacity and subsequent path dependence in a quickly moving technological field, forms a condition where the cessation in R&D investments places a firm hard to sustain competitiveness in the field.[66] Firm level and public investment in R&D as critical impact factors for absorptive capacity is demonstrated in comparative studies between East Asia and Latin American economies, whereby the stark difference in public investment on research and tertiary education attributed to different performing results of economic competitiveness.[67] The debate on absorptive capacity also takes place in the diffusion process of learning as well. Diffusion of innovation is realized through strong linkages between R&D, production, technological import, and customer reception. The stark difference between Japan and USSR in these linkages present different outcomes of innovation and sustained economic development. Structural integration of firm level R&D,

63 Ibid., p. 116.
64 Ibid., p. 223.
65 Wesley M. Cohen and Daniel A. Levinthal, "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administration Science Quarterly*, Vol. 35, No. 1, p. 131.
66 Ibid., p. 141.
67 Christopher Freeman, "The National System of Innovation in Historical Perspective," Cambridge Journal of Economics, 1995, 19, p. 13.

production, technology imports, and user level interfaces remained strong in the Japanese innovation system, whereas these linkages remained weak in the Soviet structure.[68] Thus, the positive correlation between absorptive capacity and firm's R&D investment has proven critical for an organization's competitiveness and innovative applications.

Zahra and George proposed a model that expanded Cohen and Levinthal's R&D focused concept and definition of absorptive capacity into a more specified category classified as 'potential absorptive capacity' and 'realized absorptive capacity'.[69] Potential absorptive capacity, or receptivity, is an identification process of a firm to acquire externally generated knowledge and assimilate the subject knowledge into the firm's operations through analysis and interpretation.[70] It is a concept that incorporates accumulation and assimilation. Realized absorptive capacity, or innovative routines, is an exploitation practice that refines the acquired knowledge with existing firm knowledge into a transformative form, hence it is an expanded concept of exploitation suggested by Cohen and Levinthal.[71] Currently, the debate on absorptive capacity is mostly concentrated on 'dynamic capabilities' of an organization in a rapidly changing market environment. It covers two distinct elements of firm behavior in building up core competencies for competitive advantage[72]; paradigmatic shifts adaptive to radical and discontinuous change, while ensuring competitive survival by maintaining threshold capability standards.[73] A dynamic capability is a process of adapting the organizational routines of a firm's resource base to the increasingly unpredictable fluctuations derived from the external environment. This is often extremely challenging due to organizational inertia and path dependencies of organizations in the subject field of consideration. Most evident case was shown in the recent turbulence of Nokia, which used to be a globally leading firm in the vibrantly changing telecommunication industry, however only to fall back in the competition from other rising competitors due to difficulties in overcoming existing practices.[74]

In a similar but different perspective, absorptive capacity sets the ground for the diffusion of technology and its innovative outcomes within organizations. Diffusion is a practice that realizes the value of knowledge ventures. The degree and intensity of diffusion determines the social and economic impact of innovation in general. Hence, under the context of absorptive capacity, the diffusion of innovation is primarily a process of adaptive learning, through unit level cost-benefit assessments of replacing incumbent systems with newly emerging innovative findings, at which point the feedback of this process generates improvements in products or procedural practices. The organizational behaviorist

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[68] Ibid., p. 12.
[69] Zahra and George (2002), "Absorptive Capacity: A Review, Reconceptualization, and Extension", *Academy of Management Review*, Volume 27, Issue 2, p.190.
[70] Ibid., 191.
[71] Ibid., p. 193.
[72] Teece, David; Pisano, Gary; Shuen, Amy (August 1997). Dynamic Capabilities and Strategic Management "Dynamic Capabilities and Strategic Management". Strategic Management Journal 18 (7): 512.
[73] Threshold Capability Standards is the minimum requirement of a firm in terms of resources to remain in the game as a competitive player.
[74] Ludwig, Gregory and Pemberton, Jon (2011). "A managerial perspective of dynamic capabilities in emerging markets: the case of the Russian steel industry", *Journal of East European Management Studies*, 16(3), p.220.

and sociologist perspective of diffusion studies, highlighted in the landmark researches of Rogers (2003), give its core focus on the relative easiness of adopting innovation at the receiving end.[75] Sitting at the core of this assertion is five analytic categories that attributes to the art of diffusing innovation – relative advantage, compatibility, complexity, trial-ability, and observability of innovation.[76] The idea of diffusion additionally elaborates that the process itself is interactive, which provides feedback for further improvement and change, thus becomes an occasion of spinning-off new innovations.[77] On the other hand, although defined in a similar account, economists consider diffusion as a process of calculating the costs and benefits of adopting innovation to an already established custom, from which costs and benefits are calculated under the premises of uncertainty and limited information.[78] The diffusion patterns are explained by describing concepts of network effects (or externalities) in order to complement the shortcomings of not accounting for the social feedback effects of individual adoption and social connectedness. Basically, the diffusion process typically follows an S-curve shape, as the rate of adoption initially starts at a snail's pace but further accelerates as the innovation spreads throughout the adopting population, and eventually slows down as the adoption matures and saturates in the final phases. The two mechanisms that attribute to this process are known to be the heterogeneity of adopting agents, and the medium of learning on the subject matter. Heterogeneous agents, or the multitude of different consumer tastes, at first have different expectations in calculating the benefits from new innovative discoveries, while conclusively converges into the S-form through the progression of time as the agents continue to learn that the expectation on the benefits of adoption exceeds the cost of replacement.

2.2.4. The Role of Institutions in Innovation Systems

The NIS literature highly values the role of institutions in innovation studies. The largest distinction between innovation studies and neoclassical studies of economics is perhaps the way how each school pictures the economy; whether as a process of interaction and cumulative causation or simply a system of equilibrium. In the context of the Schumpeterian School, innovation is understood as a learning process rather than a uniquely transformative event. The learning process is transmitted through established institutional settings. However, institutions have both stimulating and retarding effects to innovation. Established institutions in learning serve as conduits of channeling and diffusing knowledge. But in another sense, institutions display characteristics of inertia and rigidity that hampers the dynamics of technical development. In many cases, institutions often resist change and in many instances lag behind technological developments. Rigidities in institutions are built by layered complexities in government structure and growing influences of interest groups in the society, which

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[75] Rogers, E., Diffusion of Innovations, p. 219.
[76] Ibid., p. 222.
[77] Rosenberg, N., "Factors Affecting the Diffusion of Technology," Explorations in Economic History, Vol. 10 Issue. 1, 1972, p. 13.
[78] Bronwyn H. Hall, "Innovation and Diffusion," in Oxford Handbook of Innovation, p. 462.

reduces the responsiveness of the economic system against market signals such as price changes and technological advancements.[79]

Institutions establish norms in actions, routines in processes, and coordinate the use of knowledge and information, which consequently enable a more predictable outcome by reducing uncertainty for people and organizations. Institutions are the social stabilizers when change occurs, including changes in technology. However, if the institutional setting incentivizes an established trajectory not condoning necessary changes for innovation, then the consequences may lead to lagging stagnation or even degradation in competitiveness.[80] In order to avoid this, the act of forgetting, coined in a Schumpeterian term called 'creative destruction', functions to eliminate these hurdles and often paves the way for new innovations. In this respect, institutions shape the remembering and forgetting mechanism of learning through a cultural process that arranges selection and perception of information.[81] The institutional configurations filter and accumulate essential knowledge that is considered critical for technical and organizational advancement. The forgetting mechanism shuts down obsolete practices in technological and economic development. Consequently, institutions establish the routines for a systematic and organized searching for new knowledge, while concurrently running the forgetting mechanisms of obsolete economic practices.[82] The institutional setting determines the way how conflicting interests from resisting forces occurring in the change process, such as labor unions, production systems, etc., are mitigated. The intensity of this mitigation process, demonstrated by the institutional capacities, either expedites or retards the innovation cycle.

In terms of the characteristics of interactive learning, frequent interaction between different but relevant components of learning defines the intensity of innovation. Institutions coordinate these interactive processes. Learning by searching, or learning by producing, practices displayed in organized search closely connected with production activities of a firm.[83] In a techno-economic paradigm, learning by exploring practices is demonstrated mainly from pure scientific research from science labs or universities. Technology management in Japanese firms proved effective for incremental innovation as it practiced the routines of closely coordinated interactions in user-producer relationships.[84] Culturally dependent norms tend to appear in a more tacit knowledge form. Henceforth, such culturally dependent norms are constructed by informal institutional notions such as time horizon of agents, role of trust, and the actual mix of rationality.[85] Complex technology requires a longer term commitment that reaches a point of penetration for innovation. Trust relates to expectations for behavioral

[79] Johnson B. and Lundvall, B-A, "Flexibility and Institutional Learning," in Jessop, B. et al., The Politics of Flexibility, Edward Elgar, 1991, p. 135.
[80] Perez, C., "Long Waves and Changes in Socioeconomic Organization," IDS Bulletin, Vol. 16, No. 1, Sussex, Institute of Development Studies, 1985, p. 31.
[81] Charles Edquist, Systems of Innovation, in Oxford Handbook of Innovation, 2005, p. 202.
[82] Ibid., p. 203.
[83] Amable, B., "Institutional Complementarity and Diversity of Social Systems of Innovation and Production," Review of International Political Economy, Vol. 7, No. 4, 2002, p. 675.
[84] Economist, December, 1989
[85] Lundvall et al., Research Policy, Vol. 31, 2002, p. 220.

consistency that reveals reliable information with the notion of no potentials to exploit weaknesses of incumbents. Mixed rationality finds its foundations in institutional understanding while tolerating communicative differences. Regarding the process of learning by searching (or exploring) in a knowledge based society, the role of formal institutions, such as in-house R&D departments or extramural R&D organizations such as universities and technical engineering laboratories, interfaces as bridging mechanisms between science and technology stimulates increased productivity and creativity.[86] Through this interaction process, the higher anticipations of capacity building realize the utilization of unexpected novelty, which is a fundamental course for innovation.[87]

Institutional diversity coexisting in the economic system, supported from the idea of ‘flexibility ‘and ‘impurity principle’, creates options for various stock of knowledge to interact and generate novelty through enhanced learning capacities, while makes the system more resilient to disturbances and fluctuations.[88]

Scientific and Technical Institutions in National Innovation Systems

Institutions in the development of science and technology has proven even more critical in its role as history traces back into the 19th century, reminiscent of the demising British technological prowess overwhelmed by the ascending technological stardom of Germany and America. Despite its leading technological accomplishments, British institutions were unable to effectively diffuse these accomplishments into the wider spectrum of its economy, which was later labeled by Schumpeter ‘entrepreneurial failure’, while the institutional settings of German and American industries, as a latecomer in the field, sufficiently diffused and exploited these innovative achievements through in-house R&D and professional education of engineers.[89]

Schumpeter observed oligopolistic advantages of firms after acknowledging the historical accounts of German electrical companies such as AEG and Siemens in the early 20th century as its technical departments developed new products and processes through professional internalization of R&D.[90] In this domain, German networks of technology diffusion incorporated not only corporate R&D, but also bolstered interactive learning with universities supported by strong government research institutes by coordinating different technological standards as well as training legions of high skill labor forces, which became characteristic of industrial countries in later days. Putting into account the sectoral varieties and differences, the Second World War has legitimately expanded the scale and widened the horizons of government led R&D and the importance of specialized R&D departments.[91] In this wider

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86 Ibid., p. 223.
87 Anderson, 1991, p. 15.
88 Charles Edquist, 2005, p. 205.
89 Christopher Freeman, “National Innovation Systems in Historical Perspective,” *Cambridge Journal of Economics*, Vol. 19, No. 1, 1995, p. 20.
90 Christopher Freeman, “Formal Scientific and Technical Institutions in the National System of Innovation,” in Lundvall ed., National Systems of Innovation, 2010, p. 174.
91 Keith Pavitt, “Innovation Process,” in Oxford Handbook of Innovation, 2005, p. 106.

process of production and R&D, without much reference to R&D outputs, incremental innovations were continuously generated by production engineers and shop-floor workers, which became a major source of productivity improvement.[92] Such characteristics were built through the capacity to fluently communicate and interact with various components existing outside the conventional boundaries of a production unit. Thus, the lost in opportunity costs for lacking such networking capacities in a national system becomes a huge burden for firms.[93] The case of agglomerated economies such as Silicon Valley demonstrates the crucial importance of communication and trust between entrepreneurs, R&D units, suppliers, and end users of a technology dependent on both geographical and cultural proximity.[94] Rigorous R&D work serves as the contributing factor of radical discontinuities in innovation, but when it comes to incremental trajectories of innovation, interaction with end users of the technology become the dominant factor.[95]

2.3. Varieties of Capitalism (VoC)

Capitalism has placed itself in various forms within the national economic setting that resulted in differing economic outcomes and performances executed through diverse policy mechanisms. Such difference in expectations has raised the classic question of the apparent role and functionality of market systems and the holistic view of how the system interconnects itself with distinctive social components that constitute the entirety of an economic structure. Typical capitalist economies such as the U.S. and Germany by and large represent contrasting elements that differ widely in the institutional configuration of the economy organized around the market. Thus, the emerging literature in institutional economics, veering away from the traditional neoclassical school, has concentrated its attention towards strategic complementarities on organizational elements considering the disparate idiosyncrasies socially embedded within existing national borders of countries that generate different outcomes in technological innovation and economic growth.[96] Here, among various preliminary researches on comparative capitalism, the literature commonly labeled "Varieties of Capitalism" (VoC) compares organized production regimes through financial systems, corporate governance structure, industrial relations, and education and training systems, thus explains different political institutions serving as principal agents as the source for different innovative behavior.

2.3.1. Overview of the VoC Literature

While mainstream studies on comparative capitalism focuses on the state and its interaction with the market, the basis of the VoC approach is drawn from the resource-based idea of firms

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[92] Ibid. p. 107.
[93] Freeman, 1995, p. 23.
[94] Saxenian A., "Origins and Dynamics of Production Networks in Silicon Valley, Research Policy, Vol. 20, No. 5, 1991, p. 425.
[95] Ibid., p. 426.
[96] Gregory Jackson and Richard Deeg, "How Many Varieties of Capitalism? Comparing the Comparative Institutional Analyses of Capitalist Diversity," MPIfG Discussion Paper 06/2, 2006, p. 11.

developing core competencies through building or managing relationships with other firms and agents that generate transaction costs and principal-agent problems, at which conflicting coordination problems are resolved in the context of institutional establishments. Here, differences among countries are results entitled ‘comparative institutional advantage’. The main contribution of the VoC approach to the scholarly literature of comparative capitalism is the relationship between institutional complementarities and country performance, hence the interdependent institutional establishments enhancing performance expectations of the national system. This was partially proven through empirically measuring institutional outcomes as endogenous variables and its relations to national income levels, which concluded the quality of institutions, among other measured variables such as geography and integration, play the biggest role in national income performances; thus a proven functional hypothesis on the variety of institutional contributions leading to a country’s national competitiveness.[97] Here, a point of departure worth noting is that the primacy of institutions does not necessarily relate to the effectiveness of macroeconomic policies, but instead, the focus shifts on how countries strive to implement policy innovations that fundamentally reshape the institutional setting of their respective economies.[98]

The idea further elaborates on the two distinctive types of capitalist regimes known as liberal market economies (LME) and coordinated market economies (CME), based on how the regimes interact with market mechanisms. LMEs represent systems that appear more evident in Anglo-Saxon market economies, such as the United States and the United Kingdom, where the coordinating mechanism is centered on the market with limited state intervention. Because of the arm’s length nature of the state in coordinating economic behavior, LMEs show characteristics of strong inter-company competition supported by short-term oriented company finance with deregulated employment relationships, followed by a labor force trained under a general education system. CMEs shows contrasting propensities mostly evident in Germany, Sweden, and Switzerland, where economic behavior is coordinated through nonmarket intermediations in a form of interest groups, government entities, as well as public and private institutions.[99] Here the political economic mechanism is formed through competitive market arrangements, at which the legal system forms its basis respective to complete and formal contracting. Firms obtain higher bargaining power over other economic entities, therefore employment relations are mostly determined by firm decisions and the institutions that supports these firm-centric system encourages competition and freer movements of inputs. Conclusively, innovation occurred in a Liberal Market Economy is considered highly radical, therefore technological breakthroughs often choose their birth places in these systems. LMEs show comparative advantages

[97] Dani Rodrik et al., “Institutions Rule: The Primacy of Institutions Over Geography and Integration in Economic Development,” Journal of Economic Growth, 9, 2004, p. 136.
[98] Ibid., p. 156.
[99] Baron, D.P., “Integrated Strategy: Market and Non-market Components,” California Management Review, Vol. 37, Issue. 2, 1995. p. 57

mostly in the high-tech and service sectors.[100]

Opposed to LMEs, CMEs are highlighted by longer term company finance and cooperative industry relations, associated by high levels of vocational training and standardized technological standings. Scandinavian countries, Germany, and Japan present distinct types of Coordinated Market Economies. The market mechanism mostly relies on non-market relations such as government initiated formal institutions to regulate the market and coordinate the interaction of firms and firm relations with suppliers, customers, employees, and financiers, represented in a form of state led capitalism. CMEs tend to be characterized by relatively long-term relations between economic actors that are also relatively cooperative. In the field of human resource management, CMEs tend to have high levels of job security, a good record on training and development, institutionalized forms of worker participation, based on works councils, and relatively cooperative relations between trade unions and employers' associations. These long-term, cooperative relations provide CMEs with their source of comparative advantage in the world economy: they tend to be good at process innovation and the production of high quality, high value-added goods in mature manufacturing industries.[101] The most representative case of CMEs is shown in the German economic model entitled *Rhineland Capitalism*, or *organized capitalism*. The Institutional characteristics of the German system is featured in centralized decision making primarily made by the private sector, at which public and private associations exert greater influence in economic and social policies that enables dedicated capital to observe long-term interests of the firm instead of submitting to short-term returns.[102] In order to salvage the backward conditions of a catch-up economy compared to the fledging British and American enterprises of the early 20th century, the German *Hausbank* model imposed a dynamic corporatist economic order in German industrial development by providing stable financial support to its emerging heavy industry sector, which established close coordinating connections between large businesses and financial institutions. The business-financial arrangements continued into post-war economic planning, which set the basis for the German tradition of highly cooperative unions and strong employer associations, industry-firm specific technical training and education system, and a long-term collaborative network between industry, research institutions, and universities.[103] Institutional structures, placed at the core of the innovation system concept, are considered as the rules of the game in a society, in which a distinction can be made between formal institutions and informal institutions. Formal institutions are mainly rules that are codified and enforced by the authorities, whereas informal rules are more normative and values generally accepted within the society.[104] An extended discussion over the role of institutions is

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[100] Peter Hall and David Soskice, Varieties of Capitalism: The Institutional Foundations of Comparative Advantage, Oxford University Press, 2001, p. 8.
[101] Ibid., p. 12.
[102] Andreas Busch, "Globalisation and National Varieties of Capitalism: The Contested Viability of the German Model," German Politics, Col. 14, No. 2, 2005, p. 127.
[103] David Soskice, German Technology Policy, Innovation, and National Institutional Frameworks, September 1996, WZB Discussion Paper, No. FS I 96-319.
[104] Rothwell, R., "Successful Industrial Innovation: Critical Factors for the 1990s," *R&D Management*, 3, 1992, p. 225.

technological structures that consist of artifacts and infrastructures in which they are integrated. These features are crucial for understanding the feedback mechanisms between technological change and institutional change. An analysis of structures typically yields insight into systemic features - complementarities and conflicts - that constitute drivers and barriers for technology diffusion at a certain moment or within a given period in time.

In the Post-Cold War era and the spread of globalization signaled the transformation of the German model. The demise of Rhineland Capitalism demonstrated in the sclerotic economic growth of Germany in the post-unification era, that disintegrated notable features of Germany's organized capitalist system such as the Hausbank model, and the bargaining power of employer associations and labor unions, has introduced substantial elements of market mechanisms, or a LME type institutional setting. Although it is considered premature to state a total collapse of the *Model Deutschland*, it is fair enough to consider the emergence of a hybrid pattern in the form of a 'convergent' model in a globalized economic system.[105] Hence, there is a need to highlight the changes of VoC regimes pressured by globalization. The international flow of capital associated with the growing nature of the internationally integrated production system has seriously eroded the genuine structure of CME type countries into a more liberalized economy. Although discussions remain whether this is a form of convergence to the liberal market or divergence resulting from the comparative advantage of different capitalist systems, there is no gainsaying to the fact that VoC systems, in an era of globalization, have shifted into a more hybrid form on both ends of the debate.[106] Continued internationalization has exposed CME systems into the global competition market, at which competitiveness cannot be sustained by quality control but also by price. Additionally in the financial area, the growing alteration towards stock market capitalization, in conjunction with the traditional 'big banks' remodeling its strategies towards a more investment oriented practice, has transformed government policies favorable to shareholder values, which placed firms in a position eligible to hostile takeovers.[107] The composition of corporate leadership was equally effected by this wave of change when senior managerial positions, mainly promoted from the hierarchy of technical echelons, were being replaced by lawyers and financiers seeking short-term returns in order to respond to shareholder demands.[108] Therefore, although appearing in divergent forms respective to the capitalist characteristics of the economy, the wave of globalization has introduced a degree of deregulation and decentralization into the socio-economic engine of CME countries, belittling the traditional role of corporatist bargaining of unions and associations to a certain extent, while enlarging the scope of market power. In a similar case, LMEs also experienced some overhaul in its laissez-faire system. After a series of financial scandals in the U.K.,

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[105] Christopher S. Allen, "Ideas, Institutions, and Organized Capitalism: The German Model of Political Economy Twenty Years after Unification," German Politics and Society, Issue 95, Vol. 28, No. 2, Summer 2010, p. 145.

[106] Pedersen, O. K., "Denmark's negotiated economy," in J. L. Campbell, J. A. Hall, & O. K. Pedersen, National Identity and the Varieties of Capitalism: The Danish Experience, McGill-Queen's University Press, 2006, p. 260

[107] Jurgen Hoffman, Coordinated Continental European Market Economies Under Pressure From Globalisation: Germany's "Rhineland Capitalism" DWP 1 February 2004, p. 5.

[108] Ibid., p. 12.

which culminated in the collapse of the historically distinguished Barings Bank, the need for public oversight into the financial industry has encouraged the British Government to establish a regulatory system that consolidated the authorities of separate public institutions into a single entity called the 'Financial Service Authority', which was considered a surprising move for a country like the U.K. that exercises predominantly self-regulating policies in the banking sector.[109]

Although not included in the original classification of the VoC literature, countries like France, Japan, or the East Asian developmental states that demonstrate strong influence from the government in state capitalism, have a rather more state-influenced economic structure that show a mixed form of market economies from both ends of the VoC approach. The original authors of the VoC debate briefly cited these variations as "mixed-market economies" (MME), primarily highlighting Southern European states along the coastlines of the Mediterranean such as France, Spain, and Italy.[110] But a more sophisticated study of these economies, with a focus of countries showing histories of significant state intervention in finance and labor politics, were elaborated as "state-influenced market economies" (SME).[111] In a SME system, the state intervenes in significant sectors where perceived suitable, but not in all domains of the society. In France, dirigiste government initiatives permeated the state into business activities and labor control, which generated economic growth through nationalized industries and placed the market under wage coordinating mechanisms.[112] Under this assertion, the Mediterranean countries such as Spain and Italy labeled as MMEs do not necessarily coincide with the strong state led characteristics of France, but align more prone to the British system in areas such as income distribution and labor policies. Countries that show higher resemblance to the SME system are Japan, or the East Asian developmental states such as the Republic of Korea or Taiwan.[113] It is under these two comparative capitalist regimes that show different patterns of innovative outcomes based on its respective institutional configurations. The characteristics of SME systems will be discussed in more detail in the following section on East Asian capitalism later in this chapter.

2.3.2. Variety of Capitalism Literature on Technological Innovation

Contrary to conventional economics, Schumpeterian growth theory highly values the role of technology and its contribution to innovative behaviors. Within this context, learning is the conduit for technological advancement, and the learning process is supported under the auspices of institutions. The cross national difference in technology adoption, diffusion, and exploitation is determined by the institutional configuration of a society that leads to different innovative outcomes. Here, innovation

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[109] Clive Briault, "Revisiting the rationale for a single national financial services regulator," Occasional Paper Series 16, Financial Services Authority, February 2002, p. 9.
[110] Peter A. Hall and Daniel W. Gingerich, Varieties of Capitalism and Institutional Complementarities in the Macroeconomy: An Empirical Analysis, MPIfG Discussion Paper 04/5, p. 35.
[111] Vivien A. Schmidt, "Putting the Political Back into Political Economy by Bringing the State Back in Yet Again," *World Politics*, Vol. 61, Issue 3, 2009, p. 521.
[112] Vivien A. Schmidt, "What Happened to the State Influenced Market Economies (SMEs)?," in Wilson and Grant eds., The Consequences of the Global Financial Crisis, Oxford, p. 158.
[113] Ibid. p. 161.

generally comes in two categories; radical and incremental alignments. The VoC theory predicts a society showing strong LME propensities tend to concentrate its creative talent into radical technological change whereas societies showing strong CME propensities focus more on incremental technological change. Therefore, a society highly reliant on market mechanism is geared towards more radical innovations while a society with more nonmarket forces is shaped more around incremental innovations. Radical innovation is a phenomenon that "entails substantial shifts in product lines, the development of entirely new goods, or major changes to the production processes."[114] Radical innovation is critical for production in the high-tech sectors of complex systems such as biotechnology, semiconductors, aerospace, etc., where rapid and significant changes constantly occur. Incremental innovation is defined as "continuous but small scale improvements to existing product lines and production processes."[115] The priority of incremental innovation is to sustain high quality in already established artifacts, which pertains to improvements made in production processes primarily for cost reduction, hence to promote competitiveness in material goods such as machine tools, consumer items, engines, etc. The institutional difference, however, does not confine a society solely to either end of innovation types, but explains the difference in institutional configurations lead to diverse forms of comparative institutional advantages for innovators.

<table>
<tr><th colspan="2"></th><th>Coordinated Market Economies</th><th>Liberal Market Economies</th></tr>
<tr><td colspan="2">Innovation Type</td><td>Incremental, process innovation</td><td>Radical, product innovation</td></tr>
<tr><td colspan="2">Control Mechanism</td><td>Nonmarket</td><td>Market</td></tr>
<tr><td rowspan="5">Corporate Governance</td><td>Decision Making (corporate leadership)</td><td>work council and consensus style decision making</td><td>top-down unilateral control</td></tr>
<tr><td>Inter-corporate linkages</td><td>interlocking corporate directors, cross shareholding</td><td>equity markets with dispersed shareholders</td></tr>
<tr><td>Business Priorities</td><td>Growth and employment</td><td>emphasizes current profitability</td></tr>
<tr><td>Corporate Strategies</td><td>product differentiation</td><td>intense product competition</td></tr>
<tr><td>M&A possibilities</td><td>against hostile takeovers</td><td>few restrictions to hostile takeovers</td></tr>
<tr><td rowspan="2">Finance</td><td>Regulation</td><td>Long-term commitment,</td><td>Expects short-term equity returns</td></tr>
<tr><td>Corporate finance</td><td>large state owned banks</td><td>Recapitalized on stock markets, high reliance on venture capital</td></tr>
<tr><td colspan="2">Inter-firm Collaboration</td><td>highly coordinated industrial relations</td><td>low inter-firm collaboration by restrictive anti-trust and contract laws</td></tr>
<tr><td rowspan="4">Labor Market</td><td>Job Security</td><td>long term (inflexible)</td><td>short term (flexible)</td></tr>
<tr><td>Work Collaboration</td><td>autonomous</td><td>independent</td></tr>
<tr><td>Education/Training</td><td>Industry/Corporate specific vocational skills</td><td>mobile general skills</td></tr>
<tr><td>Unions and Associations</td><td>Strong</td><td>Mediocre or nonexistent</td></tr>
<tr><td colspan="2">Representative Countries</td><td>Continental Europe: Austria, Belgium, Germany, Switzerland, Nordic States</td><td>Anglo-Saxon Economies: U.S.A., Canada, UK, Australia, New Zealand, Ireland</td></tr>
</table>

Table 2. Comparison of LME and CME

114 Hall and Soskice, 2001, p. 38.
115 Ibid., p. 39

The institutional configurations in CMEs relates to highly coordinated industrial-relation systems supported by corporate governance structures portrayed as work councils and consensus style decision making. Corporate governance is also outlined by interlocking corporate directors and cross shareholding that secludes hostile takeovers while easing the burdens of turnarounds on profits. The combination of typical CME institutions secures longevity in employment, corporate strategies essential to product differentiation than product competition, and institutional workforce education nurturing higher skills in industry or company specific technology. All these elements assume a definite attitude that fosters incremental innovation. Despite the encouraging characteristics of incremental innovation, however, the institutional configurations are accepted as stumbling blocks for radical innovation. In the manner that consensus style decision making, as well as the interlocking nature of corporate directorship in the corporate structure, facilitating incremental innovation, resultantly obstructs radical change deemed necessary for reorganization of the established structure and hinders the diffusion of innovations. The consequences of cross shareholdings making mergers and acquisition more difficult inadvertently results in continued challenges for acquiring new technological knowledge.[116]

The ambivalence of LMEs also contains both sides of a same coin in a reverse fashion. Flexible employment patterns in LMEs enable intense changes in production lines of firms while maintaining the proper labor mix. The relatively easy conditions for corporate M&A open new opportunities of firm level asset exchanges, including technological knowhow and scientific expertise. In terms of corporate decision making, the top-down control system permits corporate leadership to enforce rapid organizational changes responding to external developments. The flip side of the coin for LME supported institutions puts into account that corporate strategies concentrating on shareholder interest, seeking short term returns for profits, curtailing job security, eventually impedes worker commitment in developing industry/firm specific skills, which is considered a crucial factor for incremental innovation.

2.3.3. Theoretical Limits of the VoC Debate

A strong dispute against the dichotomy regarding the VoC way of aligning LME and CME countries based on innovation performances, however, claims that the empirical evidence in technological outcomes, mainly derived through the form of patent data, does not necessarily support the discourse of LME countries specializing in more radical sectors than CMEs. Opposing propositions mainly argue that the VoC categorization on prevalent innovation types confines its scope in only two representative countries, the United States and Germany. Such hasty generalization subsequently resulted in committing a biased analysis of the VoC way of thinking. A recent study describes the evidence provoked by the VoC literature is not supportable when the theory excludes the United States from the survey, stating that the United States remains as a major *outlier* in innovative performances

[116] Ibid. pp. 48-52.

among the surveyed countries, of which seriously lopsided the results on the study of capitalism.[117] Also, the survey indicated mixed outcomes of CME and LME scientific achievements, claiming that CMEs, in some cases, appeared higher than LMEs in certain industrial sectors considered radical in technological innovation.[118] Another study that validated the VoC statements through reviewing USPTO analysis, which also showed similar results, asserting that LMEs roughly showed patterns of radical innovation while CMEs in incremental innovation.[119] The study further argued that both types of capitalist market economies, although showing some distinctive features of each prevalent type, generally exhibited diverse patterns of specialization, which resulted in quite heterogeneous outcomes across industries.[120]

The VoC literature accentuates the major success factor in macroeconomic performance depends on the implementation of institutional coherence.[121] That is, coherence defined by institutional consistency pertinent to either side of the binary dichotomy of market or nonmarket forces – centralized wage policies and powerful unions coupled with a corporatist government, or a decentralized wage setting and weak unions coupled with a liberal government – generate conditions for stronger economic growth. Thus, the more the institutions coherently arrange to either side of the capitalist market economies, whether LME or CME types, the chances of economic growth becomes more likely. The literature further advocates a market structure that obviously aligns under one of the main capitalist categories performs socioeconomically better than countries that show hybrid patterns.[122] It argues that an obvious alignment under one of the two categories congruently arranges better conditions for institutional complementarities that generate favorable synergy towards innovation in each of its respective sector of industrial specialty.[123] However, the continued process of social mobility caused by globalization has eroded much of the conventional boundaries of these two distinctive alignments. In some cases shown in Nordic economies, which are primarily considered CMEs, countries such as Denmark or Sweden, after adopting critical institutional aspects of LME practices, whereby introducing a more hybrid structure through some dynamic interaction between market and nonmarket institutions, have consequently become more competitive in its national performances, thus defying the principles of mainstream VoC assertions on institutional complementarities.[124] Especially in the Danish case, political decentralization in industrial policy was shown as the most critical factor that led to the diminishing bargaining power of corporatist unions and associations. This resulted in more

[117] Mark Zachary Taylor, "Empirical Evidence against Varieties of Capitalism's Theory of Technological Innovation," International Organization 58, Summer 2004, pp. 607-609.
[118] Ibid., p.617.
[119] Dirk Akkermans et. Al., "Do liberal market economies really innovate more radically than coordinated market economies? Hall and Soskice reconsidered," Research Policy 38 (2009) p. 188.
[120] Ibid., p. 190.
[121] Lane Kenworth, "Institutional Coherence and Macroeconomic Performance," *Socio-Economic Review*, No. 4, 2006, p. 73.
[122] Hall & Soskice, p. 45.
[123] Ibid., p.17.
[124] John L. Campbell and Ove K. Pederson, "The Varieties of Capitalism and Hybrid Success: Denmark in the Global Economy," Comparative Political Studies, Vol. 40, No. 3, 2007, p. 308.

institutionalized collaboration between private and public sector entities, or market and nonmarket figures, which enabled to transform the Danish economic landscape from a low-end primary industry to a vibrant high-tech economy.[125] The corporatist debate of the Nordic model will be further reviewed in the following section.

Distinctive development patterns regarding the categorization of LMEs and CMEs tend to intermingle more towards convergence when considering sectoral differences, especially in areas of complex high-tech systems. The case of bio-tech, or bio-economy, shows more evident trends in convergence considering this matter. The bio-economy is a sector that consists of dynamic public-private interdependencies in R&D, sponsored by multiple arrays of venture capital financing, orchestrated under sophisticated state regulation that fosters a better condition for learning and the diffusion of innovation. After comparing some leading countries in bio-tech, grouped in accordance with the VoC way of classification, it was concluded that sectoral policies matter more than national policy inclinations.[126] Thus, an obvious CME state like Sweden compared to a LME state like the US did not show much difference in the institutional layout that sustains each bio-economic sector, which shows an apparent pattern of hybrid institutional layouts in the economy.

2.3.4. Alternative Capitalist Models: Nordic Model of Neo-Corporatism

The Nordic model implies to the economic and social success model of Nordic countries represented by welfare politics and free market economies. The common trait of this model is demonstrated through the continued support for a universalist welfare state, at which the promotion of individual autonomy and social mobility is granted alongside a commitment to free trade. The elements of a universalist welfare state become more evident when scrutinizing the remarkable growth patterns alongside with low income inequality and maximum labor force participation. Generally, these characteristics constitute CME type industrial structures where major industrial expectations are shaped around incremental innovative performances. On the contrary, the industrial efforts of Nordic countries also incorporate significant sectors in the radical innovative realm as well. For instance, Finnish telecommunication firms take a competitive market share of the international mobile phone markets, Denmark competes in the radically innovative sectors of therapeutic drugs, and Sweden established a strategic footage in the highly vibrant global aerospace industry.[127] Therefore, it would be too overreaching to narrow the scope of innovation in Nordic welfare states simply to incremental innovation sectors. In this respect, the Nordic model has been studied under the framework of a neo-corporatist perspective, which transitioned from conservatively protective institutions to a more liberal market driven competitive stature, and now transformed to become an effective knowledge-intensive

[125] Ibid., 322.
[126] Mats Benner and Hans Lofgren, “The Bio-economy and the Competition State: Transcending the Dichotomy between Coordinated and Liberal Market Economies,” New Political Science, Vol.29, No. 1, 2007, p. 94.
[127] Yumiko Okamoto, “A Comparative Study on Biotechnology Companies in Sweden and Denmark: Why Do They Perform Differently?”, Doshisha University Policy Studies, 2010, p. 139.

economic structure.

Traditional corporatist debates illustrate neo-corporatism as a theory of interest representation, demonstrated in a coordinated form of interaction between interest groups and governments within a highly bureaucratized economic system of an interventionist state, with an exclusive focus on western industrial democracies.[128] It once served as a dominant form of governance implemented by established protective institutions in existing industries that moderated the conflicting interests between trade unions and employer associations, which politically exchanged for industrial peace, generous social benefits, and expansionary fiscal policies.[129] However, these legacy institutions inadvertently complicated the transition of Western European corporatist systems into a high-tech economic structure. Especially when considering the economic opportunity of information technologies presented to East Asian developmental states, the same technology situation was eroding the industrial niches of western corporatist states.[130] Nonetheless, the Nordic corporatist model, represented by Denmark, Finland, Norway, and Sweden, proved its accommodating capacities to the fledgling information revolution, as well as its perseverance to the shockwave of the global financial crisis.

Corporatist Institutions	Financial Markets	Labor Markets	Industrial Policy (knowledge)	Countries
Conservative	Patient capital and banking blocs	Employment protections, unemployment benefits	Defensive policies to mobilize resources around existing sectors	Austria, Belgium, Germany
Competitive	Tax reductions and liberalized markets	Social consensus on Reduced social benefits and employment protection	Fiscal austerity to promote market competition	Ireland, Netherlands
Creative	Risk capital and venture capital promotion	Human capital investment in disruptive sectors	Concentration in basic and applied R&D in emerging industries	Finland, Denmark, Sweden

Table 3. Corporatist Institutions

Policies of centralized collective wage bargaining and fiscal policies supportive of full employment forms the basis of the primary characteristics expected for conservative corporatist institutions, at which was considered as a highly effective governance tool in Western European welfare states during the 1970s and 80s.[131] Firm and industry specific skills were nurtured through protective industrial policies against outside investments. In this instance, financial markets are committed to long term patient capital channeled through universal banks, and employs investment strategies to grant employment as part of providing services to protect and incrementally upgrade the established industrial structure.[132] Thus, social transactions remain conservative whereby protective measures are imposed for existing industries whereas efforts to promote movement into newer sectors are insufficient. Consequently, social resources are concentrated on reliable, low-medium tech industries posing lesser

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[128] Frank L. Wilson, "Interest Groups and Politics in Western Europe: The Neo-Corporatist Approach," Comparative Politics, Vol. 16, No. 1, 1983, p. 106.
[129] Ibid., p. 108.
[130] Jingjing Huo and John D. Stephens, "From Industrial Corporatism to the Social Investment State," in Stephen Leibfried et al., Oxford Handbook on Transformation of the State, Oxford University Press, 2015, p. 411.
[131] Alexander Hicks and Lane Kenworthy, "Varieties of Welfare Capitalism," *Socio-Economic Review*, 1, 2003, p. 29.
[132] Ibid., p. 31.

risks towards competence destroying innovations.[133] Conservative corporatist institutions therefore has proven competencies in low-tech niches and established industries, but is not a recommended route for competence destroying innovations nor capable in responding against external economic shock.

Competitive corporatism, on the other hand, is more prone towards market led adjustments. Compared to the conservative corporatist approach that focuses on the degree of coordination in the production level, competitive corporatism places more efforts on social concertation in policy formulation.[134] It resembles neoliberal market measures as it promotes market enhancing measures such as reduced government spending, less generous social benefits, and the expansion of part time or irregular contracts.[135] As part of redistributing efforts of financial resources from underperforming noncompetitive industries to new growth oriented enterprises, competitive corporatist practices assertively function towards cutting income taxes in the personal or corporate level. Therefore, it is accepted as a convention for competence-enhancing innovations by facilitating the transition of low-tech industries into high-tech markets.[136] However, the industrial sector that exhibits more elements favorable to competitive corporatist institutions are in basic manufacturing or assembly operations rather than knowledge intensive sectors.

Creative corporatism takes further action into the stance of competitive corporatist institutions in terms of consensus building and coordination in the production level. The collaborative nexus of sharing resources and information between firms, labor, and policy makers enables countries to adequately respond against disruptive economic changes by effectively decoupling traditional investments in declining sectors while targeting new knowledge intensive activities.[137] The flexible employment of public funds into new enterprises that are devoted in novel research and development works. However, the introduction of creative corporatist norms also exposed countries to disruptive technological innovations, which constantly threatens incumbent firms in the high-tech sector from external challenges.[138] The traits of conservative corporatist institutions were palpable to Nordic countries until the late 1980s. In the case of universal banks, the Danish Privatbanken and Finnish banking blocs served as capital providers in established sectors such as pulp and forestry in Finland or food processing in Denmark that arranged protective constellations for economic growth in low-tech niches. But these protective barriers later hindered the economic adjustment into newer enterprise markets as the pre-established sectors evolved into price-fixing cartels that prevented the flow of capital into rising high-tech demands. It was only after the elimination of such protective financial collusion and the subsequent employment of selective bargaining strategies that enabled the Nordic economies to

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133 Ibid., p. 33.
134 Erik Jones, "Is 'Competitive Corporatism an Adequate Response to Globalisation? Evidence from the Low Countries," West European Politics, Vol. 22, No. 3, p. 160.
135 Ibid., p. 161.
136 Ibid., p. 163.
137 Darius Ornston, "Creative Corporatism: The Politics of High Technology Competition in Nordic Europe," Comparative Political Studies, 2012, p. 9.
138 Darius Ornston, When Small States Make Big Leaps: Institutional Innovation and High-Tech Competition in Western Europe, Cornell University Press, 2012, p. 56.

revamp its competitiveness in the regional and global trade establishments.[139] In this regard, sources of Nordic competitiveness originated from the fact of significantly overhauling traditional neo-corporatist institutions by implementing neo-liberalist reform without sacrificing much of the essential corporatist ordeals.

The pinnacle of Finland's innovation policy is its successful transition into a knowledge intensive value added economy by effectively redistributing national resources into high-tech research and development, not just simply eradicating existing normative foundations. The transition was implemented by creating supporting institutions that linked firms, research institutes, and public universities, forming a vibrant consortium of high-tech corporate research. In a sectoral perspective, R&D efforts avoided simple assembly operations, which are generally sensitive to cost changes, and non-tradable services such as residential construction, while concentrated most of its efforts in high-end ICT and biotechnology.[140] The initiatives were structurally implemented by funneling sizable investments into high-tech R&D with public funds made available through a public institution called the Finnish Funding Agency for Technology and Innovation (Tekes), as well as launching new venture capital funds, based on the directives of the tripartite Science Policy Council.[141] The Finnish industrial tradition of constructive state-business engagement and inter-firm collaboration between banking blocs and price-fixing cartels facilitated firms to share sensitive information and selectively allocate scare resources, which attributed to the successful implementation of these initiatives.[142]

In the mobile telecommunication industry, the establishment of the Nordic Mobile Telephone (NMT) technology standard in 1981 created economies of scale with a noticeable joint market size, which operated as an open standard inducing competition. The NMT placed Nordic players well to compete in a digital standard called Groupe Special Mobile (GSM), which became adopted by three quarters of the world.[143] Denmark's model of innovation is highlighted in policies supportive to start-ups and spin-off firms rather than providing for incumbents that already have established footprints in the market.[144] The policy finds its basis from a long tradition of bipartite cooperation between trade unions and industry in skill formation that vertically covers peak-level forums down to the shop floor. It is coined by the term 'flexicurity', which represents proactively flexible labor market policies that allow managerial practices the liberty to hire and dismiss employment with minimum government intervention in the labor market while still providing post-employment security for workers.[145] In terms of unemployment benefits, flexicurity balances between social rights and public obligations in welfare

[139] Ibid., p. 46.
[140] Ibid., p. 62.
[141] Available online at http://www.tekes.fi/en/tekes/strategy/
[142] D, Czarnitzki, B. Ebersberger, A. Fier, "The Relationship Between R&D Collaboration, Subsidies, and R&D Performance: Empirical Evidence from Finland and Germany," Journal of Applied Econometrics, Vol. 22, 2007, p. 1349.
[143] Jane Lehenkar and Reijo Miettinen, "Standardisation in the Construction of a Large Technological System – The Case of the Nordic Mobile Telephone System," *Telecommunications Policy*, Vol. 26, Issue 3/4, 2002, p. 112.
[144] Michael S. Dahl, Christian O. R. Pedersen, and Bent Dalum, "Entry by Spinoff in a High-tech Cluster," *DRUID Working Paper*, No 03-11, p. 18.
[145] Bredgaard, T., F. Larsen and P. K. Madsen, "The Flexible Danish Labour Market – A Review," Centre for Labour Market Research (CARMA) Research Paper No. 31, 2005, p 23.

schemes by imposing motivational effects in tailored vocational training programs that accommodates social needs.[146] R&D schemes came in a form of building a strong network of small and medium sized enterprises at the local level where producers and suppliers were familiar with each other through previous educational and technological experiences provided by approved technological service institutes or universities.[147] The networks allowed participating firms to diversify into a higher value added sectors of interest that facilitated spin-off firms divested from larger incumbents as well as establishing favorable grounds for start-up firms.[148]

2.4. Complex Product and Systems (CoPS)

2.4.1. Overview of CoPS Literature

High technology sectors are known as areas holding significant percentages of human capital jobs, such as scientists, engineers, indicated through high R&D expenditures, information intensity, stock of capital, and various elements accommodating definitions as such.[149] Other characteristics of high-tech also delineate effective knowledge sharing channels, highly geographically concentrated innovation clusters, and separation of design and manufacturing functions.[150] High technology sectors referred in this study are those labeled as industrial products characterized with a large hierarchically-organized supply chain interconnected with a network of prime contractors and suppliers. This sector normally has significant economic and political values to the customers and producers, which is characterized by highly capital intensive, low volume production, tailored design products, and the vast scope of interconnected networks for R&D, production, and operations. The sector is relatively considered either a novel product area, associated with rapid growth in a self-sustaining manner, or a significantly extensive system area that spans into a long life cycle lasting over decades. In this respect, innovation emerges in an evolutionary fashion in terms of the insertion of new technological features conducted through a phased system upgrade and modification procedure.[151] As such, these features make the sector discernable from conventional mass produced industrial products. Intuitively distinguishing this form of evolving product areas from the conventional commodity products of mass production, complex products and systems are often cited in a general term as CoPS. The subject industrial fields of CoPS embody significant uncertainty and risks, involving a myriad of components, interconnected network architecture, and control mechanisms after completion of production, which conceptually brings in typically intricate attributes represented by coordination and innovation throughout the production process.

[146] Ibid., p. 29.
[147] Malgorzata Runiewicz-Wardyn, Knowledge Flows, Technological Change, and Regional Growth in the European Union, Springer, 2013, p. 82.
[148] Ibid., p. 89.
[149] Ann Markusen, Peter Hall and Amy Glasmeier, High Tech America: The What, How, Where and Why of Sunrise Industries, Unwin Hyman, 1987, p. 5.
[150] Ashok Bardhan, Dwight Jaffee, Cynthia Kroll, *Globalization and a High-Tech Economy: California, the United States and Beyond*, Kluwer Academic Publishers, 2004, p. 21.
[151] Mike Hobday, “Product complexity, innovation and industrial organization,” Research Policy No. 26, 1998, p. 672.

Firstly, unlike mass production commodity items where the firm is identified as the main unit of analysis, the CoPS project itself, which spans into cross sectoral collaboration between various entities such as the prime contractor (often designated as the system integrator), bidding party (in many cases governments or large businesses or consortiums of such), subcontractors and associated supply chain, constitutes the main unit of analysis. The absolute reality here is the fact that CoPS development mostly exceeds the engineering capacities of a single firm, which strongly requires the accommodation of other professional entities performing in its established area of expertise within the project boundaries. Here, the public appeal of CoPS is through promoting the idea of the project itself opposed to mass product items where products become the primary subject for soliciting marketing promotion. In this aspect, due to the small batches of production, CoPS is more influenced by customer needs than regular market dynamics. Therefore, the traditional product-life cycle debate resonates marginally into the discourse of CoPS. In this regard, CoPS projects are hierarchically structured, meaning that each phase of technical development and production are closely connected, at which unit costs and technical complexity become extensively attached from the previous phase to the next phase of designing and manufacturing. Therefore, the integration of disparate components and modules thus needs to be closely coordinated and engineered.[152]

Secondly, cross-sectoral coordination constitutes a major feature of CoPS. Traditional organizations show predominantly vertical structures, which eventually result in inflexibility, coordination difficulties, and low integration. The complexity of system design and production of major end items from this sector requires a high aggregation of knowledge and an intricate manufacturing base Here, it becomes imperative for the central agent called the system integrator to coordinate the participation of external supplier units that provide a wide range of expertise and components essential to the product development process.[153] The array of different system components plays distinctive and interrelated roles, hence each serving in independently functional areas but comprehensively synchronized to achieve a common goal. Also, the larger and more complex structure of the system makes the knowledge transfer process more relational base and tacit in nature throughout the project design and execution phase, where small numbers of expert technicians in relevant fields eventually turn out to be the only feasible sources of major manufacturing functions. In this aspect, the relationship between the system integrating firms and subcontracting supplier units become critical in the course of developing and manufacturing complex products. Adding to the already immoderate complexity challenges of coordination, military systems also require substantial feedback loops from downstream to upstream production phases, which substantially alters system architectures and design specifics in

[152] Ibid., p. 689.
[153] M.C. Becker and F. Zirpoli, “Beyond product architecture: Division of labour and competence accumulation in complex product development,” Conference Proceedings in Entrepreneurship and Innovation-Organizations, Institutions, Systems, and Regions, 2008, p. 3.

the system integration process.[154]

Thirdly, CoPS are inherently subject to public norms and regulations, which often serve as either catalysts or impediments for innovation. Mostly in the realms of public safety compliances and standardized interfaces, the regulatory preconditions over CoPS development and manufacturing processes customarily facilitate the engineering and manufacturing phases. For instance, standardization of system components not only assists compatibility with other systems within the network structure, but also promotes knowledge transfer to other learning units as well. However, such standardization mechanism in some occasion confines CoPS units from further exploring novel opportunities or adopt evolutionary technologies into the overall system. The current conundrum with military GPS encryption supports this notion.[155] Another aspect of regulatory control over CoPS is represented in export control regimes of certain products, mostly associated with military applications. The fundamental objective of US high-tech export control policies was to preclude the transfer of state-of-the-art defense technologies to adversaries such as the Soviet Union and members of the Warsaw Pact, which adversely had harmful impacts onto the US economy in terms of sustaining technological competitiveness.[156] It was demonstrated that the discouragement of diffusing technological knowhow by these control regimes have obstructed subsequent learning opportunities through knowledge diffusion to improve the skill sets and technological readiness of the industrial sectors.

A fourth aspect of CoPS is the growing importance of informal relationships. As mentioned in the second chapter, the diffusion of tacit knowledge, which mostly embodies deep experience and high-tech artisanship, is associated with inter-relational attributes that often requires the circumvention of formally established procedures and communication protocols of an organization. However, it is through these means of communication where rapid exchanges of ideas and information proliferates and creates successful convergent processes for better innovative outcomes.[157] These exchanges through informal channels are deemed critical for the development of novel products. A brief description of informal relationships refers to social interactions or the amassing of social capitals of the firm. In this relational perspective, the buildup of ‘trust’ is considered the most important element for stronger and sustained exchanges.[158]

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154 Jerry Lake, “Systems Engineering Re-Energized: Impacts of the Revised DoD Acquisition Process,” INCOSE International Symposium, 1991.

155 US DoD’s decision to transition its current GPS security architecture to SAASM based modules has initiated a series of interoperability challenges with ally countries using legacy US military GPS encryption, which compels these countries to abolish the older system and adopt newer encryption modules while bearing the significant replacement costs; Government Accountability Office, Global Positioning System: Challenges in Upgrading and Sustaining Capabilities Persist, GAO-10-636, September 2010, p. 37.

156 Arvind Parkhe, “U.S. National Security Export Controls: Implications for Global Competitiveness of U.S. High Tech Firms,” Strategic Management Journal, Vol. 13, No. 1, 1992, p. 49

157 Dorothy Leonard and Sylvia Sensiper, “The Role of Tacit Knowledge in Group Innovation,” California Management Review, Vol. 40, No. 3, 1998, pp.113-115.

158 Daniel Levin and Rob Cross, “The Strength of Weak Ties You Can Trust: The Mediating Role of Trust in Effective Knowledge Transfer,” Management Science, Vol. 50 Issue 11, p. 1477.

2.4.2. Integrated Analytical Framework of CoPS

The conditions described above presents continued challenges in various ways. An integrated analytical framework over these CoPS challenges mainly highlights four areas of concern; Business, Systems Integration Process, Organization, and External Circumstances.[159] Business aspects of CoPS engage in the analysis of strategic business objectives such as market share and cooperative alliances with other firms. In a sense of firm level relationships, intercorporate technology alliances are viewed as pipelines for the focal firm to obtain access into a larger variety of knowledge and resources.[160] Thus, the better the resources in business portfolio the partner firm obtains the more benefits to the focal firm by establishing access relationships to those resources through alliances. Such traits are shown evident in high-technology sectors where a network of shared knowledge and interaction becomes a norm for innovative processes and outcomes. For instance, the typical business practices of Japanese companies in the form of firm level learning and the effectiveness of production networks are demonstrated in the Toyota case where knowledge transfers across organizational boundaries are facilitated by inter-organizational routines constructed under strong network identities generated through knowledge sharing mechanisms; rules for knowledge protection against free riders; creation of cost reducing knowledge sharing processes in sub-networks.[161] Human asset specificity, or human specialization, which efficiently allows the transfer of know-how and technology, is a well-known substance formed from long term inter-firm relationships and continuous information exchanging instruments that are deemed integral for innovation.[162]

Systems integration and project management constitute the core capabilities of the CoPS supply chain. The effective organizational form adaptive for CoPS is described as a Project Based Organization (PBO), which is normally a temporary project formed with the objective to develop, manufacture, and operate customary products considered in the realm of CoPS. The PBO is intrinsically flexible and reconfigurable to changing client needs opposed to the general notion of large hierarchical organizations being rigid and obtrusive to customer changes and innovations.[163] Opposed to the conventional form of matrix organizations, where functional divisions such as finance, marketing, engineering, human resources, R&D, manufacturing, etc. represent the division of operating functions and capabilities, in a PBO the functional resources are shared by each project. Here, the governing mechanism between project divisions and functional divisions primarily lie upon the delegated authorities from senior corporate management boards to project managers and functional managers. A

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[159] Ying-Tao Ren and Khim-Teck Yeo, “Research Challenges on Complex Product Systems Innovation,” Journal of the Chinese Institute of Industrial Engineers, Vol. 23, Issue 6, 2006,

[160] Toby Stuart, “Interorganizational Alliances and the Performance of Firms: A Study of Growth and Innovation Rates in a High Technology Industry,” Strategic Management Journal, Vol. 21, No. 8, p. 791.

[161] Jeffrey H. Dyer and Kentaro Nobeoka, “Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case,” *Strategic Management Journal* Vo. 21, No.3, 2004, p. 345.

[162] Elsie L. Echeverri-Carroll, “Knowledge Flows in Innovation Networks: A Comparative Analysis of Japanese and US High-Technology Firms,” *Journal of Knowledge Management*, Vo. 3, No. 4, pp. 298-300.

[163] Mike Hobday, “The project based organization: an ideal form for managing complex products and systems?”, Research Policy 29 (2000), p. 874.

typical project manager in a PBO demonstrate stronger authorities over decision making than functional managers when coping with emerging properties or responding to changing client requirements, whereas functional managers exercise stronger authorities vice versa over routine production and engineering tasks.[164]

Risk factors associated with large CoPS projects are likely to involve institutional commitments that may entrap industries or the society in general from the respective business. The legal, organizational, and political institutions originally arranged to support CoPS projects create inertia that causes inferior technology paths to survive the business cycle long after it should've been abandoned.[165] The technological lock-in reinforced by the close relationship between states and businesses, which prevent the democratic functioning of market forces, eventually result in catastrophic outcomes where the society has to pay for the remedies of extricating from the business. The British Thermal Oxide Reprocessing Plant (THORP) Project is a case that exemplifies this situation where the decision to sustain the project ended up in paying huge losses by the society in terms of remedy payments as well as losses in opportunities to invest in other more promising fields.

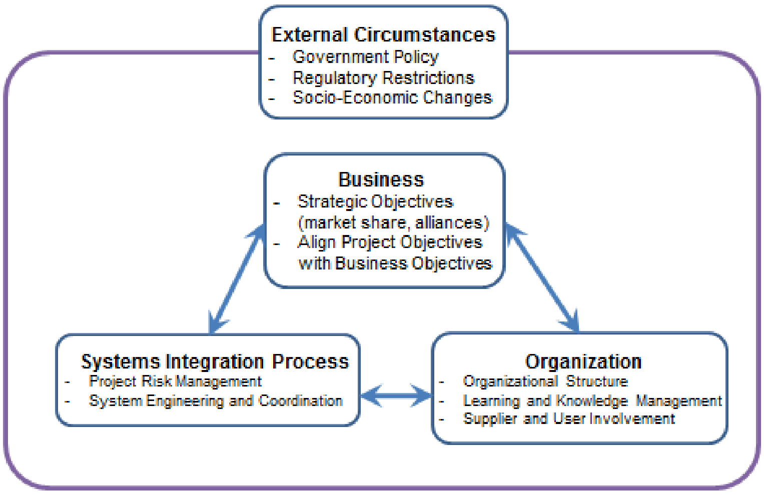

Figure 1. CoPS Integrated Analytic Framework
(*Adopted and reproduced from Ren and Yeo, "Research Challenges on CoPS Innovation", Journal of the Chinese Institute of Industrial Engineers, Vol. 23, Issue 6, 2006.*)

2.4.3. Progressive Dynamics of System Integration: CoPS and Innovation Networks

The sequential aspects of economic catch-up models suggest the feasibility of firms short-cutting certain developmental phases in the industrialization process. As stated in previous sections of this chapter, after acquiring the requisite knowledge and skill base in the respective manufacturing subjects, firms were able to skip, or create, certain developmental processes in the course of catching up. Under the context of CoPS domain, however, certain circumventing efforts do not necessarily lead into successful catch-up outcomes. The repetitive and iterative natures of CoPS manufacturing calls for

164 Ibid., p. 878.
165 William Walker, "Entrapment in large technology systems: Institutional commitment and power relations," Research Policy 29, 2000, p. 833.

deepen accumulation of knowledge (R&D) and skillsets (manufacturing), which require governments to coordinate coherent development strategies and firms to build capacities for engineering and manufacturing. In this aspect, the path following credentials through the practice of OEM-ODM-OBM process is the most assured pathway for technological catch-up. Especially, in a Schumpeterian Mark II technological regime where economies of scale and scope relies on an integrated R&D structure and a horizontally collaborative production system between public and private entities, catch-up strategies adheres to the phased development sequences pre-established by the forerunners in the sector.[166] Catching-up in the CoPS domain require extensive networking with major actors with a broad and deep integrated knowledge base and skillset. The pivotal role of institutions managing to coordinate and leverage these capabilities determines the success factors of a CoPS project.[167]

Sources of knowledge in highly concentrated technological fields are widely distributed, at which brings the point where no firm or entity singlehandedly obtains the required skill set that can bring innovation to the market. Thus, extensive collaboration from all dimensions formed through routed membership becomes a prerequisite that can effectively manage these diversified patterns of technological progression and innovation. Organizations that established a multitude of collaborative ties most likely construct improved protocols to exchange and filter critical information. These collaborative relationships mapped as networks become the locus of innovation that directly impacts on competitive positions.[168]

In the sense of technological innovation, networks are formed around contractual relationships demonstrated in cross industrial disciplinary research consortia, strategic alliances between firms, professional memberships in various technological associations, and so forth. Intensiveness of relationships is divided into strong and weak ties. Strong ties become obvious in risk sharing instances such as in R&D partnerships, joint ventures, and equitable alliances, whereas weak ties appear evident in risk averse relationships such as in licensing or patenting agreements.[169] However, tacit knowledge is more transferrable through strong ties while novel opportunities are mostly formed around weak ties. The more sophisticated the knowledge and technological applications are in place, the importance of network mechanisms in R&D, product development and distribution become ostensible. Other related studies show positive correlation between technological sophistication and intensity of strategic alliances.[170] Innovation in complex systems such as the aerospace sector shows apparent features of this trait. Informal ties make significant contributions to innovation because it facilitates the sharing of

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166 Mehdi Majidpour, "Technological Catch-up in Complex Product Systems," Journal of Engineering and Technology Management, Vol. 41, 2016, p. 103.
167 Park Tae Young, "How a Latecomer Succeeded in a Complex Product System Industry: Three Case Studies in the Korean Telecommunication Systems," Industrial and Corporate Change, Vol. 22, No. 2, 2012, p. 368.
168 Walter W. Powell and Stine Grodal, Networks of Innovations, in Jan Fagerberg et. al., The Oxford Handbook of Innovation, p. 59.
169 Tim Rowley et. al., "Redundant Governance Structures: An Analysis of Structural and Relational Embeddedness in the Steel and Semiconductor Industries," Strategic Management Journal, Vol. 21, 2000, pp. 371-375.
170 Christopher Freeman, "Networks of Innovators: A Synthesis of Research Issues," Research Policy, Vol. 20, Issue 5, 1991, p. 512.

complex information. Innovation Networks can positively serve as conduits or channels of information flows and exchanges. But on the flip side, innovation networks also present challenges in effectively exploiting innovation opportunities. Established networks that form strong ties and mutually dependent collaborations often enmesh the relationship into path dependent inflexibilities that often obstruct further advancement of technological opportunities. Network connectivity thus also has its declining limitations shown by diminishing returns in effectiveness and efficiency of patenting performances. Cohesiveness in networks facilitates the flow of information but often does not recognize promising sources of new ideas. An optimal blend of strong and weak ties is therefore necessary, but it is also a difficult task to surmount.[171]

Market failures and network failures are together known causes why certain countries cannot excel in S&T. Markets fail when informed rational individuals are absent, or when exchange of goods, services, and capital are nonexistent, or when innovation and economic efficiency fail to appear. Governments intervene in order to prevent market failures. General notion understood as basic primers used by governments to build strong market forces are highlighted in the five pillar construct; 1) Property Rights; 2) R&D Subsidies; 3) STEM Education; 4) Research Universities; 5) Trade Policy. There is no silver bullet that defines the pathway to innovation, whereas the five pillars proportionately interacting with each other determines the national innovation rates of countries in S&T capacities.[172] Another noteworthy element that constitutes absorptive capacities in S&T considers the institutionalization of technical standards. Often coined measurement standards, a narrow definition of the term relates with well documented technical specifics, codified criterion, or accepted practices in products, processes, and performances. Technical standards carry significant weight that enable efficient communication between different systems or network participants, and becomes more critical in highly complex product systems.[173]

2.5. Chapter Conclusion

Institutions have always served as a conduit of innovation. Different accounts of innovation were generated by differing establishments and cultural heritages, but the concept of transferring information and ideas among people, enterprises, via institutions, remains almost identical. Innovation and the following developments in technology results from a complex set of relationships among actors in the system, which include enterprises, universities, and government research centers. In this context, policy makers need to understand these mechanisms to leverage better performances and improving overall

[171] W. Powell, K. Koput, L. Smith-Doerr, and J. Owen-Smith, “Network Position and Firm Performance: Organizational Returns of Collaboration in the Biotech Industry,” in S. Adrews and D. Knoke eds., Networks in Around Organizations, Emerald Groups Publishing, 1999.
[172] Mark Zachary Taylor, The Politics of Innovation: Why Some Countries Are Better Than Others At Science & Technology, Oxford, 2016, p. 74.
[173] Robert H. Allen and Ram D. Sriram, “The Role of Standards in Innovation,” *Technological Forecasting and Social Change*, No. 64, 2000, p. 173.

competitiveness by nurturing the systems of innovation beyond national level boundaries. In this regard, policies which seek to improve networking among the actors and institutions in the system and which aim at enhancing the innovative capacity of firms, particularly their ability to identify and absorb technologies, are most valuable in the practice of innovation.

Putting this into consideration, the study intended to apply different sets of innovation theories with a vested interest on institutional arrangements as an analytical framework in the overall attempt to review the industrial upgrading process of a fast following economy. The constrained discourse of the developmental state theorem in the post Asian Financial Crisis era, regarding the country's strong willingness to enter the realm of Schumpeterian Mark II technological regimes, have posed several challenges in regards to the structural adaptations of the subject innovation system. State driven economic planning initiatives receded where corporate Korea has taken over more shares in the innovation responsibility. Vertical stovepipes embedded within the state decision making process, which was proven effective during the days of fast economic catch-up, have turned out to be laggards and inadequate in the course of responding against undefined setbacks originated from market forces. In this regard, state bureaucracy driven by technocrats has transitioned to market professionalism. The economy, especially in high tech complex product systems, diversified into a myriad of business sectors where state technocrats could no longer regulate the entire planning and development process. The technological/industrial upgrading process has phased out the public expectation of short business returns and necessitated the requirements to institute long gestation periods over R&D investments and a process to effectively accumulate knowledge and experience.[174] In respect to legacy developmental state assertions, fast following countries successfully stretched the defined pathways of economic development, which embodied low risk and assured investment outcomes. The circumstances transitioned to entering undefined high risk developmental processes blended in uncertain business prospectus. The innovation system accustomed to codified processes in engineering and manufacturing is compelled to transform into a system attuned to learning and exploiting tacit knowledge and engineering practices in the respective sectoral area of expertise. Development schemes now have to learn how to conceptually design products and competently integrate various engineering functions into a system platform. The daunting engineering and manufacturing tasks of complex product systems has dissolved the vertically integrated production system into a more horizontally collaborative network structure. The incorporation of every actor that counts in the development process, from university/government laboratories, statesmen, workshop level technicians, and so forth, has become indispensable. Thus, the mechanism to institutionally coordinate the various aspects of launching the innovation engine has become identifiable as the key area of focus for the analysis of this study.

This study endeavored to capture these elements in the below diagram that strived to

[174] Ambitious/aggressive development schedules deteriorate conditions for accumulating adequate experiences and skills because it forces the program authorities to seek short-sighted answers instead of long-term solutions that should allow a duration of incubation.

accommodate the four primary theoretical discussions of innovation studies – developmental state, national innovation system, varieties of capitalism, complex product systems.

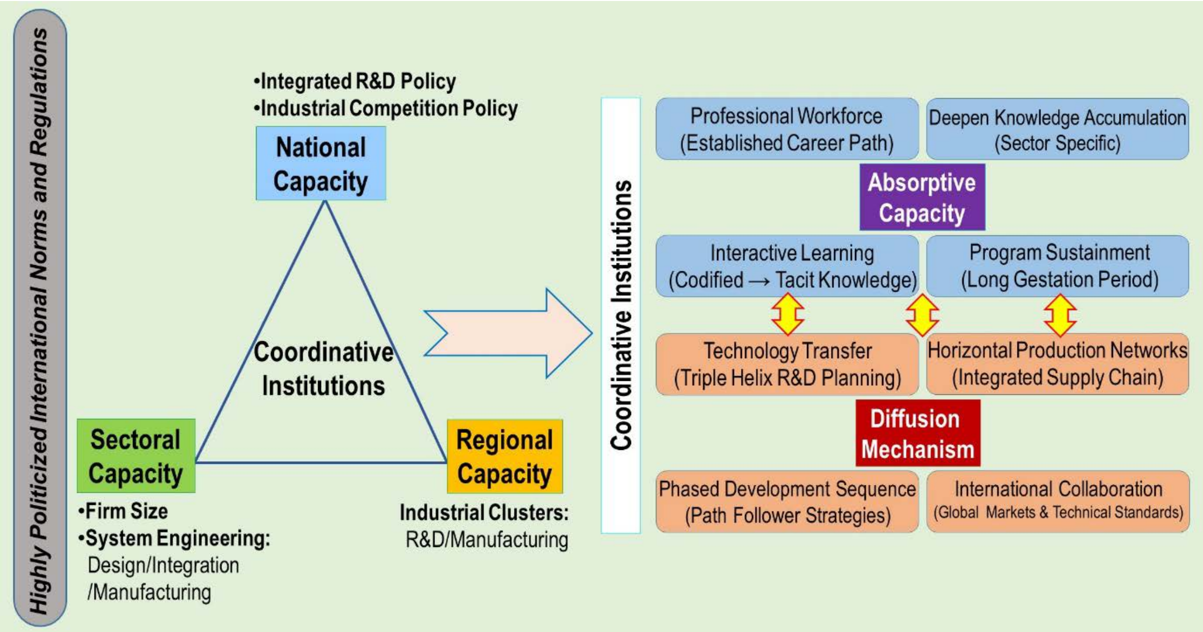

Figure 2. Analytical Framework of Catch-up Strategies in Schumpeterian Mark II Technological Regimes

The analysis focuses on the coordinative institutions that function as a linchpin among the major actors in a Schumpeterian Mark II technological regime for late entrants in the sector. Hence, the interactive coordination processes that accommodate absorptive capacities represented by the concerted efforts of knowledge accumulation, and the diffusion mechanisms represented by the production networks have been placed in the center of the analysis. Coordinative institutions, in this regard, not only considers government roles in terms of regulating the innovation process, but also covers the regional and sectoral innovation system spontaneously established and instituted throughout the process of building foundational capacities.

Chapter 3: The Global Aerospace and Defense Industry

3.1. Overview

The global aerospace industry is generally regarded a white man's playground, considering the fact of the industry being predominantly dissected by American and Western European firms. Aerospace is a field that has been generally labeled together with the armament industry, thus frequently cited as aerospace and defense, although the commercial aircraft manufacturing sector constitute a comfortable majority in the global business. Along with motor vehicles and other transport equipment, aircraft manufacturing is categorized as complex product systems and is therefore arranged under the technological regime of Schumpeterian Mark II sectors.[175]

The aerospace industry is a high-tech knowledge intensive industrial sector that induces high performance outcomes in production and employment. According to the US Aerospace Industries Association in 2007, the average salaries in aerospace (USD 93K) performed 44% higher than that of other manufacturing sectors (USD 65K).[176] European firms also show similar patterns in value added where the per capita productivity of value added marked EUR 82K, which performed higher than automobiles (EUR 62K), and locomotives (EUR 44K). In terms of business sales indicators comparative to employment rates as of 2015, the net sales of Boeing produced USD 96 billion with an employment of 161,400, whereas Samsung produced USD 171 billion with an employment of 308,745.[177]

Aerospace represents a characteristic of a lengthy product development period with a life cycle that spans into decades, in addition to high entry barriers in terms of technology refinement and capital investments. Based on the comparatively long life cycle of an aircraft product, when a firm once successfully penetrates and settles into the industry, the position guarantees a secure and stable condition in terms of business earnings. For instance, the Boeing 747 has extended its operations for nearly 40 years throughout multiple phases of repairs and overhauls after its maiden flight in 1970.[178] The F-4 Phantom is still in use after being constantly upgraded since its first deployment in 1961. Considering the long product life cycle of an aircraft, maintenance, repair, and overhaul (MRO) is a source of sustained growth opportunities, where it generates substantial business returns measured twice as much as manufacturing aircrafts.[179] The broad scope in coverage between commercial aviation and military aircrafts, this paper intends to primarily focus on the defense sector.

[175] Orietta Marsili and Bart Verspagen, "Technological Regimes and Innovation: Looking for Regularities in Dutch Manufacturing," DRUID Conference Papers, May 2001.
[176] 2016 Industry Statistics, Aerospace Industries Association, available online at https://www.aia-aerospace.org/research-center/statistics/industry-data/workforce/
[177] Boeing, Current Market Outlook 2015-2034," Boeing Corporation, 2015; 2015 Samsung Electronics News Releases.
[178] Oliver Smith, "The slow death of the jumbo jet – where are they all now?" The Telegraph, January 5, 2018.
[179] Chris Pocock, "Pharewell to the Phantom," Aviation International News, December 27, 2016.

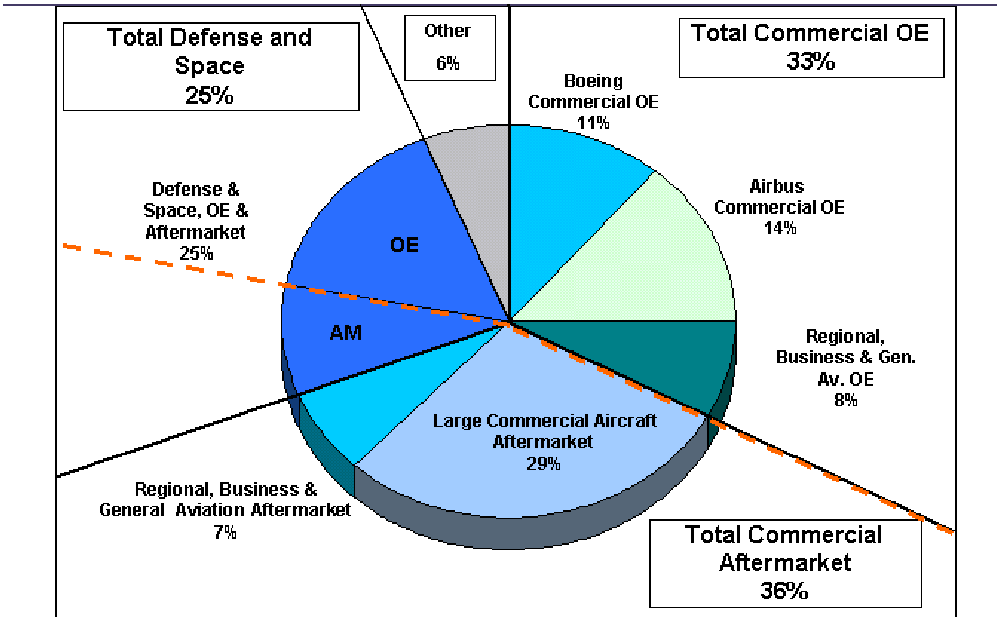

Figure 3. Global Aerospace and Defense Market Breakdown: Goodrich Corporation 2007 Investor Conference, New York City, 31 October 2007

Major technological breakthroughs in modern aviation history achieved by entrepreneurial pioneers such as the Loughead Brothers, Jack Northrop, Claudius Dornier, and so forth, constructed an industry centralized across the Atlantic, which continues to thrive even now. The highly sophisticated and delicate nature of aeronautical engineering constantly requires highly skilled artisanship organized in a standardized arrangement suitable for developing and manufacturing aircrafts with assured quality and safety that strictly complies with international norms and regulations. The rules and institutional setting for aerospace firms were primarily formed around the interaction between technological progress and business interests of Western European and American firms. Thus, the evolutionary trajectory of the industry was in favor of the companies operating within the physical boundaries of these two continents. However, the globalization trends of the high tech sector and the ensuing pursuit of catch-up firms in this playground has introduced new contenders into the field of aerospace, but has yet produced any noteworthy outcomes for the new entrants in terms of business performance and an established corporate reputation. Thus, penetrating the thick barriers of the industry has been a challenge for new entrants in various ways. This chapter attempts to review the general characteristics of the aerospace industry in technological complexity, institutional arrangements, and industry structure, under the context of seeking to identify the challenges of enhancing sectoral competitiveness in this realm.

3.2. Technological Complexity and High Cost Factors

A quote from a local Seattle engineer at a Boeing plant once claimed that an aircraft is a million pieces flying together in one single formation. The increasing number of components interconnected to higher operational systems makes aircraft products more complex with the continued technological progression of aeronautical engineering.

3.2.1. Aerospace Industry as Schumpeterian Mark II Technological Regimes

In the early days of aircraft-manufacturing, the comparatively easy entry into competition and the frequent erosion of an incumbent's market position precipitated by new firm entries have labeled the sector as a technological regime under Schumpeter Mark I. However, as aircraft-manufacturing transformed into a science based industry, with the growing complexity of technology and ensuing establishment of sector specific technological regimes, highlighted under internationally compatible technology standards, regulatory safety protocols, and the sustained dominance of several global champion firms, the sector became labeled under Schumpeter Mark II technological regimes.[180] Essentially, aerospace involves complex engineering processes through the integration of electronics, aerodynamics, propulsion science, composite materials, etc., in which activities for deepen knowledge accumulation and technology diffusion processes becomes paramount when striving to sustain business operations in this cutthroat competitive environment. In reference to the Boeing 747-8 Intercontinental, having made its first delivery in 2012, the airplane consists of over 6 million individual components, and was optimally designed to incorporate new composite materials to improve rising demands of global fuel economy standards. Manufacturing points of critical aircraft components were distributed to nearly 30 countries, supplied by 550 supplier firms.[181]

Combat aircraft development is considered an expensive venture as it accompanies exorbitant price tags for development, production, and life cycle sustainment. Therefore, only a handful of firms in the world are capable of manufacturing modern combat aircrafts.[182] According to a recent RAND survey on combat aircraft cost increasing factors through comparing the development and production unit price of the F-15A (1975) and F-22A (2005), system complexity represented in material, equipment, and labor components contributed almost 40% towards price escalation. Accounting for other contributing factors, including the learning process of these complex systems (15%), the total price escalation factors caused by technical complexity grew to a portion of approximately 55%.[183] Such trend is more evident when reviewing major aerospace and development programs. Many of these programs have suffered large substantial cost increases and schedule delays, while exhibited lower than expected performances. The risk factor identified so far largely contributes to the ambitious development objectives that exceeds technological capabilities within the given budget and timeline.[184] This is attributed by the increasing technological complexity of these systems compounded by a risk averse culture that has nearly no tolerance of failure under a budget-constrained and economically

[180] Jorge Niosi, "Science-based industries: a new Schumpeterian taxonomy," Technology in Society, Issue 22, 2000, p. 439.
[181] Boeing Celebrates Delivery of 50th 747-8, http://www.aerospacemanufacturinganddesign.com/article/boeing-lufthansa-747-8-deliveries-053113/
[182] Only 12 countries have track records in developing fourth generation fighters. Those are the United States, Russia, China, Japan, India, Pakistan, United Kingdom, France, Sweden, Italy, and Spain
[183] The F-15A unit cost as of 1998 was posted USD 27.9 million whereas the F-22A was USD 150 million; Mark V. Arena et al., Why Has the cost of Fixed-Wing Aircraft Risen? A Macroscopic Examination of the Trends in the U.S. Military Aircraft Costs over the Past Several Decades, RAND Corporation, 2008, p. 17.
[184] GAO-09-326SP, Assessments of Major Weapon Programs, pp 22

pessimistic environment. Although new systems engineering technologies and processes pioneered aeronautical engineering programs in the heydays of the aerospace and defense industry, the complexity of aerospace and defense programs has outpaced the advancement of these systems engineering tools in functional fields of advanced simulation, spiral development, complex adaptive systems, and so forth.[185]

For security reasons, countries prefer to localize the supply base of critical armaments. However, the risk factor associated with a country's decision to introduce combat aircrafts relates to the ever increasing cost pressure alongside with the degree of compromising national security through foreign procurement. Country's tend to retain domestic capabilities of supplying critical defense products such as ammunition or command control and reconnaissance platforms for security reasons, whereas costly complex product systems entailed with significant development risks such as combat aircrafts and underwater naval systems attract comparatively less attention in terms of indigenous supply capabilities. Thus, to the surprise of many, combat aircrafts have become an internationally marketable commodity that can be substituted by foreign products. Figure 2 describes the relational aspects between domestic supply aspirations (security pressure) and cost realities (cost pressure). The higher the development risk associated with increasing cost projections, a country shows lesser interest in attaining indigenous supply capabilities, which increases the possibility of foreign product substitution.[186]

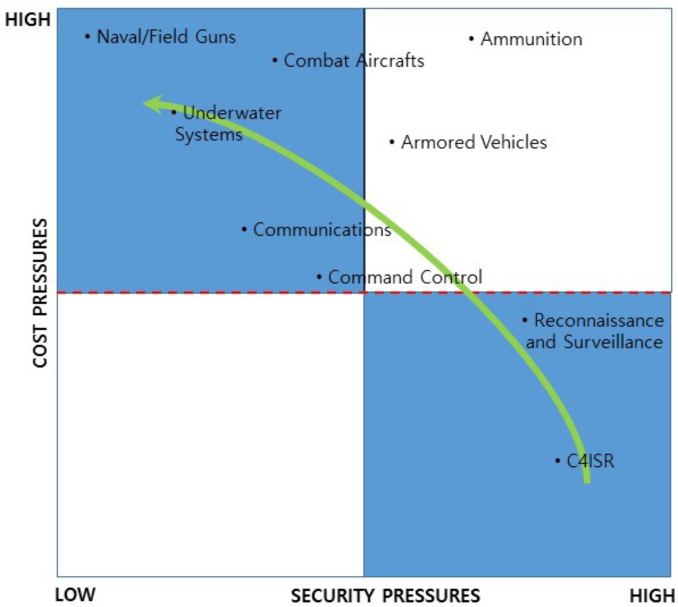

Figure 4. Cost vs. Security Pressures in Procuring Major Defense Equipment
Source: PriceWaterhouseCooper, The Defense Industry in the 21st Century, 2005.

On the other hand, the cost-benefits of technology upgrades over system performance are marginal. Technological complexity and associated cost increases account negatively to product

185 Report by Charles River Associates, "Innovation in Aerospace and Defense," CRA Project No. M13385-05, p. 21.
186 PriceWaterhouseCooper, The Defense Industry in the 21st Century, 2005, pp. 7-10.

competitiveness in the international market. The marginal utility of introducing slightly advanced system performance in modern aircrafts consequently incurs sharp increases in development costs. Therefore, no matter how feasible the performance improvement applied to the aircraft, the outcome results in slightly superior technological performances compared to the previous levels. Consequently, the substantial increase in price tags significantly degrades product competitiveness in the international market.[187] Considering commercial risk factors, a sizeable scale of upfront capital investments is the industry norm in a sense of enduring long term recuperation periods projected on investment returns over development costs. For instance, in order to deliver a large commercial aircraft in the 1970s, an upfront development cost of approximately USD 2 billion was the norm, at which the business revenues started flowing in after four years of initial delivery. In this regard, the industry has to undergo an average breakeven point around 10 to 12 years. The economy of scale at least allows the commercial sector to predict market trends and performances, but the military sector entirely depends on government procurement, which makes it tremendously challenging for sustainable business operations after the conclusion of the program.[188] In an already overcrowded commercial aircraft market, for instance, the cancellation of the MD-11 medium-long range transport has signified the era of smaller and more efficient transport aircraft types in the civil aircraft industry, which permanently ousted McDonnell Douglas from the civil aircraft business.[189]

In a program management perspective, the traditional development strategies of aircraft manufacturing follow a concurrent engineering practice rather than sequential prototyping. Concurrent engineering is a method that allows program authorities to combine the developmental stages of engineering together with the manufacturing phase within a condense timeline. In comparison, sequential development results in long development periods over a thorough verification process before final product delivery, thus has not been a preferred procurement method in defense products. In concurrent engineering, program milestones often proceed to the next stage without adequately conducting test and evaluation over major prototypes in each developmental phase. In this aspect, concurrent engineering carries substantial engineering risks, which requires retrofitting efforts before entering into low rate initial production phases of the subject defense product. The retrofitting sequences result in chronic program delays and cost increases. The U.S. defense apparatus initially adopted this procurement practice during the Second World War and subsequently into the Cold War, with strategic reasons over maintaining military advantage in the arms race against the Soviet Bloc, supported by a

[187] Emilio Esposito, “Strategic Alliances and Internationalisation in the Aircraft Manufacturing Industry,” Technological Forecasting & Social Change, Vol. 71, 2004, p. 452.

[188] It was also due to MD’s reluctance to commit heavily in the commercial aircraft-manufacturing market based on its historical lexicon primarily as a defense contractor, whereas Boeing had much more tolerance over prevailing risks, and was committed to develop in both the long range large commercial as well as the short to medium range commercial aircrafts. The 7X7 series, ranging from 727 to 767, exemplifies this intent to persevere in the market and effectively compete against the European Airbus’ A300, which gave Boeing a 60% share of the market; Dave Gillett and H.O. Stekler, “Introducing Technologically Advanced Products: Strategies in the Commercial Aircraft Industry,” Technological Forecasting and Social Change, No. 48, 1995, p. 131.

[189] Enrique Perrella, “The Twilight of the MD-11,” Airways, June 14, 2016.

sizeable defense budget to attain ambitious performance requirements. Notably, the U.S. Air Force's strategic bomber fleet after WWII, ranging from the Boeing B-47 Stratojet all the way to the Northrop Grumman B-2 Spirit, has all selected concurrent engineering methods as the primary practice for development in order to comply with critical program milestones. Such engineering methodologies have become a norm in military aircraft-manufacturing worldwide.[190]

In a systems integration point of view, the developmental standpoint of complex systems such as aerospace products have become extremely costly and involves diverse technological capabilities. Relationships with subcontractors are critical for prime contractors to successfully design and construct various subsystems and modules into the main platform, at which system integration work becomes the paramount phase of all development and production efforts. The requirement to assemble the complex aerodynamics of propulsion systems, avionics, operations software, and armaments, to name a few, in a single platform effectively enough to surmount the developmental objectives, has made it crucially important for the prime contractor to understand the engineering specifics of its suppliers. Thus, the aerospace industry comprises a network of interconnected firms providing modularized subcomponents, where the prime contractor – in many cases the overall system designer and integrator – plays the core of the developmental work, while the remaining design and manufacturing efforts are outsourced to other subcontractors.[191]

The development and manufacturing of an aircraft requires high level of precision work, involving the intricacies of incorporating various technologies that apply increasingly segmental and specialized production practices. In the case of the Quebec aeronautical industry, the sector consists of traditional layers of primes and subcontractors with highly specialized suppliers forming the basis of the hierarchical production structure.[192] The primes forming the first tier are mainly the system designers, integrators, and marketers of the final end product. The second tier consists of subcontractors that provide engines, propulsion systems, and other major subassemblies such as fuselage and undercarriage systems. Often times these second tier subcontractors are considered system integrators themselves because of the major end item produced in this sphere embody a high degree of complexity and completion. Opposed to other industrial fields, these second tier subcontractors hold the proprietary rights and brand titles of their own products, thus maintains equitable relationship within the prime and subcontractor relationship. The third tier are the more traditional subcontractors that supply a large spectrum of services such as mechanics, thermal and surface treatments, electronics, and other composite materials. Figure 1. shows the hierarchical structure of Quebec's aeronautical industry, which shows the complexity of technologies presenting untenable challenges for a single firm to master all the

[190] Michael E. Brown, Flying Blind: The Politics of the U.S. Strategic Bomber Program, Cornell University Press, 1992, pp. 327-342.
[191] Mayer, K.J., Teece, D.J., "Unpacking Strategic Alliances: The Structure and Purpose of Alliance versus Supplier Relationships," Journal of Economic Behavior and Organization, Vol. 66, No. 1, 2008, p. 108.
[192] Fernand Amesse, et al., "Issues on Partnering: Evidences from Subcontracting in Aeronautics," Technovation, No. 21, 2001, p. 560.

knowledge and skills required to manufacture a modern aircraft, thus representing strong demands for subcontracting, inter-firm partnerships, or strategic alliances unfolding not only horizontally, but globally. Throughout these vertical or horizontal efforts of subcontracting, either considered collaborative or simple outsourcing, substantial volumes of technology transfers take place.

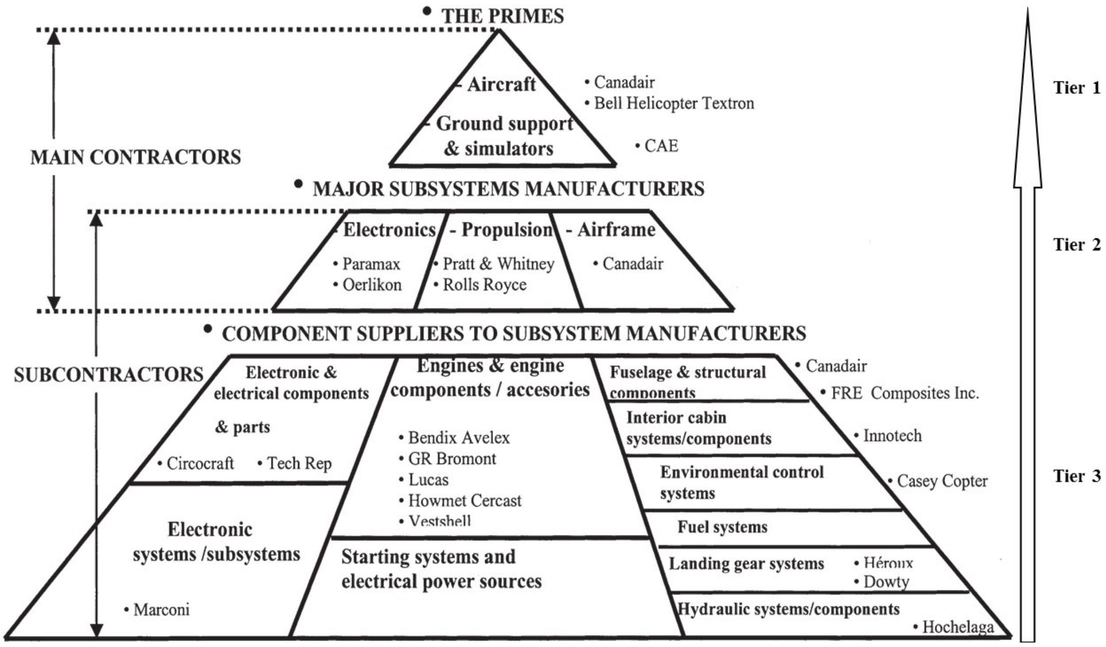

Figure 5. Production Pyramid of the Aeronautical Industry; Source: Reproduced from Amesse (2001) and Niosi & Zhegu (2005) (Incorporate AT Kearney' description on different manufacturing tiers)

Systems of Learning and Knowledge Diffusion in the Aerospace Industry

Although the effects of globalization continue to grow in the overall aerospace industry, the military sector is referred to as the epitome of national innovation systems because of its physical presence residing within national borders. The secretive and self-sufficient nature of the military aerospace sector restrictively places collaboration with foreign entities inside national borders, in which national interests protect the proprietary rights of technology transfer processes and corporate ownership structures.[193] The systems that constitute the national innovation systems of the military aerospace sector are no different from the conventional constructs of national innovation systems. Primarily, the aerospace and defense sector in major developed countries, which is often termed the 'Iron Triangle' or the 'Military Industrial Complex', consists of the interlocking and self-reinforcing interests of the military, defense industry, and political linkages within the executive and legislative branch, who are all motivated to pursue their own respective objectives.[194] Institutionally, the aerospace and defense sector is held within a supply chain network between primes and subcontractors; supported by an independent research and development program that combines government sponsored research

[193] John Lovering, "The Defense Industry as a Paradigmatic Case of Actual Existing Globalization," in Judith Reppy, ed., The Place of the Defense Industry in National Systems of Innovation, Occasional Papers No. 25, Cornell University Peace Studies Program, April 2000, p. 15.
[194] Gordon Adams, *The Iron Triangle: The Politics of Defense Contracting*, Council on Economic Priorities, New York, 1981, p. 12.

programs and in-house private R&D; the deployment of the critical workforce, or also termed as 'revolving door' movement, between the military, government agencies, Congress, and defense firms. The network is also reinforced by interwoven connections of university researchers engaged in government sponsored R&D programs, and a number of think tanks serving in advocacy roles.[195]

Knowledge flows of tacit information take place in the course of informal communication between the parties involved in the transfer process, of which most of the interaction occurring in the workshop level when passing down critical design technology and manufacturing skills. In a business relationship aspect, such transfer is realized through formal collaborative efforts such as strategic alliances, joint ventures, cooperative development arrangements, and various other prime-subcontracting relationships. This is also a valued feature proven important and effective throughout product development in complex industrial sectors such as the automotive industry. The transmission of tacit knowledge is especially evident in the aerospace industry where patent citations or licenses are rarely published due to the industry considering these materials as 'secret'. Therefore, supply chain linkages between the OEM firm and its subcontractors serves as a critical force that drives the flow of knowledge flows in this sector. These supply chains are mostly internationally and dispersed throughout critical industrial clusters of the world. Aerospace supply chains has transformed from arm's length American style procurement practices to a more Japanese way of collaborating with OEMs and supplier firms exchanging critical information on manufacturing processes, subassembly items, and costs. Aerospace clusters are specialized based on the manufacturing specialty of the respective product. For instance, aircraft assembly clusters.[196]

3.2.2. Regulated Technology Transfer Mechanisms: Defense Offsets

Defense offset trade are reciprocal contracting instruments commonly practiced in defense contracts between purchasing countries and the service providing firm as an arrangement for compensations in a non-monetary form over a certain procurement of an article or service. It is typically undertaken when the selling company accommodates the formal or informal demands made by the purchasing entity. Definitions vary by different organizations and individuals, but a common description used by the U.S. Department of State defines offsets that cover a wide range of industrial compensation practices required as a pre-condition of purchase in either government-to-government transactions or commercial sale arrangements of defense articles and/or services as defined under the U.S. Arms Export Control Act (AECA) and the International Traffic in Arms Regulation (ITAR).[197] Offsets are very important features in the exports of U.S. aerospace and defense products since defense firms employ

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[195] Judith Reppy, "Conceptualizing the Role of the Defense Industries in National Systems of Innovation," in Judith Reppy ed., The Place of the Defense Industry in National Systems of Innovation, Cornell University Peace Study Programs Occasional Paper 25, 2000, pp. 4-6.
[196] Jorge Niosi and Malinda Zhegu, "Aerospace Clusters: Local or Global Knowledge Spillovers?" Industry and Innovation, Vol. 12, No. 1, March 2005, p. 8.
[197] Executive Office of the President, *Offsets in Military Exports*, Office of Management and Budget, Washington D.C., 1988, p. 3.

offset strategies as a primary means of inducement or promotion schemes for purchasing countries when making procurement decisions. The program of record between 1947 and 1980 that accounts for the number of U.S. aerospace articles co-produced with foreign firms totals 28 programs. Recent records range as high as 98%, which means nearly the entire value of exports in the aerospace category is offset by countervailing purchases or the transfer of technology.[198]

Direct offsets occurs in cases where a purchasing arrangement between the selling company and purchasing country over goods or services directly related to the primary equipment the purchasing country originally acquired.[199] For instance, a purchase made by the selling company on subcomponents produced by the purchasing country for the primary equipment, such as engine parts for a jet aircraft or turret structures for a main battle tank, would be considered a direct offset transaction. Indirect offsets are transaction practices of goods or services that has no relevance with the primary equipment itself, but more as incentives that include foreign investments or countertrade such as in barter, arrangements for technology transfer, co-production, counter-purchase, or buy-back deals.[200] Foreign countries utilize offsets as a conduit for cost saving, obtaining advanced technology and manufacturing knowledge/skills, increasing local employment opportunities, building sector specific capacities for defense firms, and making effective use of the tax payer’s money. Second tiered supplier groups in aerospace, rather than first tiered prime contractor groups, benefit mostly from both of these offset arrangements attributed to the agreements providing for technologies related with machine tools, production capacity, repair and maintenance functions, and so forth. In the longer term, the current trend in aerospace offsets implies that there will be higher pressure for offsets considering the competitive structure of the industry in a period of declining military budget. This reflects competition between prime contractors such as Boeing, Airbus, and Lockheed Martin in airframes, and competition between engine manufacturers such as Rolls Royce, General Electric, and Pratt and Whitney. In this regard, skeptical perspectives over the utility of defense offsets argues the net benefits from these trade transactions are hard to measure and define since the opportunity costs of these offset arrangements mostly result in higher price levels of the original acquisition.[201]

However, public perspectives in the selling countries over defense offsets come in two divided ways, where one perspective views it as positive and indispensable for doing defense trade business with foreign partners, whereas another perspective argues mostly on the negative impact on local jobs and the industrial base. In the U.S., the subcontracting of a foreign supplier over a domestic company results in lost business opportunities and reduced local jobs. Most of the foreign supplier subcontracting arrangement are established as long-term commitments, which makes it even harsher for domestic firms

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198 U.S. Office of Management and Budget, 1990.

199 Jurgen Brauer and J. Paul Dunne, “Arms Trade Offsets and Development,” paper presented in the 8th International Conference on Economics and Security, June 2004.

200 Ibid.

201 This is mostly because the effects of offsets accrue over an average of 7.5 years instead of a lump sum monetary payment. Travis K. Taylor, Countertrade Offsets in International Procurement: Theory and Evidence, in M.A. Yulek and T.K Taylor (eds), Designing Public Procurement, Springer, 2012, p. 17.

to endure, especially when dealing with large scale production programs associated with high tech product items. In another sense, provisions through defense offsets may contribute to the emergence of a potential competitor in the sector. In this regard, with the objective of restraining the adverse impacts on offsets, the U.S. Department of Defense has been engaged in series of negotiations since 1992 with partner countries such as Canada, U.K., Netherlands, and France, to discuss the possibilities of reducing offset provisos in defense trades.[202]

3.3. High Technology Barriers and International Technology Security Regimes

Growing volumes of international defense trade has facilitated the transfer and diffusion of sensitive military technologies from first-tier advanced industrialized countries to fast following late industrializing countries. Especially, highly advanced U.S. defense products dominate the international defense export market in sophisticated military technology product groups.

Globalization of arms transfers, or defense exports in other words, have consequently placed a dilemma on advanced defense exporters in terms of attaining strategic interests while looking out for economic pursuits. In one sense, international arms transfers imply significant efforts of alliance building with countries that share a common threat perception towards a collective resolution. Conversely, the increasing statistics of U.S. defense exports in high tech has adversely eroded America's commanding lead in military technology. Thus, for countries like the United Kingdom or the United States, the connotations of defense exports resonate as a foreign policy tool that is instrumental in building partnership capacities. On the economic perspective, with the diminishing defense budget in the Post-Cold War era, defense exports have been sought out as an alternative marketing opportunity against the saturated domestic demand pull. Sustaining the production like by promoting defense exports has been deemed critical in not only securing local employments, but most of all in maintaining a sound defense industrial base. These elements constitute the motivation of promoting international arms trade for both strategic and economic objectives.[203]

However, the second part of the predicament relates to the adverse effect of defense exports. The proliferation of arms, especially the platforms and systems that contain cutting-edge technology, have unfavorably resulted in eroding the comparative advantage of global military powers in a technological sense. Technology transfers or production workshares that grown out from defense offset trade arrangements have enhanced the technological capacities of potential competitors in the field. As discussed in previous sections of this chapter, the work-breakdown structure between prime contractors and international subcontractors have impacted on shrinking employment rates in the advanced defense industrial countries, while improved technological competitiveness of later entry firms or countries in the defense sector. As long as the global defense firms view international arms transfers as a vehicle of

[202] Katherine V. Schinasi, "U.S. Congress on Defense Trade: Observations on Issues Concerning Offsets," United States General Accounting Office, GAO-01-278T, December 15, 2000, pp. 2-5.
[203] Marcy Agmon et. al., Arms Proliferation Policy: Support to the Presidential Advisory Board, RAND, 1996, p. 7.

bolstering financial viability, the issue of regulating these transactions have been raised to preserve both the strategic interests and economic objectives of global defense giants. Regulating international arms sales is a matter of optimally balancing between strategic and economic intentions.[204]

The United States presumably institutes the most stringent technology security measures among all advanced defense industrial countries. The conventional arms transfer policies in the United States was announced to serve for this purpose. The primary means of U.S. defense exports are through Foreign Military Sales (FMS0 and Direct Commercial Sales (DCS). In the line of executing defense exports as a foreign policy tool, the Department of State servers as the primary agent of approval under close coordination with the Department of Defense and Department of Commerce. FMS is a government to government transaction where the U.S. Government makes the purchase of the respective defense product, or government-furnished equipment, on behalf of the customer country. The arrangement constitutes a total package approach that include product acquisition, education and training, sustainment, and other supporting services for countries intending introduce the capability. DCS is a transaction arrangement between the original equipment manufacturer and either the customer country or private entity making the purchase. U.S. defense products subject to restrictive control measures in terms of end use monitoring and third party transfers are strictly controlled under the FMS regime, whereas items that entail lesser control standards are available through DCS. The export approval is processed and granted by the Department of State, after going through a rigorous interagency review board that scrutinizes the political-military implications of potential arms transfer impacts. In order to promote U.S. defense exports, the number of hybrid cases that combine both FMS and DCS purchasing methods are growing in big numbers lately.[205]

Because of the high value of technology associated with national security matters in the aerospace industry, various control measures are imposed on critical technology, which inhibits the affluent flow of technology transfers to new entrants in the industry. Thus, existing control measures over defense exports and technology transfers become challenging for new entry firms or countries when negotiating technology transfer deals or concluding on technical assistance agreements. The flow of international arms transfers is regulated by two legislations – Arms Export Control Act (AECA) of 1976 and the Export Administration Act (EAA) of 1979. The AECA administers the import and export of defense articles and services to foreign countries. The implementing provisions of the AECA are covered in the International Transfer of Arms Regulation (ITAR), which define the scope of defense articles and services under a controlled manifest called the United States Munitions List (USML). The retransfer of the defense articles to third party entities are also subject of continued monitoring under

[204] Ibid., pp. 13-17.
[205] Chapter 15: A Comparison of Foreign Military Sales and Direct Commercial Sales, Security Assistance Management Manual, Defense Security Cooperation Agency, 2015, p. 15-6.

the ITAR regime. The EAA contains a more complex application of arms transfer as it deals with dual use technology that has significant implications for diversion into military use. [206]

Strategic interests of U.S. foreign affairs policies are considered the priority over economic performances. Still the dilemma of arms exports as a foreign policy tool against critical economic interests continues to place major security cooperation decisions into complicated junctures.

3.4. Globalization of the Industry: Changing Dynamics of the Aerospace Supply Chain

The aerospace sector has been experiencing a healthy growth in overall performance the past decade. As of 2015, the global aerospace industry employed roughly around 1.2 million, in which 49 percent is employed in the U.S., 35 percent in Europe, 7.5 percent in Canada, and 2.7 in Japan. The workload in these countries between military and commercial aircrafts is roughly 60 percent (military) and 40 percent (commercial). Reflecting the decreasing defense budget in each country worldwide, there was a lost in about 185,000 jobs in the military sector, which presented serious risks in sustaining critical skill bases in the industry. This lost was partially offset by improved performances in the commercial sector through increased sale in products and manufacturing efficiency. [207]

Based on a survey of top 100 aerospace and defense firms, the industry earned revenues of USD 674.4 billion in 2015, which is a 3.8% growth from the previous year's revenue of USD 649.7. In an effort to reduce costs, substantial efforts of the manufacturing process are outsourced to external entities such as in engines, landing gears, structures, and avionics.[208] This factors into the growing demand from burgeoning Asian markets and the declining military budgets from the US and major Western European countries, primary OEMs and Tier-1 firms in aerospace are relocating major business operations to China, Russia, and the East Asia, and partnering with competent regional suppliers in this area in order to stay connected with the changing market conditions. For instance, Boeing has established a design center in Moscow[209], while Airbus opened a new engineering center at Bangalore, India.[210] In conjunction to these efforts, major aerospace firms – such as Rockwell Collins, Pratt & Whitney, GE Aviation, Rolls Royce, and so forth – have been rushing into China, clustering in areas at Xi'an, Harbin, Tianjin, Shanghai/Suzhou, Chengdu, etc. Thus, as global aerospace OEMS continue to seek global partners in fast growing markets, the competition to secure positions in Tier-2/3/4 supplier markets is becoming more intense. Because of the growing manufacturing costs in aircraft components, the global supply chain in aerospace has trickled down from first-tier system integrators to second-tier subsystem manufacturers. The spread of the manufacturing workshare has become the source of

[206] Mark A. Lorell et. al., Going Global? U.S. Government Policy and the Defense Aerospace Industry, RAND, 2003, p. 106.
[207] Deloitte, US Aerospace & Defense Labor Market Study: Employment Outlook Upbeat, Reversing Job Losses, February 2016.
[208] Deloitte, 2016 Global Aerospace and Defense Subsector Financial Performance Study, July 2016.
[209] http://www.boeing.com/resources/boeingdotcom/company/key_orgs/boeing-international/pdf/russia-cisbackgrounder.pdf
[210] Raghuvir Badrinath, "Airbus to Partner Indian Firms for Offshore Centre," Business Standard, May 30 2011, available online at http://www.business-standard.com/article/companies/airbus-to-partner-indian-firms-for-offshore-centre-111053000049_1.html

technology diffusion and knowledge accumulation for second-tier subsystem providers. In the case of Boeing, the global aerospace giant has shifted its focus from technology development to restraining program costs and development schedules. Retaining domestic jobs was not of utmost importance to the company compared to delivering products and systems to its customers. In this regard, substantial volumes of manufacturing work have been transferred overseas, of which the benefits went to three Japanese subcontractors – Mitsubishi, Kawasaki, and Ishikawajima-Harima.[211]

In addition to this global repositioning of OEMs and Tier-1 firms, new contenders, supported by government driven aggressive catch-up strategies, gaining access into the global value chain is injecting more fuel into this fierce competition. Bombardier and Embraer are moving up to the ranks from their traditional regional jet aircrafts and striving to enter the turf of Boeing and Airbus, whereas midsized OEMs such as Gulfstream, Mitsubishi Aircraft Corporation, and Sukhoi are pressuring the upper-tiered groups for market access.[212] Additionally, the client-supplier relationship is becoming more integrated since OEMs have been reducing the number of suppliers in new development programs, while increasing more collaborative risk sharing partners as the design and performance features of aircrafts are becoming more sophisticated, thus requiring closer collaboration between OEM, Tier-1 system integrators, and supplier firms. For instance, Embraer has been reducing the numbers of suppliers from 346 to 22 between 1999 2004, while increasing the number of risk sharing supplier firms from 4 to 16. This is the result of OEMs refocusing their core competencies to design, system integration, and marketing fields. Therefore, manufacturing activities have been concentrated down the supply chain towards major component suppliers. Through the practices of outsourcing, international transfer of knowledge and technological spillovers took place and created new growth opportunities in this rigid industrial sector, especially in East Asia.

Sustaining a solid percentage of a highly skilled workforce is also presenting some challenges in this industry as well. The aerospace industry has been confronting challenges in talent shortages lately. Unlike other industrial sectors, the aerospace industry was not able to enhance employee productivity by vast introductions of automated techniques through IT investments because of the complex nature of the technical materials that must be assembled into the aircraft system.[213] The industry is knowledge intensive but also exhibits features of labor intensive performances because the actual engineering and production techniques are executed by individual technicians and not automated machines. The number of new employments that obtain competent skills has been falling behind the number of high skill technicians retiring from work, hence the workforce is turning gray and aging. The

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[211] John Newhouse, Boeing Versus Airbus, Vintage Books, 2007, p. 172.
[212] Roch Champagne et. al., "A New Reality of the Aerospace Supply Chain," Deloitte, November 12, 2013.
[213] However, the contribution of ICT development has facilitated the construction of global supply chains in vastly dispersed worldwide in the aerospace industry.

restrictive employment situation that extensively scrutinizes background checks of new entrants is considered the main reason why firms are losing talented workers in this field.[214]

The aspects of innovation in the global aerospace supply chain depend on risk-sharing partnerships established and efforts to sustain this relationship. In a way of characterizing four types of innovation promoters through this partnership structure in the global aerospace supply chain, there is first the power promoter, mainly performed by the airframe manufacturer (i.e. prime contractor), who drives the project with necessary hierarchical power. Secondly, there is the expert promoter, performed by subsystem integrators or component suppliers that obtain specific technical knowledge required for the innovation process. Thirdly is the process promoter who obtains requisite know how in organizations and network building within the supply chain. Lastly is the relationship promoter that has strong individual ties with outside organizations.[215] Because of the long enduring relationship between prime contractors and suppliers in the aerospace value chain, technological innovation under this relationship structure is driven by coordination and integration amongst customers and suppliers. The instruments to develop and sustain this partnership is advocated by transparency and trust through replacing individual benefits with mutual benefits, and to some extent, shared ownership in building the aircraft, thus requiring early participation in the design and exploratory research phase.

A developing pattern in the global supply chain is the growing demands in massive customization and network virtualization as a result of ICT development. The vast dispersal of supplier networks that are no longer bounded by physical proximity, as well as the growing dependency on software design and control mechanisms, has promoted the need to design aircraft structures in a modularized form. Product modularity was possible with the development of ICT capabilities, which facilitates communication and coordination work within the prime contractor-subsystem provider-customer relationship. Modular products allow higher degrees of flexibility without incurring unnecessary costs in the development and production phase in such ways the customer has the option to choose from each module.[216] Modularity in system design also permits efficient management controls for parallel development such as in customized system upgrades or life cycle management, tailored in a way that meets customer needs. The case of A380 integrated modular avionics is an example where modular solutions were proven suitable for robustly integrating different system types compatibly with other system modules for hosting different applications.[217]

3.4.1. Industry Characteristics

Prime contractor and subcontractor relationship

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[214] Abby Mayer, “Supply Chain Metrics That Matter: A Focus on Aerospace and Defense,” Supply Chain Insights LLC, March 2014.

[215] Christen Rose-Anderssen et. al., “Aerospace Supply Chain as Evolutionary Networks of Activities: Innovation via Risk-Sharing Partnerships,” Creativity and Innovation Management, Vol. 17, Issue 4, 2008, p. 306.

[216] Carlos R. Monroy and Jose Arto, “Analysis of Global Manufacturing Virtual Networks in the Aeronautical Industry,” International Journal of Production Economics, Vol. 126, 2010, p. 321.

[217] Jean-Bernard Itier, “A380 Integrated Modular Avionics,” Presented in 2007 ARTIST2 – IMA conference.

Based on the assessment of labeling aerospace under the technological regimes of Schumpeter Mark II, the sector mainly displays technologically transformative patterns close to incremental innovation, with the exception of the introduction of the jet engine during the 1950s.[218] The prime contractor and subcontractor relationship in the aircraft industry during the earlier development period used to be highly fragmented. But because of the increasing complexity of aerospace technology, the subcontractors, or the supplier base in other words, have become more important in terms of providing for integrated products and systems. Similar to the Toyota practices in production system, inter-firm learning in the global aerospace industry show strong relational characteristics between prime contractors and supplier firms. This is attributed to the complex nature of development and production of an aircraft have presented conditions where subcontractors become required to actively participate in the early phases of the drawing board, thus contributing significantly to the overall development process of an aircraft.[219]

The seeming complexity of aerospace products and systems shows that no firms can singlehandedly manage a vertical supply chain in development or manufacturing aircraft systems. The complexity of an aircraft structure makes relevant knowledge and diversified component structures highly interdependent to the overall system architecture, which requires deep involvement of supplier firms early in the development and production phase. In a detailed econometric study conducted on 243 industrial contracts of Airbus, the conclusion was that the earlier the subcontracting supplier firms interact with the system integrator, the more efficient the production of the aircraft in terms of effectively overcoming inherent technological risks and efficiently managing manufacturing costs.[220] In other words, the earlier the supplier becomes incorporated into the integral design and development phases of aircraft manufacturing, the more authorities and responsibilities are delegated to the respective supplier firm with higher degrees of interaction with the prime contractor.

Traditionally a unidirectional learning pattern from the prime contractor to the subcontractor was considered a norm. But recent trends in the aerospace industry show often reverse conditions where supplier companies provide more learning opportunities to the prime contractor. Here, the best contractor holds a particular competitive advantage in areas either intangible, difficult to imitate, or not easily transferable. Through this trend, prime contractors and system integrators are outsourcing structural and component production instead of performing the efforts themselves in order to draw more attention towards their genuine core activities.[221] This outsourcing trend is more obvious not only because of technological competencies, but also because of market access challenges as well. Due to

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218 McGuire, "Sectoral Innovation Patterns and the Rise of New Competitors: The Case of Civil Aerospace in Asia," *Industry and Innovation,* No. 6, 1999, p. 160.
219 Claudia Rebolledo and Jean Nollet, "Learning from Suppliers in the Aerospace Industry," International Journal of Production Economics, No. 129, 2011, p. 328.
220 Ayshe Cagli, Med Kechidi, and Rachel Levy, "Complex product and supplier interfaces in aeronautics," Journal of Manufacturing Technology, Vo. 23, No. 6, 2012, p. 717.
221 Susan Morton et. Al., "Managing Relationships to Improve Performance: A Case Study in the Global Aerospace Industry," International Journal of Production Research, Vol. 44, Issue. 16, 2006, p.

the increasing demand from the purchasing entity towards the prime contractors when making subcontracting choices, prime contractors are compelled to abandon the traditional local subcontracting base and choose to establish contracts with firms dictated by the purchasing entity. Thus, the purchasing entity is exerting more influence to prime contractors regarding the choice of location for subcontracting activities.[222]

In order to cope with the fierce competitive circumstances of the global aerospace industry, Lefebvre asserted that the critical capabilities required for ideally performing subcontractors were mainly highlighted in the domains of Total Quality Management (TQM), managerial skills, and network stabilities.[223] In the technical aspects, TQM is considered a non-negotiable standard in terms of accrediting safety certifications in aerospace technology. R&D investments assess subcontractor absorptive capacity for acquiring and maintaining the required level of knowledge and technical skills. In the management piece, coordination and integration of activities and functions including the ability to ensure durable relationships with customers and suppliers, plus marketing skills are highly appreciated. In this aspect, quality of customer service obviously serves to maintain enduring relationships with prime contractors. Here, the combination of technological expertise and managerial capabilities defines continued excellence in a high-tech industry. Lastly, Stability of networks between customers and suppliers are considered a more important element in large domestic markets whereas reputation between customers and suppliers has bigger impacts in smaller markets such as Canada and UK.

Strategic Alliances

Alliance formulation in the global aircraft industry show trends of matching core competencies such as skills and resources among a network of partners and suppliers in order to spread increasing technical and financial risks associated with aircraft development and production. Especially, the inherent technological complexities, financial burdens, and market barriers compels the aircraft manufacturing firms to form various forms of alliances with partner firms, both domestically and internationally. For instance, the development of a long-range transport aircraft such as the Boeing 707 in the 1950s costs approximately $2 billion, whereas an Airbus A380 in the 2000s costs have grown around $12 billion, which exemplifies no single firm can sustain a large aircraft development program.[224] Strategic alliances is a commonly chosen strategy for latecomers in the sector as well. The highly complex nature of the systems engineering and manufacturing process, alongside the highly politicized institutional barriers of sector, addresses the need to align with international forerunners in

[222] The projection of the growing trajectory of the Asian air traffic market and the increasing defense budgets of East Asian countries show stronger leverages of the purchasing country in this region over the global aircraft manufacturers. For instance, Korean firms took about 40% of the entire workload from the KF-16 co-production program.

[223] Elisabeth Lefebvre and Louis A. Lefebvre, Global Strategic Benchmarking, Critical Capabilities and Performance of Aerospace Subcontractors, Technovation, Vol. 18 Issue 4, 1998

[224] Teal Group, “World Military & Civil Aircraft Briefing,” Teal Group Briefing Book Series, Fairfax, 2001.

aircraft-manufacturing to overcome initial limitations in the technological and program management perspective.[225]

In order to reduce these development risks and financial burdens, recent trends in the aircraft industry observed the build-up of complex network relationships among major firms and its partners. One way of labeling this alliances trend show extensive partnering between firms centered on new development programs. For example, a European consortium of firms, which consists of Aerospatiale, BAE, DASA, and CASA, formed up as Airbus to develop the A330 and A340 transport aircraft in the 1990s. Boeing, Lockheed Martin, and Northrop Grumman partnered up to form the Advanced Tactical Fighter (F-22 Raptor) and Joint Strike Fighter (F-35 Lightning II). Together with the industrial crisis that hit the worldwide aerospace and defense sector in the Post-Cold War era and the compounding technical and financial barriers for new development, the global aircraft manufacturing industry consolidated and integrated into six major clusters, two formed in Europe and four formed in the United States.[226]

Aerospace is a relationship-specific sector where the supply chain of firm specific products proves most effective under established supplier networks. Tier-one system integrators have become selective in choosing Tier-two subsystem manufacturers, in which secondary supplier networks have assumed more responsibility in the design and manufacturing phases of aircraft manufacturing.[227] For instance, with the objective to introduce competition in jet engine manufacturing, the U.S. Navy directed Pratt & Whitney to produce an alternate source jet engine for the McDonnell Douglas F/A-18 Hornets, at which General Electric provided the F414 turbofan engine as the primary propulsion system. To the dismay of General Electric, a volume of engineering diagrams and blue prints were provided to its arch rival, but the second sourcing efforts eventually became frustrated after Pratt & Whitney failed to replicate an engine commensurate to the performance level specific to support the F/A-18 capability.[228] A similar case in a reverse situation was shown in the F-35 Joint Strike Fighter Alternate Engine Program, at which the two engine giants collided once again over the most complex and troublesome fighter aircraft development programs of all time. Despite the advanced performances of the General Electric F-136 as an alternate propulsion source for the F-35 program against the primary Pratt & Whitney F-135 turbofan engine, the rising development costs and insurmountable system integration challenges have forced the cancellation of the second sourcing process.[229] Thus, although considered a global contender that splits the international market share of jet engines, relationship

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225 Lee Joosung and Yoon Hyungseok, "A comparative study of technological learning and organizational capability development in complex products systems: Distinctive paths of three latecomers in military aircraft industry," Research Policy, Vol. 44, 2015, p. 1296.

226 In Europe, consolidation of major aerospace and defense players formed the Airbus Group and BAE Systems. In the United States, Boeing, Lockheed Martin, Raytheon Systems, and Northrop Grumman was formed; Esposito, p. 459.

227 Daniela Moncenco, "Supply Chain Features of the Aerospace Industry," Scientific Bulletin-Economic Sciences, Vol. 14, Issue 2, p. 19.

228 John Newhouse, p. 173.

229 Jeremiah Gerlter, "F-35 Alternate Engine Program: Background and Issues for Congress, Congressional Research Service, January 10, 2012, p. 16.

specific arrangements between the system integrator and major subsystem provider creates challenging circumstances for other firms to penetrate the established supply chain.

Resource challenges also necessitate aircraft firms to build horizontal alliances as well. According to a study conducted on 310 aircraft production programs from 1945 to 2000, the main factor that compels firms to make horizontal alliance choices depended on the matching between available firm resources and required project resources.[230] The greater the resource requirement is to what the firm can afford in developing new products, the higher the likelihood the firm will choose to establish horizontal alliances rather than to pursue an autonomous route. Specifically, horizontal alliances were driven not only by resource challenges but by decisions for product expansion in this regard. However, larger firms with established engineering reputation, or firms receiving larger shares of military expenditures from its originating country, choose to expand autonomously rather than making choices for horizontal alliances. Ostensibly in a technologically more complex setting, the tendency to establish horizontal alliances to achieve product expansion objectives grows larger.[231]

Alliance formulation has become a norm in the aircraft industry that takes the form of joint ventures or mergers and acquisition of different firms. Most notable case is the second largest shareholder of the international market (32%), Airbus consortium, that constitutes four major European contenders in the industry; Deutsche Aerospace, British Aerospace, CASA, and Aerospatiale. The merger of Boeing and McDonnell Douglas, joint development research between Boeing and Deutsche Aerospace on jumbo jet aircrafts, or the 50/50 joint venture between GE Aircraft Engines and SNECMA are just a few cases that exemplifies this trend.[232] Consequently, as a result of constant efforts to reduce technological risks associated with supplier networks, major aircraft manufacturing firms exercised strong control over the members that constitute these alliances. Major aircraft firms dictate which suppliers they will ally with in addition to precept design and manufacturing details.[233]

Aircraft	Aircraft Engines	Components or Materials
Aerospatiale/Deutsche Aerospace/British Aerospace/CASA⇒Airbus Boeing/Deutsche Aerospace ⇒jumbo jet research MBB/Fokker Boeing/Mitsubishi/Kawasaki/Fuji ⇒Boeing 777	GE/SNECMA⇒CFM International GE/SNECMA/IHI/FiatAvio⇒GE90 BMW/Rolls Royce⇒BR710 Rolls Royce/Avio/ITP/MTU ⇒EuroJet Turbo GmbH	FiatAvio/GE⇒gearboxes Hispano-Suiza/Grumman ⇒NACELLS Hispano-Suiza/SPECO⇒gearboxes

Table 4. Strategic Alliances in the Aircraft Industry

230 Bernard Garrette et. al., "Horizontal Alliances as an Alternative to Autonomous Production: Product Expansion Mode Choice in the Worldwide Aircraft Industry 1945-2000," Strategic Management Journal, No. 30, 2009, p. 885.
231 Ibid., p. 887.
232 Carl R. Frear and Lynn E. Metcalf, Strategic Alliances and Technology Networks: A Study of a Cast-Products Supplier in the Aircraft Industry, Industrial Marketing Management, No. 24, 1995, p. 380.
233 Ibid., p. 389.

The industry concentration is polarized in the engine sector with dynamic competition among major firms, but maintains a stable duopoly structure and lesser cutthroat competition. Surveys conducted on turboprop and jet engine sectors indicate that the engine industry shows high levels of industrial concentration but differs in the level of market share from the past 50 years of industrial observation. The turboprop engine sector shows a certain degree of oscillation but maintains a stable level of concentration where primary contenders of the market consists of traditional players such as Rolls Royce, Pratt & Whitney, General Electric, and so forth. Whereas the jet engine sector shows obvious trends of decrease in industrial concentration, from which the dominance of Pratt & Whitney diminishes to third in place, giving ways to General Electric and Rolls Royce. This indicates the oligopoly of the jet engine sector was substantially affected by new entries into the market such as CFM International and the growth of the commercial jet engine sector while orders from the military sector gradually decreased.[234] The relational aspects of the engine industry represented in network structures show conditions of more intense competition as both sectors endeavor to retain a central position in relations with the buyers. The relational aspects results in an oligopolistic industrial structure with a low level of concentration caused by such intensity, which conclusively disapproves any attempt to drive a competitor out of the industry, opposed to the aircraft manufacturing industry.[235] Strategic alliances between firms are described in more detail in the following sections.

3.4.2. Industrial Structure and International Competitive Environment

Vertical and horizontal mergers can lead to better efficiencies in regards to innovative development of new products or significant reduction in costs due to synergy effects from economies of scopes. In the case of industrial consolidations with regards to competition and innovation, the outcomes and impact results in various forms. The economic case against undue concentration on the supply side of a particular market is relatively well known. If a particular product is dominated by a monopoly, then the producer has little incentive to minimize cost to the buyer, especially where cost-plus reimbursement systems are the rule. Much of the defense economics literature grapples with the problem of how to price weapons, especially when the market is restricted to a monopsonist end user, namely the government.[236]

In regards to the impact of mergers on innovation, on a separate note, is likely to be negative. Enjoying the higher returns on production than on research and development, contractors tend to favor larger runs of existing weapons over riskier R&D contracts. Therefore, under this context, the difference among markets with multiple contenders can be quite substantial. A monopolist will shun risk in a new design and offer only marginal improvements whereas other competitors will trend to replicate each

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[234] Andrea Bonaccorsi and Paola Giuri, "Network Structure and Industrial Dynamics: The long-term evolution of the aircraft engine industry," Structural Change and Economic Dynamics, No. 12, 2001, pp. 208-210.
[235] Ibid., p. 220.
[236] William Kovacic and Dennis Smallwood, "Competition Policy, Rivalries, and Defense Industry Consolidation," *Journal of Economic Perspectives*, Vol. 8, No. 4, Fall 1994, p. 98.

other's strategy, leading to nearly identical outcomes despite the non-presence of collusion amongst each other.[237]

U.S. Aerospace and Defense Industrial Structure

The Cold War attributed different aspects of military technological development and manufacturing from the conventional norm, in which previously the norm was formed by state-run facilities constituting the foundation of the military production base. However, because of its lasted longevity extending into almost a half century, and the significant amount of dollar values invested into the development and manufacturing of arms, a large number of private entities have entered the market and continue to compete among them to date.[238] Cold War defense businesses were continuously refueled through major, but regionally contained, conflicts in addition to regulatory shifts caused by changes in U.S. government policy lines; The Korean War, Vietnam War, and the Reagan military buildups. As the defense budget in arms procurement were ranging roughly between an annual figure of $250 billion to $400 billion in FY1998 dollars, private contractors were able to find lucrative business opportunities in national defense. Hence, what was before called state-run arsenals, shipyards, or depots, has evolved into a form of a complete industrial type, dubbed the "defense industry" because of the concentrated family of products and scaled economy that sprung off from these major military buildup programs. The established government acquisition pattern that kept private contractors willing to maintain its edge in military technology as well as the U.S. government's initiative to enhance its defense capabilities sustained the continued large scale production run of weapon systems. However, such long standing supply of arms blew off as excess capacity after the fall of the Berlin Wall which triggered the end of the Cold War. At 1992, the U.S. aircraft industry operated a production line capable of manufacturing 75,000 first-line fighters, but the U.S. Air Force and Navy could field less than 3,000 aircrafts. The tank and automotive industry had a running production line for manufacturing 8,000 M-1 tanks, but the U.S. Army and Marine Corps had only six heavy divisions organic to its order of battle, fielding no more than 2,100 tanks in maximum levels. The shipbuilding industry, with less than the force requirement of new ships and submarines on the waiting list for the U.S. Navy, also suffered from over capacity of maintaining six private shipyards producing large military ships.[239]

Throughout the days of fat defense budgets in the late 1980s, the decline of U.S. defense spending in actual terms predates the East-West rapprochement, which started in 1987. In the early days of the Clinton Administration, the government projected the defense budget would experience a further decline of 37 percent until FY2000. In addition to ailing defense industry's chronic excess capacities was the continued decline of defense procurement budget, which also included R&D funds for new

[237] Ibid., p. 100.
[238] Sapolsky and Gholz, "Private Arsenals: America's Post-Cold War Burden," in Markusen et. al., *Arming the Future: A Defense Industry for the 21st Century*, Council on Foreign Relations, 1999, p. 192.
[239] Ibid., p. 193.

platforms and systems. The U.S. defense procurement budget went through a straight decline between 1985 and 1995, a decade referred to as the Lost Days. Such cuts in defense procurement directly impacted the workforce of the industry; defense related employment have dropped 39 percent between 1989 and 1997, which is a rate that constantly dropped 5 percent annually. In numerical figures, there were losses of almost 600,000 jobs between 1987 and 1992, with another loss of 600,000 jobs until 1997.[240] The U.S. defense industry was already going through a significant transformation phase that required immediate public attention.

The end of the Cold War has opened a new era of innovation and competition for the global aerospace and defense industry. The Western Alliances led by the United States and European countries no longer had to face a technologically advanced opponent such as the Soviet Union. Shrinking needs for a large scale standing conventional military and the excess of weapons production capacities have compelled governments to appropriate lesser defense budgets for force requirements, which subsequently had direct impacts on the right sizing of the global military R&D fundamentals and defense industrial base. Nevertheless, the declining numbers of aerospace and defense prime contractors have disputably deteriorated competition and innovation in this sector. The driving forces to the developing trend of the global aerospace industry constituted by global primary contractors were the United States and Western Europe.

The Bottoms Up Review (BUR) drafted by the Pentagon on 1993 determined a strategy to rationalize the structure of the defense industry in order to address the challenges and concerns of the post-Cold War world order. The BUR stressed the need to retain a force structure that can fight two war fronts simultaneously, while building force capabilities with increased mobility and advanced information technology.[241] It signified major decreases in defense budgets and downsizing of the Cold War military strength. Between 1993 and 1998, the total outlays of U.S. defense budget were reduced an average 4% annually, in addition to the $69 billion reduction during the first Clinton Administration. The gloomy economic forecasting of the U.S. defense business prompted the Department of Defense to orchestrate a massive restructuring of the U.S. arms industry, the so called ‘Last Supper’ between the Secretary of Defense and executives of major defense firms, which presented daunting challenges of the post-Cold War aerospace and defense sector in terms of downsizing the arms manufacturing business while preserving the research and development base.[242]

In this respect, during a time of receding defense budgets while maintaining a robust military force in overseas deployments with enhanced defense readiness posture, the U.S. government needed to maintain a hot production capacity as well as the ability to develop next generation systems in all major weapons categories. Inasmuch the downturn of the defense budget, the government encouraged

240 U.S. Congress, Defense Industry: Trends in DoD Spending, Industrial Productivity and Competition, General Accounting Office, January 1997, p. 10
241 Les Aspin, Report on the Bottom Up Review,
242 JA Tirpak, “The Distillation of the Defense Industry,” Air Force Magazine, 1998, p.

merger and consolidation among large defense firms. One reason was to bring down fixed costs of weapons per unit. The sole source contract managing system of the Department of Defense (DoD) made it almost impossible to assess an accurate analysis per unit weapon costs. In the late 1980s, most of the larger companies had a number of systems under sole source contracts that were in the mid-streams of its production cycle. With the perceived knowledge that the contracts were unable to be paid within the given timeframe, the DoD induced the contractors to consolidate in a fashion where the terms of these predated contracts remains to be intact whereas the companies to be able to cut down significant indirect and overhead costs, which was believed to have constituted 50 percent of major weapon programs, by eliminating redundant R&D and manufacturing functions anticipated through the consolidation efforts.[243]

Another encouraging factor of merger efforts from the U.S. government was the need to offset revenue losses in the U.S. domestic defense market through large scale exports to allied countries. The two major legislations for defense exports, the Arms Export Control Act and Foreign Assistance Act, are considered one of the most restrictive laws existing within the U.S. Code, which hindered and discouraged arms exports to overseas partners before the end of the Cold War. However, the Persian Gulf War resulted in an effective marketing campaign of U.S. defense products as the world observed the advanced targeting technology of precision guided munitions and the stealthy maneuvering of tactical bombers behind enemy line of sight by watching CNN. The end of the bipolar international security structure and the ensuing insecurity apprehended in a uni-polar world by the sole existence of a lonely super power emboldened a new arms race in other parts of the world that opened new business opportunities for U.S. firms. The Clinton Administration, in this regard, lowered the barriers of defense exports in the two legislations. The defense firms, on the other hand, significantly lacked extensive marketing and negotiation capabilities to promote their respective defense products overseas since most of their efforts were focused on the U.S. domestic market.[244] Such condition influenced relatively small and mid-sized firms to seek mergers with larger firms that obtained overseas marketing and distribution networks.

The third motivating factor initiated by the government was the provision of direct subsidies to defense firms on mergers. On July 1993, DoD allowed to add subsidies in the form of restructuring costs that included severance pay, plant closure costs, and unemployment payments, within the terms of contracts with defense firms that are engaged in merger deals with other defense related firms. In return of these subsidies, defense firms promised to pass on future savings in the form of lower prices. An estimation of industrial consolidation on five large defense firms indicated that restructuring costs equaled $1.3 billion, with costs for reimbursement amounting to about $180 million until 1997. A survey performed by the Government Accounting Office asserted that the DoD has enjoyed savings of

[243] Ibid., p. 15
[244] Michael Oden, "Defense Mega-Mergersand Alternative Strategies," in Susman and O'Keefe et. al., *The Defense Industry in the Post-Cold War Era: Corporate Strategies and Public Policy Perspectives*, Pergamon, 1997, p. 150.

$347 million or about $1.93 in procurement costs for every dollar spent on subsidizing defense firms.[245] However, the government's subsidy policy has created a whirlwind of debate within and outside the Clinton Administration, mostly originating from fair trade and anti-trust authorities claiming organization costs incurred from the private sector is not subject for government subsidies. The argument mainly criticized the unilateral decision of the DoD leadership on the implementation of such subsidy costs claiming the estimation of future savings for DoD by private companies on the anticipated reduction in price tags is baseless, and the DoD should have no business encouraging or shaping the restructuring of defense industry for the reason of promoting the rational downsizing of the defense industry.[246] This was also supported by past cases that similar mergers of these kinds end up costing rather than saving the government money, referring to a 1994 overruling by the DoD Inspector General on the claim that the merger case of Hughes Aircraft and General Dynamic's missile division saved the Pentagon $600 million.

In order to sustain its businesses and achieve economies of scale, a pro-consolidation policy took place that gave major defense firms in the U.S. the option to either go through mergers and acquisition or diversify into other sectors of the economy during the early 1990s with an ultimate objective to reduce both private and public sector assets allocated to the defense infrastructure such as property, plant, and equipment.[247] Without reducing the excessive asset base, the shrinking defense budgets would surge unit costs and inevitably deteriorate the profit margins of the industry. Expectations of economies of scale in defense firm mergers were to bring down unit procurement costs by cashing out nonessential defense company operations, whereby introducing dual-use technologies into military applications. Large government subsidies were given to defense firms for mergers and consolidating the industry structure. However, such subsidizing efforts affected as a disincentive for defense firms when diversifying into other commercial sectors of the economy, which subsequently discouraged the diffusion of related technology into nondefense fields.[248]

What used to be 50 plus in the number of major contractors specialized in the business has turned out to become less than five in 1997 as the result of massive consolidation; Boeing, Lockheed Martin, Raytheon, Northrop Grumman, and Raytheon. Boeing has acquired the aircraft mogul McDonnell Douglas and the aircraft defense sector of Rockwell in 1996, and later the satellite and communication division of Loral, which became the largest manufacturer in the aircraft industry. Lockheed acquired the aircraft section of General Dynamics and the entire business of Martin Marietta on the same year, which formed the largest and diversified defense conglomerate in the United States. Northrop acquired its competitive partner Grumman Corporation, the formerly Chance-Vought LTV,

245 Ibid., p.156.
246 Lawrence Korb, "Merger Mania: Should the Pentagon Pay for Defense Industry Restructuring?," *The Brookings Review*, Vol. 14, No. 3, Summer 1996, p. 25.
247 John Deutch, "Consolidation of the U.S. Defense Industrial Base," Acquisition Review Quarterly, Fall 2001, p. 138.
248 Michael Oden, Cashing In, Cashing Out, and Coverting: Restructuring of the Defense Industrial Base in the 1990s, in Ann R. Markusen and Sean S. Costigan eds., Arming the Future: A Defense Industry for the 21st Century, Council of Foreign Relations Press (1999) p. 78.

and the shipbuilding division of Westinghouse, while divesting its fighter aircraft division to Lockheed Martin, and formed to become the largest stakeholder in stealth-unmanned aircraft industry and C4ISR combat systems. Raytheon acquired the missile and space technology systems of General Motors and Hughes, in conjunction with the defense sector of Texas Instruments, and became the biggest contender in missiles and launcher technology. Other firms like Curtiss Wright or Fairchild Republic divested their businesses and exited from the defense industry to seek other opportunities in the civilian sector.[249] The total value of mergers and acquisition in the U.S. aerospace industry alone between 1989 and 1997 increased from a value which was less than $4 billion in 1989 to $53 billion in 1997, with an average of $34 billion between 1995 and 1997.[250] At the time of merger works on 1997, the merger movement of Boeing was valued at $48 billion in annual sales whereas Lockheed Marin valued $28 billion. The third largest in scale was Raytheon culminating in $17 billion in annual sales. The sheer magnitude of these mega mergers left only two fully capable platform manufacturers, Boeing and Lockheed Martin, remaining in the aerospace industry, opposed to the Cold War numbers of sixteen vendors.

Lockheed-Martin Marietta Merger

On 1994, Lockheed Corporation and Martin Marietta Corporation announced their intent to merge as a single entity. The $10 billion merger of the second and third largest defense contractor, which was worth in $23 billion in market value, would create the country's largest defense firm surpassing McDonnell Douglas which then held the largest share in the U.S. defense market. The two companies represented that the merger would result in substantial savings to both the companies and the DoD by reducing excess industrial capacity and overhead costs. The merger outcomes resulted in the establishment of the most diversified defense firm in the U.S., spanning into all sectors of the defense business except for helicopters, tanks, and submarines. The product base of the two companies was complementary in nature; Lockheed holding strength in military aircrafts while Martin Marietta specializing in military electronics, components, and heavy launch vehicles. However, there were also some overlaps in the production of military satellites and big rocket launchers. In this regard, the merger had high expectations of having a near monopoly over the big rocket launch sector and satellites.[251]

With concerns of antitrust complaints from competing companies, the Federal Trade Commission (FTC) identified three broad product areas in which the merger will affect as a monopoly ruler – space based early warning systems (satellites and sensors), military aircraft, and Expendable Launch Vehicles. Considering the fact that mergers are permissible only when entry into the relevant market is guaranteed that market participants could not profitably maintain a price increase above the pre-merger levels, the FTC proceeded with the antitrust analysis by giving special attention to the

[249] Ann Markusen, "The Post-Cold War Persistence of Defense Specialized Firms," in Susman and O'Keefe, p. 129.
[250] Erik Pages, "Defense Mergers: Weapons Cost, Innovation, and International Arms Industry Cooperation," in in Markusen et. al., p. 211.
[251] Mark Shwartz, "The Not So New Antitrust Environment for Consolidation in the Defense Industry: The Martin Marietta-Lockheed Merger," *Columbia Business Law Review*, 1996.

satellites, sensors, and LANTIRN.[252]

The FTC expressed concerns that the merger will most likely eliminate competition in research and development as well as competitive pricing of satellites for the use of Space Based Early Warning Systems, in which the U.S. government was having immense interest. However, the biggest concern area was on maintaining confidentiality of proprietary information that could be used in anticompetitive ways, especially on the LANTIRN issue.[253] The problem was that, the Martin Marietta, as the single market provider of the LANTIRN to the US Air Force, obtained access to proprietary information of the design specifics of the aircrafts the LANTIRN was being installed, which were mainly the competing aircrafts to Lockheed's military aircraft division. The deliberate flow of proprietary information on the design specifics of the competing aircraft would provide an opportunity for Lockheed to outbid its competitor in the defense market by taking advantage, or free riding, of the innovative works by its competitor.

As an outcome of the eventual endorsement of the merger case, the FTC placed a few restrictions on the company to reduce the anti-competitive effects of the merger. The most notable was the placement of firewalls in the form of communication barriers to prevent the flow of non-public proprietary information from the LANTIRN System division to the Military Aircraft division. Basically, the FTC made it impossible by federal regulation for the separate business entity within the same firm, Lockheed Martin, to internally communicate on these matters. A similar and equally restrictive firewall condition was mandated on the flow of sharing information about competitors between the divisions that build satellites and the divisions that launch them, for concerns mainly to prevent monopoly power in the field of space satellites and vehicular launch systems.[254]

Lockheed Martin-Northrop Grumman Merger Attempt

The attempted acquisition of Northrop Grumman by Lockheed Martin with a price tag worth $11 billion was a classic example of an antitrust case that could've impacted negatively on competition and innovation caused by the merger of two similar firms in a concentrated industrial sector. The primary reason for the two companies to consolidate was to reach economies of scale as well as collaborating for synergy effects. Lockheed Martin and Northrop Grumman, although supplementary in commercial aircraft components and stealth technologies, were mostly competitors in advanced tactical aircrafts, electronics, and missile warning systems.[255]

The attempted merger was blocked by the Department of Justice, with the support of the Department of Defense, which represents the how sever the case was handled by the authorities

[252] LANTIRN, standing for Low Altitude Navigation and Targeting Infrared for Night, is a navigation and targeting pod installed on fighter aircrafts.
[253] Marina Lao, Mergers in a Declining Defense Industry: Should the Merger Guidelines be Reassessed?," *Connecticut Law Review*, Winter 1996.
[254] Ibid.
[255] Amy Boatner, "Consolidation of the Aerospace and Defense Industries: The Effect of the Big Three Mergers in the United States Defense Industry," *Journal of Air Law and Commerce*, Summer 1999.

compared to the other antitrust rulings in which the FTC, a subordinate entity of the Department of Justice, adjudicated the ruling on behalf of the government. The concern on competition was that the business portfolios of both companies significantly overlap in airborne early warning radar systems as well as sonar systems. Such combination of two overlapping dominant firms in the market would take a share of 38 percent of the entire procurement and R&D budget from the DoD, hence exerting significant monopoly power over the lives of the soldiers with the taxpayers money.[256] Because of the gravity of these critical events, the attempted merger was terminated by both firms on July 1998, but the corporate aspirations to merge still remains even today.

Boeing-McDonnell Douglas Merger

The Boeing-McDonnell Douglas merger case was somewhat unique as it spurred heated debates on the fact that companies in a globalized business environment must consider the anti-trust laws of not only of their home countries but also of the countries in which they do business. Although there were strong controversies within the FTC in regards to the two antitrust laws – the Sherman Act and Clayton Act – over possible merger movements between Lockheed Martin and Northrop Grumman, to the surprise of the public the FTC gave its blessings on the $14 billion merger case between America's biggest aerospace firms, Boeing and McDonnell Douglas despite concerns on anticompetitive effects significant enough to jeopardize market competition. The Commission concluded that the merger would not substantially lessen competition or tend to create a monopoly in the global commercial aircraft market because the market share of McDonnell Douglas was insignificant inasmuch of its ailing financial records would prevent the company to improve its worsening market performance. Such decision was attributed to the fact that the business areas of the two companies were highly differentiated, thereby not substitutes; Boeing committed to the heavy transport and utility versions of both commercial and military sectors whereas McDonnell Douglas more focused on the military jet fighter and attack helicopter sector.[257]

In the aspect to the defense market of the two firms, the Commission considered that the two companies develop fighter aircrafts and military helicopters for different mission areas; therefore there was no anticipated procurement or marketing cases in which the two companies would compete in both the domestic and international market.[258] Boeing has shown strength in manufacturing large transport cargo aircrafts including bombers in the 1950s such as the B-17, B-29, and B-52 bombers. But the company's strength was paramount in the commercial airliner sector as it introduced the 747, 767, and the mega-hit 777 series during the 1980s and 1990s. Other representative family of Boeing products was the Ch-47 Chinook, the most popular heavy transport helicopter that was fielded in 1960 by both

[256] Department of Justice Press Release, "Justice Department Goes to Court to Block Lockheed Martin's Purchase of Northrop Grumman Merger Is Single Largest Ever Challenged," available online at http://www.justice.gov/atr/public/press_releases/1998/212681.htm
[257] Amy Boatner
[258] Ibid.

the US Army and Marine Corps. The business areas of McDonnell Douglas were primarily in the military fighter jets and attack helicopter sectors with small successes in the commercial airline industry until the company divested the commercial sector to Boeing in the 1980s before the eventual merger of the two companies were realized. The representative aircraft of McDonnell Douglas was the F-15 Striking Eagle for the U.S. Air Force and the F/A-18 Hornet for the U.S. Marine Corps. McDonnell Douglas was also the manufacturer of the well-known AH-64D Apache Long-Bow Heavy Attack Helicopter after it purchased the rotorcraft section of Hughes Helicopter in 1984. However, it would not be entirely impossible to rule out the fact that the FTC decision was in support of the U.S. DoD's tailored scheme to reap out the benefits of economies of scale through the merger deal between the two companies.

The European Commission (EC), which is the European Union's antitrust agency, has rejected the merger attempt over the concerns that the consolidation of the world's number one and number three aircraft manufacturers will significantly damage the competitiveness of Europe's aerospace giant Airbus. Although Airbus claimed to be the second largest aircraft manufacturer in the world, the company was relatively weak and essentially divided into regional headquarters because of the nature that it was a company financed by the European Union. In accordance with the Treaty of Rome, which is the companion law to the U.S. Sherman Act and Clayton Act, the EC initially disapproved the merger for three reasons; the merger will add more to Boeing's dominant world market share for large commercial jet aircraft from sixty-four in the pre-merger period to seventy in the post-merger period, the likelihood of spillover effect of defense technologies from McDonnell Douglas to Boeing which will apparently improve the technological skill set of Boeing compared to its European competitors, and most importantly the merger would strengthen Boeing's exclusive aircraft agreements with the three dominant U.S. airlines – American, Continental, and Delta Airlines. The last factor was the most troubling aspect for EC because Boeing's enhanced leverage power would absolutely lock-in the three largest commercial airliners to non-favorable agreements for Airbus for an excessive period.[259]

It wasn't until Boeing and the U.S. FTC agreed to accept three major concessions that the EC finally approved the merger deal. The concessions were basically meant to implement a probationary period between the business entities of Boeing and McDonnell Douglas, by placing McDonnell Douglas as a separate legal entity for ten years and to submit periodic reports on the business relations of the two companies to the EC.[260]

Impact and Outcomes of International Aerospace and Defense Mergers

Although there exists a number of different opinions questioning the effects of industrial consolidation, the impact of mergers and acquisition in the defense sector proved to show some positive

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[259] Kathleen Luz, "The Boeing-McDonnell Douglas Merger: Competition Law, Parochialism, and the need for a Globalized Antitrust System," *George Washington Journal of International Law and Economics*, 1999.
[260] Ibid.

gains in terms of cost efficiencies and technological innovations.

It appears that major defense merger activities were driven more by the vibrant financial markets in the commercial sector than by simply defense budget outlays.[261] Hence, economic motives were prevalent over political pressure in the defense consolidation process. The general rule of thumb in corporate mergers is that firms in the post-merger period will likely gain increased market power, such that it has higher leverage to control the market price. Subsequently, firms may likely choose to execute monopoly pricing strategies, whereby resulting in higher market prices. On the contrary, defense consolidation resulted in plant rationalization and overhead efficiencies which eventually led to lower market prices. For instance, the top four major defense firms, Boeing, Lockheed Martin, General Dynamics, and Raytheon, all experienced significant reductions in per unit costs of their concentrated production categories, ranging between 30-40%.[262] Most of the mergers took the form of market extension in order to diversify the business portfolio of defense firms instead of vertical or horizontal mergers.[263] This was mostly caused by the changing landscape of warfare in the high-tech era. The development and fielding of state of the art defense systems have become ever more complex and costly. For instance, it takes a number of efforts to bring together a modern fighter jet; the integration of different systems such as advanced avionics, aerodynamics, electronics, special coating materials, propulsion, to name a few. The complexity of system integration and the development of newer innovative platforms requires closer collaboration, or to a certain extent, would favor mergers of supplementary business portfolios in order to gain higher competitiveness in the defense market.

Although the pro-consolidation policy was encouraged by the government, the defense M&A process mostly relied on market forces, in which industry and capital markets, instead of governments, determined the best solution for the new consolidation policy. However, European defense restructuring process showed stronger state roles in the process. The consolidation of the U.S. defense industry implies aspects of industrial evolution in a highly restrictive market with stark expectations for competition and innovation in a time of growing technological development amid receding market needs for further expansion. As the industrial structure of the U.S. defense sector became more concentrated after such consolidation processes, it has become more difficult to introduce new firms in the competition. Because of the capital nature of the defense industry is highly capital/technology intensive, the growing monopoly power of defense firms have made it even more difficult to penetrate the defense market. The complications to mobilize efforts to prepare contract proposals, the ever growing complexities of weapon designs highlighted by precision guided systems and stealth platforms, the capability to carry out such scientifically daunting research, and the ability to hire the talents to

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[261] The correlation between defense merger activity and overall merger activity in the economy appeared strongly positive than the correlation with Defense budget outlays. Nayantara Hensel, "Can Industry Consolidation Lead to Greater Efficiencies? Evidence from US Defense Industry," *Business Economics*, Vol. 45, No.3, p. 201

[262] Gholz and Sapolsky, "Restructuring the U.S. Defense Industry," *International Security*, Vol. 24, No. 3, Winter 1999, p. 49.

[263] Ann Markusen, "The Economics of Defense Industry Mergers and Divestitures," *Economic Affairs*, December 1997, p. 31.

execute these tasks, are too much to ask from a new entry into the defense market.

3.5. Catch-up Strategies of Late Entrants into the Sector

Technological complexity, high capital costs, and established restrictive settings of international regimes hinders new entrants into the market. But growing globalization needs ironically induces second tiered and third tiered supplier countries to enter the market through collaborative efforts arranged between either government to government programs or industry initiated ventures. Such opportunities become potential conduits of technology transfer and diffusion.

Normal phases for technological catch-up in the aerospace industry follows a three stage development phase, in which the country first acquires basic level knowledge and skills through depot level repair and maintenance efforts, followed by collaborating with established high-tech firms in the sector throughout the form of license manufacturing or co-development/production arrangements, and finally undergoing a process of developing an indigenous variant through its own efforts in system design and manufacturing.[264]

State intervention is considered an integral part for sectoral development and promotion in the aerospace industry. Mostly considering the fact of aerospace being characterized as a highly capital intensive sector associated with complex technology and integrated systems, in order to sustain this business field requires a certain level of economy of scale, especially for late industrialized countries in this sector.[265] Conventional wisdom tells that technology transfer from advanced industrial countries to developing countries is considered an important vehicle for learning and entering critical high-tech sectors. The effectiveness of technology transfers for developing countries, however, showed only marginal contributions to technology development when reviewing the development programs from Indonesia and Romania. Especially, it appears that developing aircraft specific industrial sectors seem to be more suitable for certain countries that obtain the appropriate absorptive capacity for learning and exploiting the requisite knowledge in the learning phase.

Determinants in the operational level that constitute success factors for technology transfer is to acknowledge whether the program can extend the destination firm into sustainable positions in the industry. Firstly, to discern a viable technology worth transferring, it is important to assess the age of the respective technology relative to the existing market size.[266] For instance, the ROMBAC 1-11 program launched by the Romanian IRMA (Enterprise for the Repair of Aeronautical Materials) arranged under production licenses provided by British Aircraft Corporation (along with BAe) shows the intent of transferring the obsolete BAC 1-11 manufacturing technology to the Romanians was for

264 Jang-Ruey Tzeng, A Comparative Study of the Strategies Employed by New Entrant Nations in Developing their Aircraft Industries: An Application to the Republic of China, Doctoral Dissertation, The George Washington University, 1995, p. 38.

265 Jack S. Gansler, *The Defense Industry*, MIT Press, 1980, pp. 32-43.

266 Harm-Jan Steenhuis and Erik j. de Bruijn, “Developing Countries in the Aircraft Industry: Match or Mismatch?,” Technology in Society, Vol. 23, 2001, p. 558.

BAe to exit the declining short range jet aircraft to concentrate on the BAe-146 Short-Haul Regional Airliner.[267] Because of the deteriorating Romanian economy and no available international market to export the aircraft, the ROMBAC 1-11 production halted after delivering only nine aircrafts.

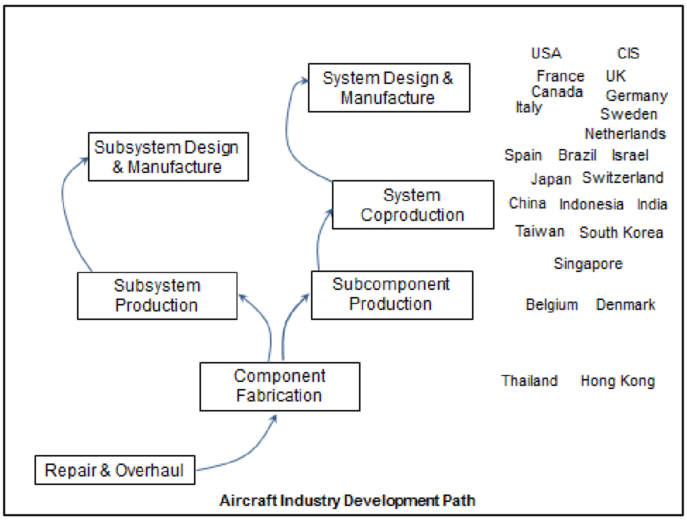

Figure 6. Aircraft Industry Development Path

A second discernable aspect for technology transfer is the portion of R&D related capabilities included in the transfer package. Especially in a complex high-tech environment where platforms and systems are developed in a long term life-cycle, possessing the knowledge and skill base early hand in preparation for systems upgrade is critical. The knowledge base for systems upgrade is obtained relative to R&D investments in technology, whilst without addressing the professional knowhow on R&D in the technology transfer package, the program becomes less competitive and short lived. Therefore, the firm at the receiving end of technology transfers should consider not only production technologies in the transfer process but also the inclusion of knowledge and skillsets for system upgrade as well.

3.6. Conclusion: Towards a Sectoral System of Innovation in the Aerospace Industry

Over the past three decades, the global aerospace and defense industry went through substantial reorganization processes in regards to the competitive structure of the market and accommodated towards a structure prone to the growing complexity of the subject aeronautical technology. In this regard, the industry has become substantially streamlined to a handful of firms. Basically a duopoly between Boeing and Airbus, and reconfigured it supply chain more attuned to advanced industrial countries that already have a significant footprint in the sector.

In the military sector, the state still remains as the absolute supply source in revenues as well as innovation in terms of breakthrough technologies and new product layouts. State stands out as the

[267] http://www.bac1-11jet.co.uk/bac1-11jet.co.uk%20Rombac.htm

biggest customers in aerospace and defense where defense offsets emerge as a major conduit of technology transfers for late entries into the sector. Such arrangement intrigued the rise of subsystem provider networks under the purview of state-led industry development efforts, which further facilitates firm level capacity building initiatives. In this regard, the overall supply chain has transformed from a vertically integrated structure to a horizontal network structure that encourages strategic alliances in search of better engineering and manufacturing capabilities. In this regard, strategic alliances have reduced development risks and became a priority option for aircraft-manufacturing firms in the sector. This is especially true for Tier-Two late entry firms where a number of domestically initiated development programs deliberately partnered with global aerospace giants in search of prospective business opportunities in the aircraft-manufacturing sector.[268]

Entry barriers built around more intensified competitive industrial arrangements, resulted under shrinking defense budgets and grown out in parallel with highly capitalized technological requirements, have created apparent challenges against second-tiered countries vying to upgrade its domestic aerospace industry in part with international standards. The next chapter reviews the state driven industrial development efforts of Korea in science and technology, with a focus on the defense industry, and further examines the innovative prospects under its national construct.

[268] David J. Smith and Michael Zhang, "Linking, leveraging and learning: sectoral systems of innovation and technological catch-up in China's commercial aerospace industry," Global Business and Economics Review, Vol. 16, No. 4, 2014, pp. 363-365.

Chapter 4: State Capitalism and the National Innovation Systems of Korea

4.1 The Capitalist System of Korea

The global economic setting remains no longer supportive for industrially developing countries. The concerted efforts demonstrated by major industrialized countries, promoted through international regimes such as the World Bank, IMF, or the WTO, show that lesser opportunities exist for state-led interventionist market policies. These intentions are seen as an act of 'kicking the ladder' for catch-up economies, which makes it increasingly more difficult to mind the technological gaps between the technologically advanced and less developed countries.[269]

4.1.1. Overview of State-Business Relationship

Under the changing dynamics of international economic arrangements, the Korean model of state capitalism constitutes one of the main debates of the developmental state discourse. Largely utilizing bureaucratic instruments to develop and transform the country's industrial structure from labor-intensive to capital-intensive, and eventually to technology-intensive industries, the process implemented strong protectionist practices governed by elite technocratic systems under strong authoritarian rule. Prices were manipulated and labor rights were repressed in order to capture comparative price advantages in the market. Nonetheless, putting aside the reminiscence of the country's developmental footprints, the dire performances of its economy is not all supportive to the current structural arrangement of its national competitiveness. Despite the aggressive investments from public and private sector R&D work, a comprehensive assessment of its effectiveness is comparatively low. According to a competitiveness ranking performed by the IMD World Competitiveness Center, Korea ranks in 5th place in R&D investments, 9th in workforce, and 10th in the number of published research. But in terms of public-private knowledge transfer the country ranks 25th in place, 41 in the number of world class engineers, and 31 in inter-firm technology cooperation, which shows the cost-benefits in R&D investments is less vibrant and inefficient in performances.[270]

What distinguishes the Korean model from other developmental state cases is the discipline the government exercised over private firms. One of the disciplinary areas considered selective industrial competition polices that nurtured family-run companies into substantially diversified business conglomerates called chaebols that capitalized public resources under corporate business strategies. In order to optimally deploy scarce resources, the government was exclusive in picking private firms in select areas of investments, in which the selection decision was driven by observations of how much firms were submissive to government directives. Hence, private firms, also known as family run firms called *Chaebols*, chosen by the government was rewarded by extensive licenses to enter privileged business sectors such as the heavy and chemical industries under highs subsidies provided from

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[269] Ha Joon Chang, Bad Samaritans,
[270] IMD World Competitiveness Center, IMD World Comptitiveness Yearbook 2014, IMD, June 2014.

government resources. Although the government did penalized firms that performed below the level of expectations, the collusive relationship between state and private companies, supported by the fledgling bureaucratic machine, became the norm for economic development in Korea.[271]

The second disciplinary tool was exercised through rationalizing overly expanded business sectors. The consequences of the collusive scheme between state and private firms were the diversification of Chaebols into unrelated markets. Often times, certain business sectors would suffer from excessive competition between private firms over a finite share of the market. Finances were strictly controlled by the government through state-run banks, which regulated interest rates and loan allocation. Underperforming firms would be either liquidated or bailed out, not only by market mechanisms but also by arbitrary decisions made by the government and not market regulations. The government would rescue important companies from financial failures through injecting bail-out money or manipulating interest rates in the financial market, while abandoning inferior firms into bankruptcy. Thus, strong state control over the supply of credit largely indebted these Chaebols under government intentions, which made these firms over reliant on government credit rationing, especially in high risk business sectors such as IT, energy, and aerospace and defense.[272]

However, as the Korean economy entered into the 1990s, tremendous changes were imposed onto this conventional state-business arrangement. The end of the military regime in 1993 and the inauguration of a new democratic administration triggered strong momentums to reform the Chaebol centric economic structure. Efforts to reform the Chaebol dominant economy unfortunately backfired into the 1997 Asian Financial Crisis. Although various theories exist on the cause of the Crisis, the predominant argument culminates into the abrupt changes made in state-business relationship. Decoupling of government economic reform policy during the Kim Young Sam Administration regarding the democratization of the market place and Chaebol business system has inadvertently resulted in reduced government control over the domestic market and Chaebols, henceforth empowered more Chaebol initiated autonomy in corporate control.[273] Earlier government economic reform guidelines in 1993 was to abolish the crony capitalism between state officials and Chaebol executives prevailing in business practices that presented high favoritism biased towards big business conglomerates. However, with a diminishing institutional enforcement mechanism that disabled strong implementation and adjudication of convoluted reform processes, such ineffective reform efforts subsequently led to lesser government influence into the domestic market where the authority of the Chaebols amassed and, in some cases, overwhelmed the traditional control of the state. In a separate context, the strong globalization drive declared by the government in November 1994 to improve corporate competitiveness by easing restrictive market rules through financial liberalization and

[271] Amsden, Alice H. Asia's Next Giant: South Korea and Late Industrialization, Oxford University Press, 1989, p. 17.
[272] Charlotte Marguerite Powers, "The Changing Role of Chaebol." *Stanford Journal of East Asian Affairs* 10.2 (2010): p.108.
[273] Sunhyuk Kim and Doh Chull Shin, Economic Crisis and Dual Transition in Korea: A Case Study in Comparative Perspective, Seoul National University Press, 2004, p. 24

deregulation have unwittingly allowed the Chaebols to pursue devastating management practices by means of exuberant borrowing and excessive expansion into diverse business sectors.[274]

Thus, in order to extensively reform such malpractices inherent in the economic structure, the succeeding Kim Dae Jung Administration imposed five principles for its efforts to reform the Chaebols, which focused on ownership structures, corporate governance, streamlined business operations, financial conditions, and transparency. Streamlining business operations, termed "Big Deals", related to selecting three or four core business lines while divesting unrelated subsidiaries through major mergers and acquisitions, or closure of business operations in some extreme cases. During this period, Korea went through a transformational process of liberalization, thus lifting regulatory barriers and adopting neoliberal economic norms as an effort to overcome the impending hardships of its ailing economy, which was an essential abandoning of its protectionist and collusive industrial policies. In the process of doing so, the debate on the authenticity of state capitalism and the developmental state theory collided with the idea of neoliberal statism. Restrictive state control over the financial sector was considered the classic model of the Korean developmental state thesis. Foreign takeover of domestic banks was prohibited and the share of total assets by foreign firms was limited to 6 percent. The situation in other non-bank financial sectors also remained dominantly controlled by domestic firms under strict government regulations. However, the 1997 Asian Financial Crisis substantially transformed this situation, where now the domestic financial market has transformed to become predominantly foreign owned.[275] Implementation of neoliberal economic reform was selective. Financial industry was more exposed to regulatory reform but other sectors of the economy, such as ICT and aerospace, remained mostly under restrictive government control. In this regard, substantial adoptions of neoliberal economic norms were enforced, but a highly imperfect neoliberal state came into fruition.[276]

4.1.2. Late Industrialization through Capacity Building in Science and Technology

The catch-up experience of Korea is described in various ways. Studies in technological innovation accentuate the institutional arrangements of public and private R&D activities. In the case of Korea, R&D investments exponentially increased over the decades. Throughout a span of 40 years between 1970 and 2010, the average rate of R&D investment increased 13.7%, which almost doubles the annual GDP growth rate of 7.3%. The government share of R&D initially accounted for 70.3% in 1970 against the 29.7% mark of private industries, but the share flipped to 28% for government and 72% private in 2010.[277] In the perspective of technology catch-up by acquiring a competent knowledge base

[274] Ha-Joon Chang, Hong-Jae Park and Chul Gyue Yoo, "Interpreting the Korean crisis: financial liberalization, industrial policy and corporate governance," Cambridge Journal of Economics, Vol. 22, 1998, p. 738.
[275] Hyun E. Kim and Byung-Yoon Lee, The Effects of Foreign Bank Entry on the Performance of Private Domestic Banks in Korea, March 2004, p. 6.
[276] Iain Pirie, "The New Korean Political Economy: Beyond the Models of Capitalism Debate." The Pacific Review, Vol. 25, No. 3, p. 366.
[277] Korea's Strategy for Development of STI Capacity: A Historical Perspective, p. 26.

through R&D consortia, Korea shows development patterns in duplicative and creative phases.[278] In these phases, the evolving scope and capacities of the triple helix structure of government technocrats-corporate industry-universities/GRIs represents the development patterns of each era.

The duplicative imitation phase, spanning from the 1960s to the late 1970s, represents constant efforts to build a trained technical workforce that can interpret explicit knowledge rendered from various foreign lending and transfer of technology. In order to exploit the building of the technical workforce, the industrial policy was to deliberately create the Chaebol with a high focus on export promotion. During this period, the biggest challenge was the recruitment of talented scientists and engineers to build-up a capable workforce. The Korean government introduced three institutions through legislation in order to resolve the recruitment problem. The first was the establishment of the Korean Institute of Science and Technology (KIST) in 1966, which is known as the mother institution that sprung off approximately 27 GRIs and the prestigious educational institute Korea Advanced Institute of Science and Technology (KAIST) in later days. The second institution was the creation of the Ministry of Science and Technology (MOST) in 1967, which served as the overarching government control tower for nurturing the national knowledge base in science and technology. A comprehensive government directive in S&T policy, planned for a 20-year outreach, was published in the same year as the Long-term Science and Technology Plan (1967-1986), which provided guidance to build up a competent S&T workforce. The third element was the creation of a consolidated S&T research park for GRIs in 1973, extending in a range of 27.8 square kilometers at Daedeok area. The Daedeok Science Park was implemented by the "Act on Development of Specialty Research", which supported the creation of six GRIs to provide industrial research for ship building, chemistry, electronics, machinery, energy, and so forth. The legislations of these three institutional elements served as baseline cases to expand the S&T basic system into other platforms to acquire a higher caliber workforce, under secure funding conditions, with a firm institutional commitment to explore other scientific and technological fields.[279]

The creative imitation phase, spanning between the 1980s and 1990s, exhibits the transition of the government-led R&D efforts into other public and private entities that continues to wage the progression of technology learning and exploitation. The transition was motivated by the demand pull generated from national and social needs considering core capabilities in higher technology domains. In this phase, the Korean society experienced more involvement from the corporate sector considering in-house R&D, as well as increased volumes of collaboration between universities and government sponsored research institutes. The Basic Science and Research Promotion Act of 1989 responded to the growing involvement of university level basic research, which was in the incubation phase. Universities

[278] Linsu Kim, "The dynamics of technological learning in industrialization", International Social Science Journal, 2001

[279] Series of legislations came into force during this period such as; Science and Technology Promotion Act (1967); Technology Service Fostering Act, National Investment Fund Act (1973); Act on Development of Specialty Research Institute (1974); Technology Development Promotion Act (1977), Venture Capital for Technology Start-ups (1978), etc.

have been establishing Science Research Centers and Engineering Research Centers supported by either government funding or corporate support. In the GRI community, the government and private industry collaborated on the Highly Advanced National Research Project (HAN). Throughout these public-private partnership programs, a number of spin-offs and spillover effects were accomplished, such as in CDMA technology, nuclear reactors, satellite programs (KISTAT-A), among others. It was also during this phase in 1999 when the defense industry, which traditionally relied on government-led R&D projects, started to initiate in-house R&D efforts as well.

However, although the economy was experiencing a growing volume of corporate investments in R&D, the overall technical capacities of the country was still in a ripening phase and the majority of firms were suffering from the gap between high technological demands and low technological capacities. In order to mind this gap, in 1987, the government introduced through legislation a more comprehensive "Industrial Development Act" that consolidated the existing industrial promotion acts such as the "Machine Industry Promotion Act", "Ship-Building Industry Promotion Act", "Electronic Industry Promotion Act", "Steel Industry Promotion Act", and so forth.[280] The intent for this legislation was to institute a more balanced industrial development policy in the exponentially expanding industrial sectors. Especially, the Industrial Development Act sponsors the development of critical technical areas that are in high demand in various corporate sectors by initiating collaborative R&D between GRIs and corporate laboratories. The Act signifies the transition from government-led industrial and R&D policy to corporate-led efforts. In the meantime, the vast diversification of public and private R&D programs expanding into various industrial and public areas rendered coordination issues within the government structure between the MOST and other Ministries, such as the Ministry of Commerce and Industry, Ministry of Information and Telecommunication, Ministry of Public Health and Welfare, etc. In order to adjudicate the coordination challenges, government established the National Science and Technology Committee (NSTC) directly under the Office of the President to effectively improve oversight of resource allocation of national R&D programs.[281]

Lastly, in the current innovation stage after the Asian Financial Crisis, increased collaboration between university level basic research functions and mission oriented applied research at GRIs, in conjunction with intense corporate research activities in a globalized R&D setting, supervised under a diversified government R&D policy is observed. Especially, when monitoring the flow of corporate research grants[282] awarded to universities and GRIs, the center of gravity has changed from GRIs in 1985 (approximately 85% awarded vs. 9% for universities) to universities in 2010 (approximately 47% awarded vs. 40% to GRIs).[283] The reason behind to this transition was primarily the improvement of

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280 공업발전법 제정 (1987)
281 국가기록원, 국가과학기술위원회, available online at http://www.archives.go.kr/next/search/listSubjectDescription.do?id=000061
282 Corporate research grants, other than those invested to in-house R&D, awarded to external research laboratories increased from $49,267,273 to $1,101,366,364.
283 신태영 외, 한국혁신체제의 동태분석과 발전전략, 정책연구 2012-14, 과학기술정책연구원, p. 276.

research capacities at the university level, but also attributed by the fact that GRIs have given more priority towards government granted research programs. The stronger bond in collaborative research between industry and academia was further encouraged by government policies during this period. The growing need to generate a new economic growth engine in a transitional period into a knowledge based industrial structure under rapid technological changes instigated the Roh, Mu-Hyun Administration to build a robust triple helix system between industry, academia, and GRIs. Institutional foundations were established after 2003 in forms of declaratory policy and detailed Presidential Directives, which was represented in the "Vision and Strategies for New Collaboration between Industry and Academia" (25 September, 2003).[284]

During this period, the need to administer inter-agency R&D activities was growing. This is the result of the rising demands in technological development throughout all sectors of the society as the country transformed into a knowledge-based economy. Thus, almost every government agency was assigned with responsibilities to administer certain portions of S&T policy. The growing resource requirements to support these R&D demands under various agencies called for a stronger coordinating mechanism between government organizations to accommodate competing priorities in global and domestic issues such as climate change, job creation, social welfare, national security, and so forth. In this regard, a new S&T governance structure was established that appointed a more centralized authority on the Ministry of Science and Technology and the NSTC.[285] Further description of the country's S&T governance structure will follow.

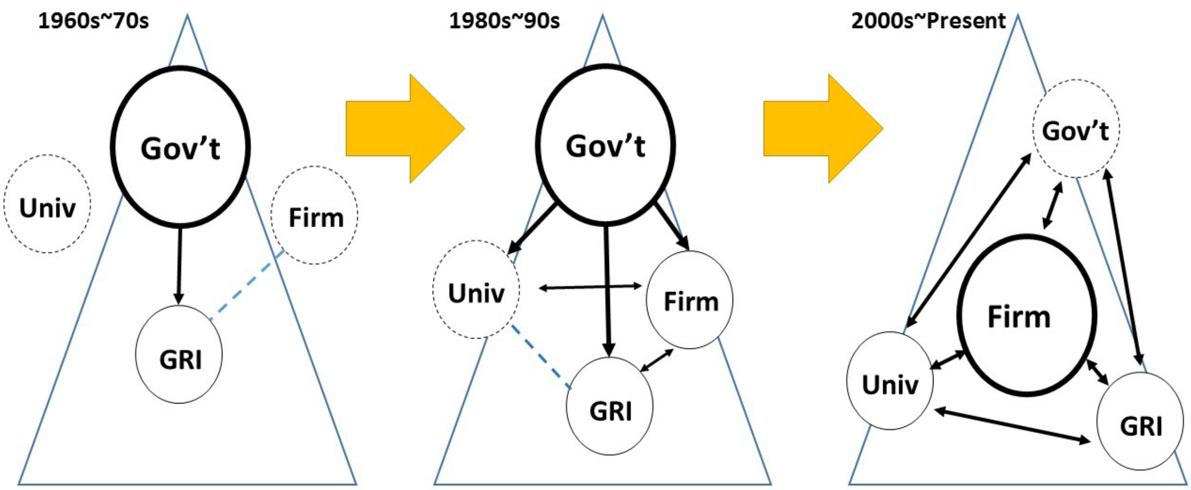

Figure 7. Dynamic Structure of Korea's Innovation Triangle, adopted from Korea's Strategy for Development of STI Capacity: A Historical Perspective, STEPI Policy Reference 2012-01.

284 참여정부의 新산학협력 비전 및 추진 전략

285 In 2004, the MOST Minister was elevated to the Deputy Prime Minster level and Deputy Chairman of the NSTC, and a permanent branch that serves as the NSTC secretariat was established (Office of Science, Technology, and Innovation) in order to coordinate the national R&D budget.

The case for catch-up economies has placed Korea in the main subject for scrutiny, mostly because it was considered a special case among the catching-up economies. Even though it remains substantially below the OECD average in terms of relative income levels, its R&D intensity is quite high and its accomplishments in patenting are growing rapidly. The changing dynamics of Korea's performance in patenting and innovative activity has transitioned from the publicly driven to the privately led, as the government share of R&D expenditure, and consequently that of the higher education outputs, have significantly diminished the past two decades. The transitional case of Korea demonstrates the idea that larger firm sizes and economies of scale constitutes one of the driving forces behind the private sector taking over major portions of the overall R&D efforts.[286] In the later phases, after the Asian Financial Crisis, R&D efforts reached a more globalized spectrum where firms started to establish overseas R&D outposts and strenuously pursued M&A strategies to overcome difficulties in obtaining advanced technologies from foreign countries through conventional technology transfer arrangements. Throughout this observation, the government involvement in national R&D efforts slowly dissipated where it transitioned to a firm-centric innovation construct while giving increased roles and capacities to basic level research from universities and mission targeted research in GRIs. Thus, the more the firm overtakes the research portion from the government, the more dynamic and vibrant the innovation system works.

4.1.3. Transition from Capital Intensive to Knowledge Intensive Industrial Structure

The rapid growth of the Korean economy was represented by large volumes of fixed capital investments in land, plants, and machinery. R&D investments were in a growing trajectory but were marked low in the overall investment portfolios of firms. The corporate growth model was based on the positive complementarity between aggressive capital investments made by large corporation, and consequent production activities of small and medium firms derived from this capital investment as such. This trend substantially changed after the Asian Financial Crisis.

Aggressive investments, but with consequently unpayable profits, were no longer permissible. Therefore, firms without the requisite technological competitiveness were unsustainable in the market, whereas firms equipped with the qualified technical skillset continued to strive. Most notably after the Asian Financial Crisis is the substantial increase in corporate R&D intensity, which represents the perceived interest of firms in R&D. In a recent study conducted by STEPI, the intensity of corporate investment in fixed capital decreased but the intensity in R&D investment substantially increased. Such trend is especially noticeable in small and medium firms where the R&D intensity ratio almost doubles that of large corporations from 4.9% to 2.1&.[287] Especially, small and medium firms listed in the Kosdaq market show higher rates of R&D investments than those listed in the Korea Exchange market.

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286 Organization for Economic Cooperation and Development, Managing National Innovation Systems, 1999, p. 103.
287 김석현, 외환위기 이후 한국 기업의 성장요인 분석: 기수혁신을 중심으로, 정책자료 2007-25, p. 50.

Larger R&D investments mostly result in improved corporate sales and employment rates. Thus, these trends occurring at the turn of the century signified the transition of the Korean economy from a capital intensive to a knowledge intensive industrial structure.[288]

In this aspect, inter-agency coordination has been raised by a number of countries to improve efficiency in effectively deploying public resources in S&T activities. An assessment proposed by the U.S. Government Accounting Office for inter-agency collaborative mechanisms highlighted collaborative structures and appointments within the Executive Office of the President, promulgation of national strategies and initiatives, building up inter-agency groups in the form of task force, councils, or committees, and the designation of leadership billets that can strongly administer these bureaucratic stovepipes.[289]

4.2. National Innovation Systems of Korea

As of 2015, the national R&D investment totals $17 billion with an S&T workforce nearly 440,000 in strength, with the production outcome reaching approximately $1.4 trillion, where $532 billion accounts for overseas exports.[290] However, the country's S&T construct is generally considered to be built around an industrially focused 'fast-follower' mentality, risk averse and passive in nature that lacks audacity and entrepreneurship.

As the country went weathered the Asian Financial Crisis of 1997 and suffered a sluggishly low economic growth rate afterwards, a robust innovation system that can reinvigorate the country's growth potentials has become in dire needs. In this regard, the proven effectiveness of Korea's national innovation system attributing to its fast paced economic growth and technology catch-up strategies no longer places the country's competence level sufficiently competitive in the global economy, both in a technological and financial sense. The Korean economy is now situated in a position where catching up through imitation is no longer a valid means to compete against its industrial peers. The country has entered an era where creativeness through innovative products and processes has become more than imperative to sustain its status in the global economy. An honest assessment of the Korean NIS show weaknesses in the overall S&T infrastructure, where insufficient institutional arrangements and inadequate S&T substructure continues to hinder the innovative potentials of the country.[291] The inefficiencies were cited in a recent survey by various agencies regarding the country's R&D input and productiveness. Overall statistics show the country experiences a low rate of return in R&D investments. The amount of R&D investments committed into basic and applied research reached about 4.29% of its Gross Domestic Product in 2014 (US$60.5 billion), which outstrips that of the next runner-up Israel

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[288] For more discussions about this transition process, read Korea and the Knowledge-based Economy (World Bank, OECD, 2001), pp. 25-37.
[289] Government Accounting Office, Managing for Results: Key Considerations for Implementing Interagency Collaborative Mechanism, GAO-12-1022, 2012, p. 5.
[290] KISTEP 통계 브리프, 2015 년도 국가연구개발사업 투자현황, 2016 년 9 월호
[291] 송위진, 이공래, 국가혁신체제론의 기본관점, 한국의 국가혁신체제, 과학기술정책관리연구소, 2008, p. 36.

(4.11%) in addition to other highly industrialized countries such as the U.S. and Japan. At the moment, Korea aspired to further invest into R&D as high as 5% of its GDP until 2017 with more coming towards its basic research programs. But the overall innovation pattern still remain within the restrictive confines of a ‘developmental-blindfolded fast-follower mentality’ in late industrialization, where major R&D efforts are generated primarily by large Chaebol conglomerates and has become narrowly focused on concentrated manufacturing sectors such as semiconductors, ICT, and other applied areas.[292] In terms of strategic linkages with key innovation players, Korea’s collaborative relationship in R&D within the triple-helix construct of industry-university-GRI levels 4.6 in a scale of 7, which places the country in 21st place out of the 35 OECD countries.[293]

A recent publication from Nature illustrates an even harsher review that shows the naked reality of Korea’s S&T competitive standing. As stated in previous paragraphs, the country is internationally recognized for its high spending patterns in R&D investment, which places Korea number one among any other country in the world. The figure showing more than 4% of GDP in R&D investment represent a commitment level higher than Israel, Japan, and the U.S., and double the level of China and the European Union. As portrayed in the later stages of Figure 7, the majority of the investment originate from industry where corporate investment account for over 75% and government 23%. Experimental development and applied research constitute over 82.5% whereas basic research only takes up a marginal share of a mere 17.5%. Even so, the figures representing public S&T sponsorship further raises stronger doubts on actual productiveness and effectiveness of these government investment efforts. In terms of publications in scientific and technological journals, Korea lags far behind the front runners such as China, UK, Germany, and Japan, where the country stands in par with Spain, which spends far lesser in proportion on public R&D programs.[294] The number of patent application displays similar circumstances as well. Since 2010, the country’s exponential rise in patent applications per 1 million people, which placed Korea in the top tiered group, do not necessarily extend into actual commercialization. About 72% of the patent applications developed by GRIs never materialized into a solid commercial program. Over half of these applications eventually become disposed of, and never see light in the commercial market afterwards. Thus, the steep increase in patent applications degenerate into mere paper practices.[295]

In respect to a culture with deep rooted Confucius conventions, the Korean society traditionally placed technological significance lower in priority against conceptually abstract ideologies, thus does not share a consensus in bolstering S&T capacities and the need to nurture scientists and engineers in a socially respectful manner. Despite the strong state sponsored academic fellowships available for national S&T programs, competition in university level basic science and engineer departments have

292 Mark Zastrow, “Why South Korea is the world’s biggest inventor in research,” NATURE NEWS FEATURE, 1 June 2016.
293 OECD Economic Surveys Korea, June 2014, p. 12.
294 Mark Zastrow, “Why South Korea is the World’s Biggest Investor in Research,” Nature, Vol. 534 Issue 7605, p. 22.
295 김명자, “과학기술혁신모델, 선형에서 삼중나선까지,” 중앙일보, 2016.9.3.

been lagging behind business or law departments.[296] Surveys show that 41% of the 814 Korean scientists and engineers who received PhD degrees from U.S. universities decided to stay in the U.S. and not return to Korea because of the comparatively poor research environments and social treatment.[297] Despite constant government efforts to reinforce technological capacities, such lack of awareness, vulnerable S&T substructure, and deficient institutional settings consequently resulted in scant linkages between principal innovation agents such as GRIs, universities, and corporate firms, which presents chronic challenges in the diffusion mechanisms for innovative technologies and its learning routines. In a technological sense, these arrangements are described as technology supply (development)-demand (commercialization)-diffusion (exploitation) policies. The principles of technology innovation rigorously arrange this connection through workforce professionalization, financial support, and knowledge management.[298] The following subchapters further illustrate this arrangement.

4.2.1. National S&T Governance Structure

Perhaps no government organization in Korea went through various structural changes driven by different political anxieties and exploits as much as the S&T governance structure. Because of the frequent organizational changes and inherent challenges latent under the guise of inter-agency coordination, Korea's S&T governance structure has to endure low fidelity from the S&T community. The country's S&T governance experienced evolutionary changes and setbacks until the structure was assigned with its highest political stature during the Roh, Mu-Hyeon Administration in 2004, when the Minister of Science and Technology was elevated to a Vice Prime Minister level and assumed all coordinating authorities for national R&D programs. The following Lee, Myung-Bak Administration, on the contrary, abolished the MOST and disseminated the S&T functions to other government agencies such as the Ministry of Education, Ministry of Knowledge Economy, and the Korean Communications Commission. This received high criticism from the S&T community because the dissolution of MOST implied the elimination of a national level control tower that should administer highly anticipated and complex R&D programs sponsored under government supervision.[299] Despite the frequent changes in the country's S&T governance structure, the current evolutionary setbacks are reflected in a general sense through the multiple layers of various agencies that perform planning, programming, and implementation roles in an overarching fashion.

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[296] 김용훈, "이공계 기피현상 분석을 통한 과학기술자의 사회적 위치 재구조화 정책방안 연구," 인적자원관리연구 제 17 권 제 2 호, 2010, pp. 183-189.

[297] David Wessel, "U.S. Keeps Foreign PhDs," The Wall Street Journal, 26 January 2010.

[298] 김진용, 국내 이공계 박사의 해외유출 특성 및 요인 분석, KISTEP Issue Paper 2010-09

[299] 황의봉, 과기부 해체! 기로에 선 과학기술계, 신동아 2008 년 3 월호.

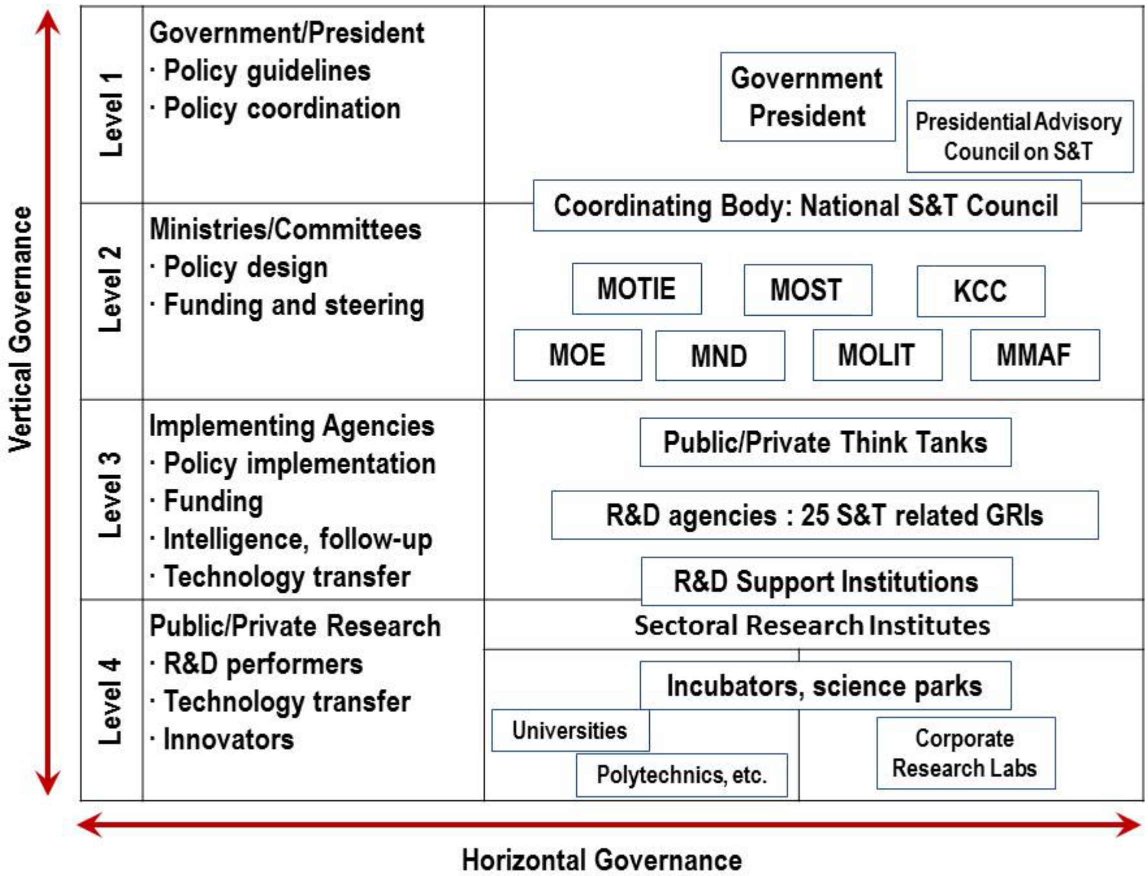

Figure 8. Figure 1. S&T Governance Structure of Korea, adopted and reproduced from OECD Governance of Innovation Systems (2005), Erik Arnold et. al., Research and Innovation Governance in Eight Countries, Technopolis, Vol 28, 2003.

The overall S&T governance structure considering the interdependent relationship and coordinating mechanisms between the upper-tiered executive apparatus and the lower-tiered implementing agencies can be more easily understood by reviewing the structure in four hierarchical levels (Figure 1). Level 1 represents the highest governance authority, the Presidential Office, and entails a coordinating body, the National Science and Technology Council, which performs accommodation and adjustment roles over competing R&D priorities between different cabinet ministries and agencies in terms of planning and resourcing. Level 2 considers planning and funding agencies that mostly consists of Ministries and cabinet level committees. Level 1 and Level 2 constitute the upper-tiered executive level policy planning and coordinating apparatus in this structure. Research labs such as GRIs and other support institutions are under Level 3 categories that mostly perform policy implementation such as R&D activities, technology planning, transfer, policy research and analysis, etc. Level 4 includes public and privately funded research labs and the business/R&D clusters such as science parks. Level 3 and 4 constitutes the lower-tiered implementing and execution agencies.[300]

Upper-tiered Executive Apparatus: National Science and Technology Council

300 홍형득, “거버넌스 관점에서 우리나라 국가혁신체제(NIS)의 변화와 특징 분석,” 한국행정논집, 제 19 권 3 호, 2007.

Before the Kim Dae Jung Administration of 1998, the MOST suffered from low political prestige and was placed under the Prime Minister's Office as merely an implementing agency for distributing R&D resources, while a substantial portion of planning and programming functions stayed under the jurisdiction of the cabinet ministries. The decentralized authorities imposed additional challenges in interagency coordination.

In the 1990s, the number of GRIs increased to 21 expanding into various scientific fields of basic research, applied engineering, and so forth. However, the general consensus was that these institutions were not producing the expected outcomes compared to the initial resources invested earlier. Whatsoever, the difficulties to coordinate differing ministerial opinions based on strongly prevalent turf wars, and the nonexistence of an institution that can adequately translate the coordinated results into actual government budgets, have hindered to create an effective innovation system in S&T affairs. In the previous decades, in order to overcome competing bureaucratic politics in drafting and adjusting complex inter-agency R&D needs, the General Science and Technology Council under the Prime Minister's Office, which was established in 1973 and restructured in 1992, assumed major coordinating responsibilities in terms of planning, programming, and budgeting government sponsored R&D programs, but the organization could not effectively cope with the growing interagency coordinative demands. In response to such public needs, the Kim Dae Jung Administration, as part of strengthening the country's national competitiveness in science and technology, has elevated the status of the Ministry of Science and Technology to an official Ministry level from the previous Agency level. Additionally, in 1999, in the course of streamlining government R&D resources dispersed under the authorities of various Ministry offices in order to improve effectiveness and efficiencies in government sponsored R&D programs, the National Science and Technology Commission (NSTC) chaired by the President and chiefly administered by the Minister of Science and Technology was launched. The primary responsibilities of the Commission were to serve as a coordination venue between the various GRIs that were assigned and administered under different branches of the government, in which the Minister of Science and Technology would serve as the administrational chief in integrating research agendas, supervising GRIs, and allocating R&D funding.[301]

If the purpose of the General S&T Council was to augment the low political stature of the MOST, the purpose of the NSTC was to adjust diverse R&D requirements incurred from different cabinet ministries as well as to support private sector R&D needs. Starting with the 1980s, a strong demand pull from various sectors of the economy called for resource assistance from the government. Various cabinet ministries such as the Ministry of Energy and Resources, Ministry of Commerce and Industry, Ministry of Public Health and Social Affairs, and so forth, initiated their own ministry specific R&D programs, while the planning, programming areas, and resourcing needs became increasingly redundant and overlapped in many ways. For efficiency and improved effectiveness, there was a strong

[301] 과학기술기본법 제 5 조, 1973.5.16.

justification to impose some cooperative division of labor between different bureaucratic sectors of the government. In this regard, the NSTC was established, which charters the President as the Chairman and the MOST Minister as the deputy, and gathered 15 ministers that administers sector specific R&D programs.[302]

However, the NSTC has been under constant criticism for its inconsistencies and discontinuity in policy executions caused by the frequent restructuring work driven by different political aspirations. After its creation in 1998, NSTC was overhauled five times until 2015, which was associated with continued degradation and elevation of the organization's authorities. The NSTC is a non-standing organization, in which the MOST mostly served in secretariat responsibilities. In comparison with similar S&T governance institutions in the United States and Japan, which are established as permanent entities exercising strong executive level national S&T coordinating authorities under complete independence from other cabinet departments, the non-permanent status of Korea's NSTC and the MOST serving in mere secretariat functions causes discontinuity and biases in decision making within this coordinative venue. This becomes troublesome and often discredits the NSTC when deliberating a consensus over critically differing inter-agency priorities.[303]

Table 5. Reorganization Milestones of the National S&T Council

	1999	**2004**	**2008**	**2011**	**2013~**	
					2013	**2015**
Standing Status	Non-standing	Non-standing	Non-standing	Standing[304]	Non-standing	
Composition	Chair: President Vice Chair: Non Members: 14 Cabinet Ministers 8 External members Secretary: MOST	Chair: President Vice Chair: Deputy Prime Minister for S&T Members: 14 Cabinet Ministers 8 External members Secretary: MOST	Chair: President Vice Chair: MEST Members: 14 Cabinet Ministers 8 External members Secretary: Senior Presidential Secretary of S&T	Chair: NSTC Chairman Vice Chair: Non Members: 2 standing members 7 External members Secretary: NSTC Secretary	Co-chairs: Prime Minister, Politically appointed external member Member: 14 cabinet members 10 external members Secretary: MOST Minster	
Secretariat	MOST	Office of S&T Innovation	MEST	NSTC Secretariat	MOST	Center for S&T Strategy

Lower-tiered Implementing Agencies: R&D Agencies and Support Institutes

As the national S&T competency continued to grow more complex and somewhat convoluted, the increasing need to create a supporting organization that covered overall planning, project management, and program evaluation roles amassed into higher demand. However, establishing such support functions within a government system presented challenges in efficiency and effectiveness considering the slow response time caused within the bureaucratic S&T governance structure. Responding to these growing programmatic demands for administrative efficiency, R&D support

302 조현대 외, 정부연구개발사업의 체계구조분석 및 정책제언, 과학기술정책연구원, 정책연구 2003-27, p. 184.
303 김성수, "미래창조과학부: 과학기술 행정체제의 진화와 역행," 한국사회와 행정연구, 제 24 권, 2 호, p. 512.
304 NSTC existing as a standing committee in 2011 is illusive because it was merely a political gesture to alleviate the public outcry of abolishing the MOST and dissemintating its functions to other cabinet ministries during the Lee Myung Bak administration.

institutions (aka Specialized R&D Management Institutes) were created as an entrusted R&D management organization under each cabinet ministries that operated sizable R&D programs, which gradually increased in numbers since 1987.[305] Starting with the creation of the Center for S&T Policy and Evaluation under the Korea Advanced Institute of Technology in 1987, additional R&D support institutions were erected in various and diversified S&T fields to manage the growing national R&D budget since 1999. Currently, there are a total of 18 public R&D support institutions operating under various ministries that employ about 3,300 in manpower supported with an annual budget of $320 million. As of 2013, these institutions administers about 56% of the $15 billion national R&D budget.[306]

However, each ministry competitively created these institutes without considering the overlaps and redundancy with other ministries. Thus in 2006, R&D support institutes accounted for 31 in number under 12 cabinet ministries, in which many overlapped in function while rated deficient in professionalism. In order to streamline these lavishly excessive support functions, the government redefined the scope and responsibilities of R&D support institutes under Executive Order-27369, *Regulations to Manage National R&D Programs,* in July 2006, and established government review procedures under the NSTC when proposing the need for creating a new R&D support institute, in addition to providing assistance for rationalizing project management and evaluation routines.[307] Despite these streamlining efforts, there still existed 14 R&D support institutes under 7 cabinet ministries in 2008, which continued to overlap in a number of research subjects without creating any cooperative linkages or productive synergies. In more detail, the 6 R&D support institutes managed by the Ministry of Knowledge Economy (formerly the Ministry of Commerce Industry & Energy), and the 3 R&D support institutes operated by the Ministry of Education and S&T all had similar but compartmental operative functions in planning, evaluation, and program execution. For instance, in the field of components and materials technology, R&D planning was conducted by the Korea Industrial Technology Foundation, program evaluation was covered by the Korea Institute of Industrial Technology Evaluation & Planning, and program execution was managed by the Korea Materials & Components Industry Agency.[308] Professionalism in leadership continued to discredit the validity and effectiveness of institutional research performances as most of the R&D support institute chair positions were politically appointed, who mostly had no science or engineering background. The lack of S&T professionalism in the upper leadership positions of these institutes caused impulsive and populist decision making in various R&D program management domains.[309] In this regard, rationalization efforts over these support institutes were continuously raised as a public agenda item during a number of election campaigns, but the dispute still remains unsolved even now.

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305 과학기술기본법 제 11 조 (국가연구개발사업의 추진) 제 4 항
306 국가과학기술심의회 운영위원회, 정부 R&D 혁신방안 추진현황 및 향후계획(안), 2015.12.11,
307 임길환, 국가 R&D 정책 평가: 지원체계 및 재정운용을 중심으로, 사업평가 15-10, 국회예산정책처, 2015, p. 25.
308 기획재정부, “공공기관 선진화 추진계획안(2 차), 2008.
309 15 out of 18 R&D support institutes were assigned with political appointments as its leadership. 임길환, p. 41.

4.2.2. Establishment of Technological Standards

The establishment of national measurement standards was a critical step for Korea towards upgrading its technical status acceptable to international specifications. Such efforts instituted compatibility with international S&T and industrial standards, which accelerated learning and diffusion of advanced technological competencies. Notably, the 21st century global supply chain and technical standards strongly demand commonality in measurement and performance evaluation, improve component interoperability, and protect end users through ensuring safety and durability in products and services. In this regard, instituting technical standards into a country's S&T capacity is accounted as a critical component to enhance national or sector specific technological competence.

Korea was mostly dependent on international assistance for institutionalizing measurement standards in the initial stage of industrialization, with the majority of the assistance provided from U.S. and Japanese sources until the early 1970s. The standardization efforts concentrated on measurements in micrometers, machinery, and electricity voltages as part of building the technical basis of its nascent industries. Especially, the provision of U.S. Government aid in the early years of development was considered a critical enabler that facilitated the country's standardization process. During the Presidential Summit meeting of 1966, U.S. President Lyndon B. Johnson presented three sets of measurement instruments as a symbolized gift for S&T assistance. The motive for such provision from the U.S. Government was to garner additional military support from Korea over the on-going U.S. military campaigns in Vietnam and Southeast Asia.[310] Subsequent to the high-level exchanges, follow-up assistance was provided by the U.S. Department of Commerce in July 1968 with objectives to create a formal measurement standards laboratory in Korea. The suggestions made during this period were; 1) Build stronger consensus to establish national measurement standards agreeable with international norms; 2) Stronger government leadership in establishing institutional structures for national measurement systems. To support this initiative, a series of surveys were conducted by the U.S. National Bureau of Standards up until November 1974, which provided not only advisory services, but also financial assistance with a funding package amounting USD 5 million in international development loans.[311]

The period from 1975 to 1988 marked the stage of rapid development and technological catch-up through imitation and reverse engineering.[312] As the country entered into the period of building heavy and chemical industries, and embarked upon initiatives in self-sufficient military modernization

[310] Korea dispatched one Corps level element, nearly 330 thousand troops, to Vietnam from 1964 to 1973, which constituted two Army divisions, one Marine Corps brigade, and other support elements such as in medical and construction. The U.S. Government bore all expenses for Korea's entry into Vietnam, which amounted in a total of $236 million in payment, modernization of the South Korean military, preferential treatment for Korean industries entering the Southeast Asian market.

[311] 전경수, "국가표준의 정점: 한국표준과학연구원," 지식재산 21 제 54 호, 1999 년 5 월호

[312] The significance of 1988 is when Korea formally joined three advisory committees under the International Committee for Weights and Measures (CIPM); 동아일보, "표준연 국제도량형위원회 정회원에 선정," 1988. 11.24.

through constructing its defense industry in the mid-70s, a more sophisticated level of technical measurement standards came into practical need. In order to address the growing domestic technical demands, the Korea Standard Research Institute (later renamed to Korea Research Institute of Standards and Science in 1991) was founded in 1975 under the Ministry of Science and Technology.[313] It served as a momentum to build more indigenous capacities in standardization measurements. The efforts were supported financially through various development aid programs lent from the Asian Development Bank, United States Agency for International Development, Overseas Economic Cooperation Fund, and so forth. A number of government officials, scientists, and engineers that attended four iterations of intensive training in the National Metrology Institute of Germany (PTB) returned to create stronger grounds for technical expertise in equipment and facilities required for further refinement of domestic measurement standards.[314]

Moving into the 1990s, various social issues in aging, welfare, public safety, environment, etc., have emerged. Also in order to enter the wealthy class countries while fend off third world developing economies, Korea was in dire need to upgrade its industrial structure to more high-tech and sophisticated systems. In the process of addressing these concerns, a diverse number of measurement fields such as in analytical chemistry, material science, safety engineering, and radiation therapy was included into the standardization requirements.[315] Institutionalizing and sustaining measurement standardization efforts took part through constant legislation work and organizational build-ups. As a late starter in industrialization, the first legislation introduced on technical standards was in 1961 as the Ministry of Commerce and Industry enacted the 'Industrial Standards Act' and created the Bureau of Standardization under its organizational structure. The Industrial Standard Act was considered in its rudimentary stage since the domestic industry was simply built-up around the light industry sector. The initiative, however, developed into the Korean Standards (KS) in later stages, which reviewed and processed manufacturing permits for industrial products.

In 1979, there were movements to invest national measurement standards into constitutional importance. During the political turmoil that followed the assassination of President Park Jung Hee in late 1979, the S&T authorities attempted to utilize the momentum in favor of instituting stronger grounds to cultivate domestic R&D capacities, such that the political vacuum of out-casting the authoritarian Yushin Constitution, and replacing it with higher democratic values opened opportunities to build in foundational technological establishments. After a yearlong deliberative effort, the National Standard Systems was included in Paragraph 2 of Section 128 of the 9th Constitutional Amendment.[316] The inclusion was the first of its kind effort worldwide where national measurement standards

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[313] http://www.archives.go.kr/next/search/listSubjectDescription.do?id=000078
[314] 한국표준과학연구원, 국민연구소 KRISS 40 년, 40 개 이야기, 2015, p. 33.
[315] MOST, A Study on the Effects of '70s – '90s Major Science Policies on S&T and Industrial Development, Policy Studies-2006-21, September 2007, p. 132.
[316] Paragraph 2 of Section 128 of the 9th Constitution reads "The State shall establish national standard systems." The clause on national standards remained intact but moved up to Section 127 in the 10th Constitutional Amendment.

comprehensively became a written paragraph in a country's constitution. But it wasn't until 20 years later in July 1999 when national measurement standards actually became legislated supported by institutional mechanisms, stipulated in the "Framework Act on National Standards". In the interim, the "Weights and Measures Act" was enforced in 1993 but was not implemented in full length until the Framework Act was introduced. The supervisory office administering the Framework Act was traditionally designated to industrial authorities, i.e. Ministry of Commerce, Industry, and Energy – Ministry of Knowledge Economy – Ministry of Trade, Industry, and Energy. Subsequent to the Framework Act, a number of supporting ordnances such as the "Operating Regulations of Standard Materials Certification", "Designation and Operation of National Calibration Institutes", and so forth were implemented.[317]

Based on the enactment of legislating measurement standards, a number of implementing agencies were established to execute the proposed policy objectives. Two primary metrology institutes that administer and execute national measurement standards are the Korea Research Institute of Standard and Science (KRISS) under the Ministry of Science and Technology, and the Korea Agency for Technology and Standards (KATS) under the Ministry of Trade, Industry, and Energy. KRISS is represented as the national metrology institute and is responsible for accrediting, developing, and maintaining national measurement standards. The responsibility of KATS is on calibrating and supplying scientific and technological standards to the end users such as firms, laboratories, public agencies, and so forth. In order to execute the calibration and accreditation functions and facilitate diffusion of technical standards, the Korea Laboratory of Accreditation Scheme (KOLAS) has been organized under KATS.[318]

Institutionalizing national measurement standards provided the basic infrastructure for rapid economic development. Starting with the Korea Textile Inspection and Testing Institute in 1961, the nine government-run test laboratories on quality assurance created to date have generated certified test reports recognized by international standards, which enabled the exports of Korean products to overseas markets. According to a 2004 study conducted by Bearing Point on the economic impact value of Korea's national measurement standards, the standardization, calibration, and accreditation services provided by KRISS between 1994 and 2003 grossed to an amount near USD 860 million. The amount is a value worth 150% of its original investment considering cost-benefit ratios, which continues to grow. Accounting for the economic impact value for only 2003 alone, the effectiveness grows even higher to 1,276%.[319]

The aspirations of reaching out for enhanced compatibility with international accreditation standards became crucially important as the domestic industry aggressively pursued the objective of

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317 국가표준기본법, http://www.law.go.kr/
318 강병구 외, "단일인정기구 출범에 따른 KOLAS 중심의 통합인정제도의 효율화 연구," 산업통상자원부 정책연구용역, 2012. 8., p. 12.
319 KRISS, National Standards Infrastructure Underpinning the Economic Growth of Korea, MOST, 2002, p. 77.

upgrading its technical competitiveness status as an effort to proceed into more complex product systems. Especially after the government started to expand the national standardization categories in 1985, the scale of public R&D investments has constantly increased to substantial levels. As of 2016, the government R&D budget appropriated for standardization activities reached KRW 52.18 billion. The trend reflected the increasing need to cope with the international trend in reinforcing technology regulations and overcome technical barriers in trade relations. As Korea continues to compete in high-end technical products, the pressing requirements to accommodate its innovation system towards inherent challenges in exporting industrial commodities for improved compatibility and exchangeability, applicable to respective market needs, became an imperative factor for sustained growth.[320] Thus, conforming the country standards to an expected level towards international accreditations emerged as a priority area for enhancing technology competitiveness. In this aspect, the government boost up its efforts to join the International Laboratory Accreditation Cooperation (ILAC) through signing Mutual Recognition Arrangements (MRA) by using ISO/IEC standards, and involving conformity assessment bodies such as calibration laboratories, testing facilities, medical testing centers, and inspection bodies.[321]

In regards to institutional constraints, despite the well-established administrative structure in national measurement standards, there has been a number of confusion caused by bureaucratic rivalries between S&T authorities and industrial forces. Most of the confusion derives from jurisdictional authorities concentrated too much on industrial forces. KRISS is administered under MOST whereas KATS is controlled under MOTIE. The two organization has overlapping functions in areas of measurement, accreditation, and calibration, which hinders flawless interagency coordination. The jurisdictional authorities come from the Framework Act on National Standards, which is under the auspices of MOST (S&T authorities). However, the implemented ordinances are all administered under MOTIE (industrial authorities), which marginalizes the authorities of KRISS and the S&T apparatus. Based on the current arrangement, the only function effectively carried out by KRISS, under the auspices of MOST, is on developing measurement standards since the measurement tools remain within the possession of these two organizations, whereas the other major standardization functions such as calibration, accreditation, and dissemination are conducted by KATS and MOTIE, which do not obtain appropriate measurement instrumentation. Without an overarching coordination committee that can effectively mitigate these discrepancies, then duplicate investments in national standards and continued inefficiencies within bureaucracies will preclude the national standard authorities from developing a streamlined vision on technical standards. Table 2 encapsulates the overall discrepancies of these legal responsibilities.[322]

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320 The number of worldwide petitions related to technical barriers to trade accounted for nearly 2000 cases. 변상근, “6 년간 표준 R&D 예산 뜯어보니,” 전자신문 2016. 12.7, http://www.etnews.com/20161207000318
321 KOLAS introduction in https://www.kolas.go.kr/english/
322 김동진 외, “우리나라 국가표준체계 현황과 선진화 방안,” 한국기술혁신학회지 제 3 권 2 호, 2000, p. 134.

National Measurement Standards Principles			Implementing Ordinances	
Agency	Responsibilities and Legal Basis		Actual Responsibilities	Agency
KRISS	Measurement Standards and Dissemination	Article 13: Representative national entity on measurement standards	Representative national entity on measurement standards	KRISS
		Article 14: Calibration Systems	Calibration Systems	KATS
		Article 15: Accreditation of standard materials	Accreditation of standard materials	
KATS	Technical Administrative Services	Article 17: Legal Metrology Systems	Legal Metrology Systems	
		Article 18: Industrial Standard Systems	Industrial Standard Systems	
		Article 21: Conformity Test	Conformity Test	
		Article 23: Accreditation of Test and Evaluation Systems	Accreditation of Test and Evaluation Systems	

Table 6. Jurisdictional Discrepancies in National Measurement Standards: 김동진 외, “우리나라 국가표준체계 현황과 선진화 방안,” 한국기술혁신학회지 제3권 2호, 2000, p. 133.

The discrepancies in legal responsibilities causes confusion in a number of national level standards where certain measurements differ from international standards. The technical expertise resides within KRISS where all the measurement tools are in possession, whereas in reality KATS executes not only the administrative services in terms of announcing national technical standards, but also perform calibration and accreditation functions, while not obtaining the technical expertise. The disconnect between these two operating agencies poses continued challenges for the country’s S&T potentials to join the ranks of international standards.

4.3.3. System Linkages in Korea’s Innovation System

Triple Helix Coordination: Public-Private Partnership (Industry-Universities-GRIs)

Represented in major technological success stories such as the DRAM and TDX programs, cooperative R&D initiatives such as public and private partnership (P/PP) in product development between GRIs and industry showed strong collaborative relationships. The recent R&D investment patterns show higher percentages in partnership projects, in which P/PP account for 37% of the total national R&D expenses.[323]

However, recent surveys show the previously close relationship between industry and GRIs has substantially diminished, while the partnership between industry and universities increased more than two fold. In an OECD conducted survey between 1997 and 2006 over the percentage of private sector funding to GRIs and higher education institutes such as universities, GRIs marked only one-third the level of investments (4.5%) compared to that of universities (13.7%). Such investment statistics sponsored mostly by the private sector to high education institutes is markedly at the highest level within the OECD, which places Korea behind Turkey and Germany as a percentage of higher education expenditure on R&D. The investment portfolio of government R&D to the private sector also marks some significant changes compared to trends from past decades. The R&D subsidies previously

[323] KISTEP Database.

awarded to large firms has dropped from 6.6% in 2000 to 2.7% in 2006, which continues to drop even now, while the R&D subsidies awarded to SMEs maintains a stable rate of 12% and higher. This indicates the contraction in collaborative relationship between government and large firms, and an upsurge of government support to small and medium businesses.[324]

However, the patenting and technology transfer aspects of system linkages do not show much strong linkages in cooperative R&D efforts as illustrated in patenting and technology transfer data. Patent applications emerging from co-operative R&D partnerships have been hovering around 6% from all domestic patent applications. Industry-university partnership in patenting is still low in statistics but has been growing in meaningful paces over the past decade. But partnership between industry and GRIs have been declining significantly in recent trends.[325] In the aspect of technology transfers from public to private sectors, universities and GRIs have been enthusiastically exerting efforts to transferring proprietary ownership of technologies to the private sector through various arrangements. Considering the technology transfer results of year 2005, about 30% of technologies owned by GRIs, and 9.3% of technologies owned by universities were transferred to the private sector through the form of licenses, direct sales, and technological alliances.[326] The contributing element to such increase in technology transfers were realized through the operation of various technology transfer consortia and the designation of Technology Licensing Offices by the Ministry of Commerce-Industry-Energy.

Technology Transfer and Diffusion Mechanisms

The vicious competitive disposition of the global economy provokes countries to strenuously exploit novel technologies to maintain a sound position within the market. The transfer and diffusion process is therefore imperative in determining the commercial success of a country's various technical business fields. It is through this diffusion process where the original technology interacts with other elements of innovation such as production systems, relevant technical domains, market demand, process engineering, and so forth. The Korean Government did not effectively sponsored technology transfer policies before the Asian Financial Crisis of 1997. Until then, despite the tremendous appetite in technological needs deriving from the explosion of firm level capacity development, state sponsored R&D policy still placed priority on GRI research programs, thus the linkage between technology development and commercial exploitation lingered weak, and the diffusion of lucrative technology remained passive. Technology diffusion from the public to private sector was initiated by the gradual migration of scientists and engineers from these GRIs to corporate research institutes, which provided promising research grants and more liberty in research scope.[327]

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324 OECD Publishing. OECD Reviews of Innovation Policy: Korea. OECD Pub., 2009.
325 KIPO, *Patent Trends in Korea 2006*, Korea Industrial Property Office, 2006, p. iiv
326 MoCIE, A Survey on the Technology Transfer of Pubic Research Institutes, Ministry of Commerce, Industry, and Energy, 2006.
327 Lee, Kong-Rae and Park, Hang-Sik, "Overview of Technology Diffusion Programmes in Korea," in OECD Diffusing Technology to Industry: Government Policies and Programmes, 1997.

Korea's technology transfers and diffusion policy is composed of objective-oriented and service-oriented policies. Objective-oriented policies are then categorized in technology-driven, agency-driven, industrially-driven, and regionally-driven.[328] Technology driven programs are managed by government agencies, and are implemented through nationally sponsored R&D programs designed to promote collaborative research between the triple helix of industry-academia-GRIs. A representative program developed from this setting is the Super-High Speed Information and Communication Network sponsored by the Ministry of Information and Communication from 1995 to 2005, which established the country's critical IT infrastructure for future dominance in this field for the next 10 years. The government aggressively exerted efforts to deploy the initial ADSL based infrastructure in all regions of the country, which made Korea the most connected country in the world and enabled promising opportunities in future IT businesses based on this essential capacity.[329]

Agency-driven programs were designed not only to support large corporate firms but also to include technological support for small and medium firms that do not possess the resources to launch strong R&D programs. Government agencies such as the Small and Medium Business Corporation, Korea Productivity Center, and the Small and Medium Business Administration provides a number of programs in technology assistance, informatization support, training and education, venture capital support, and so forth, to assist the corporate needs generated from this sector. The Systems engineering Research Institute under KIST, which later merged into the Electronics and Telecommunications Research Institute in 1997, executed technical initiatives in assisting informatization through its "Product Information System Development and Technology Training Program" in order to improve productivity and process engineering for small and medium enterprises.

Industrially-driven programs consider instigating diffusion initiatives launched by the respective government ministries responsible for specific industrial sectors, such as the Ministry of Information and Telecommunication for ICT related projects, Ministry of Public Health and Welfare for health services, Ministry of Land, Infrastructure and Transport for construction related technologies, and so forth. For instance, the Ministry of Land, Infrastructure, and Transport implements, by law, the "New Technology Designation" program to encourage the adoption of novel technologies introduced from domestic and foreign sources through undergoing processes of identification-assessment-designation-application.[330] However, industrially-driven programs are limited to a small number of business sectors that received huge government support during the development stages, and do not cover a wide range of business sectors.[331]

Regionally-driven programs promote regional clusters in diversified but relevant businesses for the purpose of creating a locally symbiotic industrial structure. The program started with Korea's

328 이공래, 기술확산정책의 전개방향, 政策資料 98- 02, 1998
329 Lee, Young Ro et. al., Analytic Study on Korea's IT Infrastructure Development Policies, National Information Society Agency Research Paper, July 2009.
330 Available online at http://www.molit.go.kr/USR/policyData/m_34681/dtl?id=185
331 이공래, 기술확산정책, 한국의 국가혁신체계, p. 124.

initiation of the Local Governance System in 1995, and is considered one of the most vibrant and active publicly sponsored diffusion programs executed by both central and local governments. The program puts local university science ad engineer departments at the center of all planning and programming functions and creates a local technical business cluster tailored for the specific technology and relevant business area. MOST built up 14 Regional Research Centers to support the diffusion of knowledge and technology to the local economy. A recent standout program is the Gwangju High-Tech Industrial Complex (aka Gwangju Innopolis). The Innopolis houses the Gwangju Institute of Science and Technology as the high-tech research hub in the center of R&D related activities, supported by local branch offices of related GRIs such as ETRI, Korea Photonics Technology Institute, Jeonnam Techno-Park, and 273 companies in the field of photonics and optical technology.[332] The technical specialization in the growing field of photonics and optical technology, in such areas of solar energy, LED, LCD, and so forth, was a huge success in attracting the attention of research labs and firms in this field, such that the business sales within the wider Gwangju area alone increased tenfold from KRW 113 billion in 1999 to KRW 1.62 trillion in 2006.[333]

Service-oriented policies are not objective based but are applied in almost every domain, especially small and medium sized firms that are in need of technical assistance. The service categories are in technology-support, industrial exhibition support, and technical-information assistance. Technology-counseling services provide supervisory services for firms that are in need of the respective technology and information. The routine technical advisory services provided by the Small and Medium Business Corporation, Designation of Novel Technology Program sponsored by the Ministry of Information and Telecommunication, and the Robotic Automation in Production Process initiated by the MOST are one of the programs that show high return rates in technical needs from small and medium sized firms. Industrial exhibition-support services present opportunities for direct interaction between producers and consumers in certain technical fields through exposition events. Exhibition assistances for new inventions sponsored by the Korean Intellectual Property Office, Air and Defense Exhibition supported by the Ministry of National Defense and Korea Defense Industry Association, and various exhibitions on mechanics hosted by the Mechanical Industry Promotion Association are some of the examples. Additionally, these expositions in many occasions incorporate academic seminars and public hearings in order to fully enhance and exploit public awareness and attention focused around these events.

Technical-information support is a service area that collects and reproduces, and disseminates technical information to entities in need of such information. Thus, the focus of the program is to make this information easily accessible to the required needs of the information consumer. The Korea Institute of National Industry and Technology Information (KINITI) under MOCIE and R&D Information

332 광주광역시, 광주첨단과학산업단지 육성, 2003. 5.
333 김동근, 광주 광산업 클러스터의 형성과 성과, 지역경제 2008 년 6 월호

Centers under MOST, which developed into the Korea Institute of Science and Technology Information (KISTI), were the two primary entities that fully operate under this diffusion platform. KINITI was later merged into KISTI in 2001 in order to create a more streamlined structure for the conversion and diffusion of S&T and industrial information. KISTI mostly concentrates on distributing S&T knowledge through publications, standardization, and statistical databases, and is supported by functional research centers that work on advanced information convergence, supercomputing, and innovation assistance for small and medium enterprises.[334] On a separate, but very relevant area worth acknowledging is the way how diffusion experts are trained and educated as a professional career path. Most of the government officials assigned to technology diffusion related billets are mostly serving in rotational terms for fixed period and departs with no sufficient replacement training. Thus, the challenge of consistency and continuity always exist.[335] Certain regional cluster programs are also abandoned because of political disagreements or popularity votes casted during election year, which is unfortunately a common theme observed across other democratic societies.

The government sponsored diffusion programs, however, do not necessarily result in high performance outcomes. The programs are criticized for being mostly piecemeal and not connected through inter-agency coordination mechanisms. Accordingly, the diffusion programs are not closely associated with the corporate commitments in niche business areas. The lack of situational awareness over the dynamically changing market conditions is attributed by the apparent disconnect between different government agencies. The stovepipe vertical structure of certain technology fields inadequately reflects the divergent needs of corporate firms competing against global competitors. As aforementioned in the industrially-driven diffusion programs, the diffusion initiatives are managed by only a handful of industrial sectors that traditionally received government support during the development periods. These programs are not horizontally coordinated with relevant components of the industry such as local governments, high education institutes, and so forth.[336]

4.3.4. Structural Constraints in Implementing an Effective S&T Governance Policy

Proprietary Restraints from Government Sponsored R&D Projects

In the whilst of rapidly transitioning the country's national innovation system from a closed-door innovation system to a universally open-door system, the characteristics of intellectual proprietary rights (IPR) are also transforming from an ownership concept to a shared-utility concept. In this process, the utilization aspects of publically sponsored R&D projects, where the government generally claims ownership over the project outcomes, have been identified as an obstructing source of fostering national innovation.[337]

334 이상엽 외, 국가연구개발사업 백서, KISTEP, 2006.
335 이공래, 기술확산정책, 한국의 국가혁신체계, p. 100.
336 이세준 외, 과학기술혁신 촉진을 위한 부처 간 연계협력 메커니즘, 과학기술정책연구원 정책연구 2013-01, 2013, p. 35-37.
337 전성태 외, 지식재산제도의 실효성 제고를 위한 법제도 기초연구, 한국지식재산연구원, 2012.12, p. 18.

Current Korean law and regulation defines the ownership of proprietary rights over a publicly funded R&D project exclusively falls under the sponsoring government agency. In contrast to the ownership rights, the law vaguely recognizes the contribution provided from the participating entities who actually performed the research itself. For instance, among the 9,521 government sponsored R&D projects in 2010, only 19% (1,802 projects) became commercialized by participating corporations. The statistics implies the IPR remains restrictively under government control, which precludes further exploitation by participating private entities seeking commercial objectives. Consequently, individual or corporate contributions become marginalized, thus degrades the potentials of the technological outcomes diffusing into greater innovation opportunities.[338] On the contrary, advanced industrial countries that perform in higher innovation categories, such as the U.S., Japan, and EU, recognizes the contribution of those who participated in the project, at which the R&D outcomes reverts to the entities that hold responsibility over the research project. Therefore, the IPR priority is rendered to the participating entities. Such condition presents favorable circumstances for technology diffusion by empowering the participating entities with higher motivations to successfully commercialize the processes and outcomes of the R&D project. However, the Korean practice of marginalizing the participating entities within government sponsored R&D projects substantially discourages the triple helix of industry-university-GRI partnership and international collaborative research initiatives.[339]

Differing government regulations regarding publically funded IPR ownership arrangements add an extra layer of difficulties in diffusing these R&D outcomes. As of 2013, the number of established regulations in support of specific R&D programs account for 379 across 19 government agencies. The different definition and standards over IPR ownership causes constant confusion and inefficiencies for participating private entities in these programs. Hence, in a survey conducted in 2012 over publically funded R&D projects, 28% of the responses demanded a more coherent definition on IPR ownership regulations, 26% demanded a more flexible and convenient technology transfer and utilization process, 15% asking for a more standardized government regulation across agencies, and 14% requesting a single government authority when managing government sponsored IPR.[340]

Competing Priorities against Economic Policies

Technological innovations often times confront constant frictions against economic priorities. Economists tend to focus more on market functions and government expenditure than science and technology programs because of the embodying high development risks and long gestation period for capital investments in R&D programs. As a matter of fact, the statistics showing only 4 out of 53 Nobel Laureates in Economic Science being recognized for their contributions in researching technology

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[338] Ibid., p. 36.
[339] Carl Dahlman and Thomas Andersson ed., Korea and the Knowledge-based Economy: Making the Transition, OECD, 2000, p. 98.
[340] Ibid., p. 120.

innovation subjects encapsulates the lopsidedness and marginalization of the studies conducted over technological developments in the economics literature.[341] S&T policies were considered a subordinate category of economic development planning, at which many national level scientific programs were driven by bureaucrats with financial backgrounds who had less exposure to technological fields. Intangible economic impact factors and feasibilities were given priorities over assessing technological development risks and associated growth potentials. Although economists or government officials constantly advocate the achievements of scientific research, this is more easily said than done. The case of the Korean S&T apparatus is nowhere different from this conundrum.

The MOST was constantly criticized for its incapacities in adequately planning and coordinating national S&T policies through inter-agency concertation. Despite the legislated responsibilities of the MOST, the budget and financial authorities mostly took over the planning and coordinating role in S&T policies. The policy coordinating roles, including S&T policies, were inherited from the Economic Planning Board (1991), Ministry of Finance and Economy (1994), and currently to the Ministry of Strategy and Finance. Under this bureaucratic condition, MOST did not obtain the wherewithal to take leadership in S&T policy making, which included the authorities to allocate national R&D resources.[342] For instance, the ICT Promotion Act legislated during the Kim Young Sam Administration, which ruminates as the critical turning point for Korea's advancement into the IT industry, was planned and coordinated not by MOST, but by the Presidential Secretary in Economic Affairs[343] The inter-agency coordinating authority was also assigned to the Minister of the Cabinet Office under the Prime Minister, who also happened to be a finance official who came with extensive experience under the Economic Planning Board, not the technocrats from MOST.[344] Putting into consideration of the significant planning requirements in S&T management roles while recognizing the apparent marginalization, the political stature and authority of MOST was once elevated and strengthened to a Deputy Prime Minister level during the two subsequent administrations in the new millennium that succeeded the Kim Young Sam Presidency, but was then again degraded and eventually abolished by the Lee Myong Bak Administration as of 2008. Therefore, no matter how ambitiously an S&T strategy was proposed and drafted, it rarely materialized as a concrete program after being frustrated by the economic and budget authorities.

Such aspect relates with the political stature of S&T agencies. National S&T policy was, and still is, an attractive subject that has accessible public appeal for politicians. In this regard, a number of Presidents fancied themselves as "S&T Presidents" and committed to a number of self-promoting declaratory policies in respect to upgrading the national S&T competitiveness up to a performance level in par with advanced industrial countries. However, most of these policies remained rhetorical campaign

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341 Michael J. Mandel, Rational Exuberance-Silencing the Enemies of Growth, Harper-Collins, 2004
342 현원복, 대통령과 과학기술, 과학사랑, 2005.
343 이웅환, 국가 경쟁력 강화 기획단 청와대에 내달 1 일 신설, 매일경제, 1994.11.23.
344 http://www.dt.co.kr/contents.html?article_no=2015112502100151607001

strategies and did not develop into a solid program initiative.[345] This mainly attributes to the relatively low profiled political stature of the MOST in comparison to other government agencies related with S&T activities. Until the Kim Young Sam Administration of 1997, the MOST was not an independent cabinet department, but was subordinated under the Prime Minister's Office. Constant replacement of Ministers heading the Science and Technology Ministry was also a source of weakness that caused inconsistency and disconnection in policy. Accounting for the period MOST Ministers stayed in office, the average tenure was a little over a year or so, while not accounting for a handful of Ministers that were appointed during the earliest days of the Ministry when the military dictatorship endowed as much power to scientists and engineers for the country's strong economic development drive.[346]

Discouraged Entrepreneurship and Demoralized Social Status of Scientists and Engineers

Conditions for R&D policy in Korea are captured in two words; inconsistency and unsustainability. Inconsistency stems from frequent policy changes and pointless organizational restructuring of Government Research Institutes (GRI) based on short-term performance assessments made by incumbent political administrations. Such destabilizing factor consequently resulted in the low esteem of scientists and engineers, and the perceived social status. The frequent reorganization work hammered onto public research labs under the initiative of GRI rationalization over the past thirty some years have left high caliber scientists insecure with their job security. The rationalization assessments of GRIs conducted in 1983, which consolidated 16 government sponsored research labs into 9, compelled thousands of S&T related officials to leave the workforce. Another rationalization effort that occurred in 1991 was revalidating the 22 GRIs considering its performances and achievements, which forced another batch of scientists departing their laboratory chambers. The third large scale reorganization work was caused by the Asian Financial Crisis of 1997, which resulted in another wave of S&T officials eliminated from GRIs. However, these three national level reorganization work on GRIs, spanning within less than two decades, had incurred some subsequently unexpected diffusion effects into the private sector, in which motivated corporate R&D efforts of the five major Chaebol companies exceeding public R&D outcomes in absolute size and value.[347]

The impact of the 1997 Asian Financial Crisis on national level science and technology policies confronted the same situation as with other sectors of the country. Compounding to the already worsen conditions of the R&D workforce was the inherent circumscription of bureaucratic inefficiency layered within populist government policies. Reigning Presidents and political parties mainly relies on popular votes, thus focus on near-sighted remedies instead of long-term solutions. Hence, R&D efforts, which

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[345] Some scholars refer to this conduct as 'Exhibitional Bureaucracy', namingly a policy that simply intends to instigate approval ratings, 함성득, "과학기술 조정 및 전문기구 변천사," 월간 과학과 기술, 1998 년 7 월호, p. 48.

[346] 성하운, 한국과학기술을 일군 개척자, 최형섭, The Science Times, 2016.3.24.

[347] Expenses for corporate R&D experienced an average growth rate of 8.7% between 1995 and 2000, accounting for the comparative 9.9% reduction in 1998 due to the Asian Financial Crisis. However, the expenditures substantially surged in 1999 and restored the previous growth rate in 2000 by a 20.3% increase, which accounted for over 50% of the overall R&D costs nationwide. 서중해, 우리나라 민간기업 연구개발활동의 구조변화, 한국개발연구원, 2002, p. 12.

normally require a tenacious mid-to-long-term strategy and incubation period, are often disturbed by such populist policy lines, therefore difficult to achieve the original research goals. Science and Technology Policy in Korea were coined to these traits since the 1980s. The Chun Doo Hwan Government that took power over a palace coup immediately started to streamline the GRIs through massive organizational consolidation under the guise of improving efficiency. The marching orders of the Ministry of Science and Technology to execute this policy were titled "Proposal to Overhaul R&D Systems and Improve Operations", which consolidated 16 GRIs into 8 clustered research fields.[348] The aftermath was a huge exodus of senior researchers from these institutions that were gathered as an extended efforts to build foundational capacities for the economy during the early developmental decades. For instance, the Korea Advanced Institute of Science and Technology (KAIST), after being compelled to consolidate with the Korea Institute of Science and Technology (KIST) experienced a departure of 41% of its senior researchers between 1981 and 1983.[349] The subsequent Roh Tae Woo Government implemented a similar effort by conducting a comprehensive performance assessment of 22 S&T related GRIs, which resulted in some internal structural adjustments of operational functions. Although not going through reform efforts in an equal magnitude of former Presidents, the Asian Financial Crisis erupted during the ensuing Kim Young Sam Administration has forced the government to substantially reduce public funding allocated to national R&D projects. The task for organizational downsizing was undertaken by the succeeding Kim Dae Jung Government, at which the national R&D budget was slashed by 20% and nearly a thousand scientists and engineers were forced to leave GRIs. A number of these experienced researchers sought asylum in foreign research labs instead of finding alternate employment opportunities inside Korea.[350]

Unit: Number of researchers, ( ) marks %

	Chaebol	**SME**	**Venture Firms**	**Total**
No. of departing researchers	92 (74.2)	9 (7.3)	23 (18.5)	124 (100)
Researchers departing by year	26 (21.0)	82 (66.1)	16 (12.9)	

Table 7. Researchers Departing for Foreign Employment (1999-2001)[351]

Unsustainability was also a major factor that obstructed national level S&T policies from fluently being implemented. One factor that attributed to this cause was frequent replacements of senior S&T leadership within the State Council. Especially after the 1980s, until the end of the Lee Myong Bak Presidency in 2013, only 8 out of 24 Ministers fulfilled their 24-month tenure as the Ministerial head to lead the MOST. Another notable factor is that over 15 Ministers served merely a year in office.

348 동아일보, 1980. 11. 13. 16 개 과학기술 연구기관 통합
349 현원복, 대통령과 과학기술, 과학사랑, 2005, p. 197.
350 산업기술백서: IMF 체제 극복을 위한 기술혁신전략, 한국산업기술진흥협의회, 1998.
351 자료: 산업기술진흥협회(2001), 기업연구소 고급인력 해외유출실태 및 정책적 시사점

Administration	Title	Minister	Tenure	Duration (months)
Park Chung Hee	Minister of Science and Technology (Agency level)	Kim, Gi Hyeong	1967.04 – 1971.06	51
		Choi, Hyeong Seob	1971.06 – 1978.12	91
		Choi, Jong Wan	1978.12 – 1979.12	13
		Seong, Jwa Gyeong	1979.12 – 1980.09	10
Chun Doo Hwan		Lee, Jeong O	1980.09 – 1985.02	54
		Kim, Seong Jin	1985.02 – 1986.01	12
		Jeon, Hak Jae	1986.01 – 1986.08	8
		Lee, Tae Seob	1986.05 – 1987.07	15
		Park, Geung Shik	1987.07 – 1988.02	8
Roh Tae Woo		Lee, Gwan	1988.02 – 1988.12	11
		Lee, Sang Hee	1988.12 – 1990.11	24
		Jeong, Geun Mo	1990.03 – 1990.11	9
		Kim, Jin Hyeon	1990.11 – 1993.02	28
Kim, Young Sam		Kim, Shi Joong	1993.02 – 1994.12	22
		Jeong, Geun Mo	1994.12 – 1996.08	21
		Ku, Bon Young	1996.08 – 1996.12	5
		Kim, Yong Jin	1996.12 – 1997.03	4
		Kwon, Sook Il	1997.03 – 1998.03	13
Kim, Dae Jung	Minister of Science and Technology (Ministry level)	Kang, Chang Hee	1998.03 – 1999.03	13
		Seo, Jeong Wook	1999.03 – 2001.03	25
		Kim, Young Hwan	2001.03 – 2002.01	11
		Chae, Young Bok	2002.01 – 2003.02	14
Roh, Mu Hyeon		Park, Ho Goon	2003.02 – 2003.12	11
	Vice Premier in Science and Technology	Oh, Myeong	2003.12 – 2006.02	27
		Kim, Woo Shik	2006.02 – 2008.02	25
Lee, Myong Bak	Minister of Education, and Science and Technology	Kim, Do Yeon	2008.02 – 2008.08	7
		Ahn, Byeong Mahn	2008.08 – 2010.08	25
		Lee, Joo Ho	2010.08 – 2013.03	32

Table 8. Chronology of MOST Leadership Changes

Also, the dualised enforcement of policy and execution functions between the Ministry of Science and Technology and the Presidential Advisory Council for Science and Technology caused conflicts in overall decision making and redundancy through overlapping authorities.

The poor treatment and abuses on scientists and engineers as a low esteemed social class resulted in weak technical links to technology exploitation and commercialization. Such aspects are detrimental to encouraging entrepreneurship in a science based highly technological field. In a recent survey conducted by Seoul National University, American top-notch engineering schools highly values venture business activities and collaborative research of its faculty members instead of simply publishing research papers in academic journals. Such valuation standards awards technology exploitation and accelerates technology commercialization, which adds real value into the economy. On the contrary, Korean universities, while sharing sluggish links in collaborative research with industry while honoring research publication work rather than technology commercialization efforts in the form of start-up companies, comparatively show lesser performance levels and insufficient contribution to innovation and further economic activities. A stunning survey shows the net worth of start-up companies established by graduates from Stanford University and MIT alone is valued $4.7 trillion, which more than triples the value of the same category within Korea’s GDP ($1.3 trillion). Faculty members concurrently serving in start-up businesses are structurally banned in a number of top engineering schools in Korea. The collaborative research and start-up business activities for S&T faculty members at Seoul National University is restrained within 20% compared to teaching and school work. KAIST halves the annual salary of faculty members to those participating in external business activities other than school work.[352] Thus, instead of exploiting or commercializing faculty research results, Korean university professors focus more on publishing papers to retain tenures, which has very marginal impact to innovation and economic performances.

4.4. Innovation Systems in the National Defense Sector through Defense Technology Development

The defense innovation system is rooted with the Defense Acquisition Management System (DAMS), which accommodates the weapon system procurement process of the Armed Forces. The weapon system procurement process consists of domestic development and foreign purchase. The defense innovation system primarily relates with the domestic development programs with additional layers contributed from foreign purchases. The DAMS is subject to the country's national security policy with an ultimate objective to keep the country safe from external security threats and foreign aggression. Thus, the DAMS is an outcome of vibrant interaction with the national security policy, military strategy, military tactics, and the incorporation of the country's industrial capacity. The following section briefly introduces the history of military capability building and the evolution of the defense acquisition system.

4.4.1. Early History: Dawn of Capacity Building in the Defense Sector

Science and Technology policy during a stretch of twenty years from the early 1950s to the late 60s was almost nonexistent. Such inability is a common theme observed throughout a number of decolonized countries after the Second World War, since the colonial occupation did not nurture a high skill workforce proficient in the language of science and technology. Such aspects were also applicable to Korea after the end of its colonial periods. As such, the Japanese Occupation discouraged the growth of S&T capacities in Korea. No public entity existed for a prolonged period over 36 years that was capable of administering government policies on education and research work related with science and technology.[353]

Throughout the Japanese Occupation, S&T subjects in high schools and colleges were absent, and only a small number of vocational schools that trained artisans and technicians were the only technical education available during that period. Secondly, the aftermath of the Korean War left the country into despair with no resources available to commit into S&T research. During this period, the

[352] College graduates from MIT or Stanford prioritize business start-ups, whereas graduates of Seoul National University or KAIST prefers employment in big businesses or pursue graduate studies. 박건형, "美 공대생 1~10 등이 창업하는데...한국은 취직 못하면 창업," 조선일보 2016. 10.6.
[353] 동아일보사, 원자력시대와 한국의 진로 좌담회, 1958. 8. 3.

organizations worth labeling as S&T research institutes were actually testing laboratories that performed surveys and quality assurance work for primary industries such as the Central Agricultural Testing Center, Central Meteorological Service, National Mineral and Geological Survey, Central Industrial Laboratory, and the Science and Technology Laboratory under the Ministry of National Defense.[354] The entire nation living under international economic aid, while experiencing vicious inflation rates caused by over currency reform and manipulations, left the Korean public authorities with no wherewithal to expand the scientific boundaries of the country. Whatsoever, perhaps the sectors worthwhile considering for S&T development during this period were those related with national security affairs.

Development efforts committed to defense technology before the 1970's were conducted in small armories existing sporadically without a centralized control agency, in such forms as technical branches of the arsenals under each military services, mainly focusing on replicating components and spare parts for repair and maintenance work on legacy defense platforms and systems leftover either from the Japanese Imperial Army or the U.S. Occupation Forces.[355] On June 15, 1950, the Science and Technology Laboratory were established under the Central Directorate of Ordnance at the Ministry of National Defense, the first research institute organized under government funding at the time. The S&T Lab expanded its branches during the Korean War and was later legislated by Presidential Decree on July 1954 as the Defense Science Laboratory under the Ministry of National Defense. The motivation for this organization was, however, driven by concerns of scientists residing in the southern part of the Peninsula being mobilized by North Korea as an effort to establish research functions in the North. In this respect, the underlying intentions of the Laboratory was not to nurture fundamental capacities in research and development, but merely a scheme to retain indigenous technicians from joining communist incitements.[356] Because of such motivations, in 1958, even after four years of its commencement, the Defense Science Laboratory was confronting challenges in becoming a more organized and systematic research institute due to shortages in funding and capable scientists.[357] The defense logistics of the Korean Military was still entirely reliant on the services rendered from U.S. Military Grant-Aid programs, thus the localization of spare parts and components were far-off from reality. A few years later, because of its unproductivity and ineffectiveness, the newly inaugurated military government that came into power through a military coup, disbanded the Defense Science Lab as part of its extended efforts to cut underperforming public organizations, and transferred the research functions under the Army Ordnance Bureau.[358] In a more political context, the closing of the Defense

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354 윤진효, 홍성만, "한국의 대통령별 기술발전 리더십 분석 – 정치체제 변화 맥락을 중심으로," 한국과학기술학회 학술대회, 2002, p. 82.
355 Sung Deuk Hahm, Da Sung Yang, "A Study of the Presidential Leadership for Science and Technology in Korea: Comparative Study Before and After the Political Democratization in 1987," Korean Political Science Revice 46(1), 2012, p. 149.
356 http://www.hellodd.com/news/article.html?no=31481
357 동아일보, 한국의 과학실태는 어떠한가(4) 국방부 과학연구소, 1958. 6. 14.
358 동아일보, 연참본부 국방부과학연구소 해체 등 국방기구가노화 정군단행으로 독소제거, 1961. 6. 29.

Science Lab moreover contained political implications to better serve for the principal forces of the military coup, which was in dour need to appeal as a legitimate government to the United States in order to sustain the military grant-programs in progress. Initially, the US Government had doubts on the legitimacy of the military coup in terms of its justification in addition to the suspicious socialist background of the coup leader, Major General Park Jung Hee, thus once considered to withdraw the grant-aid programs and transition into a simple loan program.[359]

United States Military Assistance through Grant Aid Programs

As part of stabilizing post-World War international order and containing the expansion of Communism worldwide, American foreign aid programs, which consisted of both economic development and military force build-up programs, initially started with the reconstruction of Europe under the title of the Economic Cooperation Act, also known as the Marshall Plan, in 1948. The plan later extended its scope in 1949 to non-European countries in the Middle East and Far East, including Korea and Japan.[360]

In furtherance of international aid efforts, the military assistance sector branched out and evolved into the Mutual Defense Assistance Program, which assisted the rearmament of Europe, and was further extended to 40 other countries in the Far East, Middle East, South Asia, Africa, and Africa.[361] However, despite the unconditional assistance furnished to peripheral countries, the effectiveness of these aid packages came into question in the outbreak of the Korean War. Hence, it became imperative that American foreign aid in military assistance be revalidated to include a direct force build-up program, including the transfer of technical knowhow and organizational capabilities, which shifted the focus from physical reconstruction to in-country technical capacity development. Following the Mutual Defense Assistance Program was the Mutual Security Act (MSA) of 1951, which emphasized additional weight on increasing military aid in equipment, services, and technology to American allies. Initially, nearly $7.5 billion was appropriated to the MSA in 1951 to support the military assistance efforts abroad, but was reduced to almost $5 billion due to concerns with the financial soundness of the US economy in the later years of the decade. The MSA was overhauled to the Foreign Assistance Act in 1961 and continues until now.[362]

The technological knowledge and expertise in equipment maintenance during the Korean War period until the late 1960s was mostly provided by the United States Government through the provisional military elements performing security assistance missions primarily concentrated in

[359] 김기석, 우리나라 조병기술 발전사 (2), 국방과 기술, 1990 년 3 월, p. 24. 홍성범, 민군겸용 패러다임과 기술개발전략, 정책보고 94-01, 과학기술정책관리연구소, p. 59.
[360] Walter S. Surry, The Economic Cooperation Act of 1948, California Law Review, Vol. 34, No. 4, December 1948, p. 510.
[361] United States: Mutual Defense Assistance Act of 1949, The American Journal of International Law, Vol. 44, No. 1, p. 30.
[362] Aurelius Morgner, “The American Foreign Aid Program: Costs, Accomplishments, Alternatives?,” Review of Politics, Vol. 29, No.1, 1967, p. 66.

building-up the force structure of the Korean military as part of its nation building efforts in the Peninsula. The amount of U.S. military assistance provided to the Korean military after the Korean War until the 1960's grossed approximately $8.7 billion in 1997 dollars value.[363] The assistance responsibilities were implemented by the United States Military Advisory Group to the Republic of Korea (KMAG), which executed its statutory ordeals in regards to the development of Army, Coast Guard, and National Civil Police Force in various domains of the society, including organization, education and training, provision of weapons and support systems – including the assistance of technical manuals for basic maintenance work.[364] Interestingly, almost no military assistance was provided to the Korean Air Force sector before the Korean War because the U.S. Government expressed reluctance to provide such attack capabilities due to concerns over the Seungman Rhee Administration taking offensive actions against North Korea with the risk of destabilizing the security situation of the Korean Peninsula.[365] The majority of the assistance work in the pre-war period was concentrated to the ground components where about 40% of the KMAG manpower was committed to a number of 6 division level units under the Korean Army. Thus, the criticism over the role and scope of KMAG functions came into question regarding its effectiveness and appropriateness during this period, especially putting into account the instances when KMAG advisors turned down numerous requests from the Korean Government that demanded to provide more conventional weapon systems such as tanks, howitzers, and aircrafts for building up the military strength of the country. Most of the force build-up efforts were limited to creating a provisional constabulary enforcement with a capability no lesser than a normal police force.[366]

However, the condition drastically changed after the outbreak of the Korean War in 1950. The U.S. Far Eastern Command launched a full scale war machine, including military assistance packages to support the entire force build-up program of the Korean military. In terms of security assistance work specific to the air force sector, the 6146th Air Force Advisory Group under the 314th Air Division, which later reformed to become the U.S. Air Force Military Assistance and Advisory Group, performed overarching responsibilities in the training of local Korean pilots and ground crews as well as in educating maintenance personnel assigned to various air bases, in addition to flying combat missions, during and after the Korean War.[367] The group trained Korean Air Force technicians and engineers at Sacheon Air Base in 1951 regarding the operation and maintenance of L-4, L-5, and L-16, L-19, and F-51 aircrafts. The unit relocated to Daegu in 1953 and continued the technical assistance training in a more advance level where the Korean Air Force also situated its primary logistics and maintenance depots such as the Aeronautical Maintenance Depot in the same area, while continued to train the

363 The Role of Foreign Aid in Development: South Korea and the Philippines, CBO Memorandum, September 1997, p. 23
364 Agreement for the Establishment of the United States Military Advisory Group to the Republic of Korea between the Government of the Republic of Korea and the Government of the United States of America
365 안정애, 주한미군사고문단에 관한 연구, p. 197.
366 Ibid., p. 200.
367 Judy G. Ednicott ed., The USAF in Korea: Campaigns, Units, and Stations, 1950-1953, Air Force History and Museum Program, 2001, p. 109

remaining Korean Air Force elements at Sacheon in basic level materials and tactics.[368] The group was disbanded on April 1971, and the command functions were merged into the Joint U.S. Military Assistance Group-Korea later that year.[369] The Assistance Group later evolved into the Joint U.S. Military Affairs Group-Korea (JUSMAG-K) in 1999, which represented the shift of the organization's mission statement from a grant-aid program to genuinely a project based organization.

Vietnam War and the Brown Memorandum: Pathways to Build-up an Indigenous Defense Industry

A full-scale force build-up program was offered by the U.S. Government in the start of the 1970s as the result of the Korean Government's decision to assist the U.S. military campaign in Vietnam the previous decade. In an agreed diplomatic document, commonly recalled as the 'Brown Memorandum of 1966', the U.S. agreed to provide military and economic assistance to equip and finance all necessary needs of the Korean military modernization for the next several years.[370] The delivery of these military and technical capabilities was slow in pace as an outcome of multiple negotiation sessions between Seoul and Washington D.C. Early in 1968, agreed by both countries against the imminent North Korea threat caused by frequent aggressions in the bordering areas, the USG offered a development package that would significantly modernize and strengthen Korean military capabilities.[371] From thereon, the following year's Defense Ministerial talks (SCM: Security Consultative Meeting) agreed to initiate a 3-year defense industry organization plan in 1969. Based on the agreed terms for military modernization, the U.S. provided technology assistance in building local arms production lines for ordnances and M16 rifles. The Nixon Doctrine of 1969, which asserted U.S. military disengagement in East Asia, signaled the major initiation of a full-scale military modernization subsequent to the Brown Memorandum. Following the departure of the U.S. 7th Division from the Korean Peninsula in March 1971, the USG provided $1 billion worth of military assistance in terms of technology assistance and equipment support for the next five years to fill in the capability gap caused by the retrenched U.S. military presence in the Korean Peninsula.[372]

4.5. Defense Acquisition Management System and Defense R&D Structure

4.5.1. Overview

The modernized concept of today's defense R&D and defense acquisition management system was first reorganized into the defense acquisition structure in the 1990s. Until that period, most of Korea's weapon system development programs were based on U.S. Technical Data Packages (TDP) provided through legacy military aid programs. However, the changing winds of the Cold War initiated

[368] Ibid., p. 110.
[369] http://web.archive.org/web/20120929013829/http://www.afhra.af.mil/factsheets/factsheet.asp?id=10130
[370] Brown Memorandum, Seoul Korea, March 4, 1966.
[371] Joint Communique, First Annual US-ROK Security Consultative Meeting, 28 May 1968, Washington
[372] Don Oberdorfer, The Two Koreas: A Contemporary History, Addison-Wesley, 1997, pp. 61-65.

a new paradigm shift in U.S. East Asia policy, promulgated in the East Asia Strategic Initiative (EASI). The new paradigm raised the potentials of a three phased U.S. military retrenchment from the Korean Peninsula, followed by the transition of wartime operational control from U.S. Force Korea to the sovereignty of the Korean Armed Forces. In addition to the EASI, the remarkable technical impact of modern weapon systems demonstrated in the Persian Gulf War of 1990, all against an imminent North Korean conventional and asymmetric threat, compelled the Korean political leadership to make serious strides in military modernization.[373]

1970s – 1980s	1990s	2000s
Building Foundations	*Developing System Design Capacities*	*Advanced System Design and Core Technology*
Conventional weapon systems Imitation/reverse engineering Analog systems Systems engineering approach	Precision weapon systems Cooperative/indigenous development Mixed Analog/Digital Systems engineering/M&S Methods	State-of-the-art advanced weapon systems Indigenous/cooperative development Digital systems M&S based design
20mm Vulcan Multiple-Launch Rocket System Armor Piercing Ammunition Anti-Submarine Light Torpedoes Surface-Surface Guidance Missile Submarine Vehicle	Improved Self-Propelled Howitzer Heavy Torpedoes Towed Sonar Torpedo Acoustic Counter Measure Short-range Surface-Air Guidance Missile KT-1 Basic Trainer Aircraft Mounted Electronic Countermeasure C3I Command Post Automation System	Improved Main Battle Tank Improved Light Torpedoes Anti-Ship Guidance Weapons Man Portable Anti-Aircraft Weapons Surveillance UAV KO-1 Tactical Control Aircraft Ship Based Electronic Countermeasures Military Communications Satellite (ANASIS-Koreasat-5) Improved Infantry Fighting Vehicle LPX Combat Systems Maritime Helicopter ESM System
284 Programs	48 Programs	20 Programs
Total 314 Programs		

Table 9. Evolution of Defense R&D Capacities
Source: 강인원, 이재석, "국방R&D투자 및 성과분석을 통한 생산성 향상 방안," KISTEP Issue Paper 2010-08.

Thus, the Ministry of National Defense substantially overhauled the existing defense procurement system and instituted a new regulation for weapon system development called the Weapon System Acquisition Management Regulation in August 1991. Here, the motto was "Made-in Korea", which gave first priority on domestic development. Considering the development of sophisticated weapon systems, international partnership through co-development or license production became a norm, which allowed significant transfer of advanced military technology to the defense industrial base. The new regulation attempted to synchronize the force requirement generation phase and the weapon system development phase in order effectively manage weapon system development programs in response to warfighter's needs. According to the new regulation, introduction of foreign weapon

[373] The worsening security conditions in the Korean Peninsula exacerbated by the growing North Korean nuclear threat has eventually cancelled the initiatives of the EASI. 한용섭, 한미연합지휘체제의 평가 및 개선방향, 국방대학교 안보문제연구소, 2003, p. 15.,

systems was given less priority, where emergency procurement programs was the only window for direct purchasing.[374] However, this was more easily said than done. The immediate war fighter needs made the defense authorities impatient over long gestation periods required for indigenous development programs. Thus, military spending on defense acquisition, especially over sophisticated complex product systems, heavily relied on foreign procurement. The following section reviews the overall structure and coordinating mechanisms of the defense acquisition management system under this framework.

4.5.2. Governance Structure

Looking back at the trends the country has accomplished from the past 40 years or so, the Korean defense innovation system is gradually transitioning from a conventional platform based imitation structure to a more high-tech CoPS focused creative development structure. Governing such transition is always challenging and troublesome. The Korean defense acquisition decision making apparatus consists of the planning, programming, budgeting and execution system called the PPBES cycle (Ministry of National Defense), requirement planning and management function represented by the force requirement generation and planning (Joint Chiefs of Staff), and the defense acquisition management system (Defense Acquisition Program Administration). Each of these generating routines are deeply intertwined and linked with causal relationships, and constitutes the overarching defense innovation ecosystem. In order to understand the Korean defense innovation system, it is important to comprehend the defense acquisition management system (DAMS) and its linkages with the other two decision making support systems. The technology aspects of these three systems are managed by the Agency of Defense Development (ADD) under the broader auspices of the overall DAMS, which is represented in the diagram below.

[374] 편집부, "국방부, 무기체계 획득관리 규정 개정," 국방과 기술 제 151 호, 1991, p. 80.

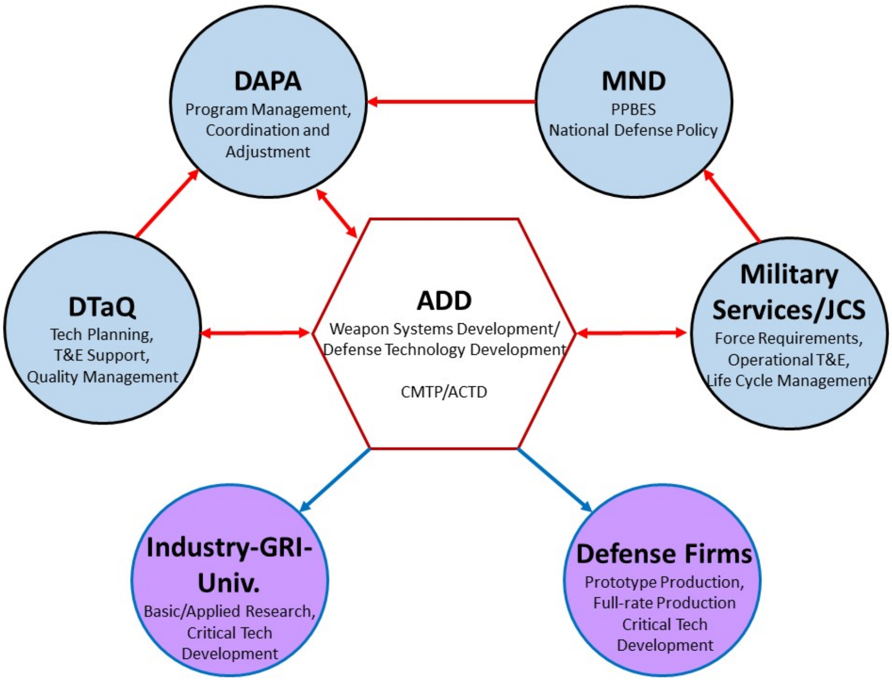

Figure 9. Key Players in the Defense Acquisition Management System, adopted and reproduced from ADD R&D introduction material (2014)

The Defense Acquisition Management System (DAMS)

The primary components of the DAMS are the force requirement generation institutes (Joint Chiefs of Staff/Military Services), policy and planning authority (Ministry of National Defense), programming agency (Defense Acquisition Program Administration), and sustainment elements (Military Services). Decision making is made by a vertically integrated process depicted in the flow chart below (Figure. 10), which briefly illustrates this working relationship. The guiding principles of major defense acquisition programs is the 'Korea First' policy by giving first priority on domestic weapon system R&D and production for the self-reliant defense of the nation. Throughout the underpinnings of 'Korea First' priorities, defense acquisition programs should set objectives to promptly introduce the most optimal weapon system solution to maximize combat readiness. In terms of institutional utilities and effectiveness, the program should incorporate an integrated logistics support system throughout the life cycle of the weapon system, obtain transparency and enhance professionalism, establish complementary relationships between the national S&T infrastructure and defense R&D practices, and construct cooperative R&D arrangements with international partners.[375]

Hinging on the guiding principles above, the acquisition strategy is deliberated through a multilayered coordination process that starts with the *Preliminary Studies* phase. The Integrated Project Team (IPT) at DAPA launches the studies by conducting multiple feasibility research on the program to assess the expediency and appropriateness of the system being introduced in terms of cost benefit analysis, technological readiness levels, economic validity and industrial contribution, and so forth. The Preliminary Studies are often conducted by the IPT itself, but for major defense acquisition programs

375 방위사업법 제11조(방위력개선사업 수행의 기본원칙)

exceeding a certain cost threshold, the studies are outsourced to public or private think tanks such as the Korea Institute of Defense Analysis, Korea Development Institute, to obtain a more objective opinion. The baseline documents of the Preliminary Studies are the major policy documents considering force requirement generation and verification drafted by the Joint Chiefs of Staff and the military services that provide guidelines on the weapon system operational environment, system interoperability, operational process, etc.[376] Based on the recommendations of the Preliminary Studies, the acquisition strategy of the weapon system program is determined through an inter-agency coordination process called the Defense Acquisition Program Executive Committee (DAPEC). The DAPEC gathers the senior government executives from the defense apparatus (MND, DAPA, JCS, military services, ADD) and relevant government agencies (MOST, MOTIE, MOE). The DAPEC is chaired by the Minister of National Defense where DAPA serves as the secretariat for the forum. The underlying intention for the interagency process is to incorporate the country's principle S&T agents together in pursuance of a better employment of national S&T resources.[377]

376 방위사업법 제

377 방위사업법 제 9 조 방위사업추진위원회

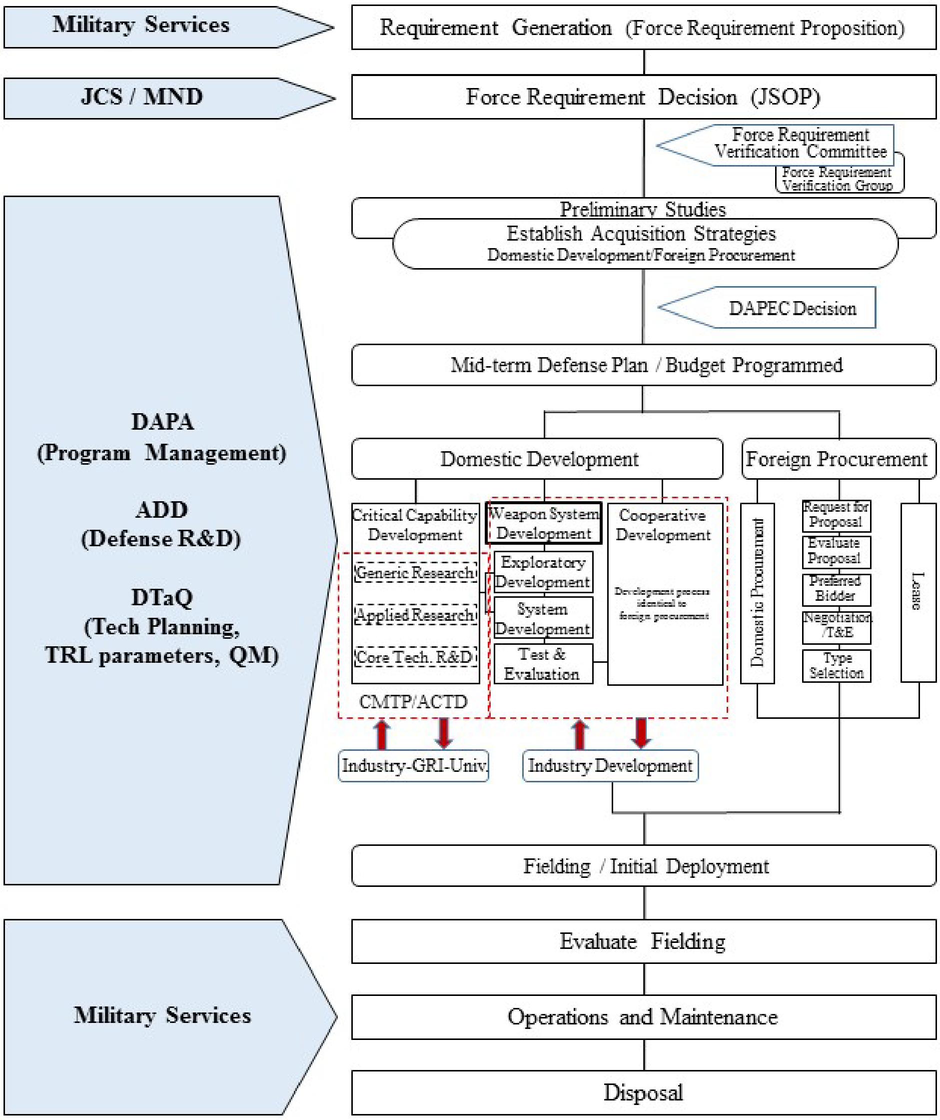

Figure 10. Defense Acquisition Management System Flow Chart, adopted and reproduced from 국방전력업무훈령, 방위사업개론

Based on the national resources and force needs, the DAPEC decides the acquisition strategy of the program, whether domestic development or foreign procurement. The defense innovation system primarily considers the domestic development portion of the defense acquisition programs. In accordance with the technological feasibility condition, domestic development pursues either a self-directed weapon systems development process or a cooperative development process. Depending on the form of R&D investment, the program is processed either through government-led development managed by ADD, or corporate-led development managed by defense firms.[378] However, considering the complexity of weapon system development alluded in previous chapters, no country can go alone with complex weapon system development. Even though complex weapon systems are designed domestically, the development process follows a hybrid domestic development and foreign procurement that incorporates various system modules and components, and are integrated by the prime contractor,

[378] 방위사업청, 방위사업개론, p. 164.

or system integrator, at the end of the production line. Currently, with the growing technical capacities of the private sector, the form of R&D investment is rapidly transitioning from government led to corporate led programs, where defense firms are assuming more responsibilities and ownership over major weapon system development programs.

Upper-tiered Policy Level Defense R&D Strategy

In order to understand the key parameters of the defense innovation system, it is critical to review the imperative linkages of the two main R&D programs, weapon systems development and defense technology development, within the DAMS. Weapon system development programs are intended to respond to military force requirement needs where the workshare is distributed to GRIs (Agency of Defense Development, other specialized research labs) and defense firms. Currently, the industry workshare in terms of R&D over Major Defense Acquisition Programs (MDAP) is growing with the industry assuming larger development responsibilities, which used to be assigned primarily to GRIs (most notably ADD). There are three major milestones that constitute the weapon system development programs.

In order to become a program of record (MDAP), the force requirements are prioritized into a planning document called the Joint Strategic Objective Plan (JSOP), which is an integrated list of capabilities consolidated by the Joint Chiefs of Staff from the military services, with a purpose to support the country's mid-to-long term military objectives. The technology support plan for the JSOP is drafted in the Defense Science and Technology Promotion Document (DSTPD). The baseline documents to draft the DSTPD are the Defense S&T Survey Report and the Critical Technology Planning Report. These two documents review the technological feasibility before launching a MDAP. The second step is the programming phase where the resources for the MDAP is deliberated in a budgeting schedule called the Midterm Defense Plan (MTDP). The programs reflected in the MTDP normally cover a five-year term and is annually updated before the program of record becomes fully deployed in the field. The third step is the actual execution of these documents at the program level. In this phase, DAPA orchestrates the overall development process where the Agency of Defense Development actively interacts with industry (manufacturer) and GRI/Universities. The technology risk factors for each development milestone are rigorously monitored by Technology Readiness Level (TRL) standards throughout the program.[379]

[379] DAPA, Introduction of Defense Technology R&D Programs, 2015, p. 14.

Figure 11. Major Defense R&D Planning Documents

Defense technology development programs are projects not necessarily associated with weapon system development, but programmed with the intention to enhance the broader Technology Readiness Level (TRL) in basic research and core technologies. The research programs consist of basic research and core technology research, and are administered by the Agency of Defense Development, structured with a bottom-up development approach in collaboration with universities and other GRI projects in order to establish a broad infrastructure masterplan on high-tech driven technologies. The distinctive characteristics of weapon systems development programs are highlighted with the development of certain technological capabilities, whereas technology development programs nurture the overall infrastructure capacities and Technology Readiness Levels (TRL) through long-term commitments into basic research and critical technology development. Especially, the scope and attributes of defense technology development, and its structural linkage with weapon system development constitutes the key in the process of building a broader picture for innovative qualities.[380] Such linkage between weapon systems development programs and defense technology development programs creates a lopsided and short-term strategy in improving TRL competitiveness by diverting public resources for long-term development efforts into short-to-midterm weapon system acquisition. One of the main strategic objectives for defense technology development is to become more technologically self-reliant by enhancing the TRL standards that leads to upgrading industrial competitiveness in critical technologies. Exerting the system's main effort into weapon system development makes each development program more dependent on foreign technology and the import of major component parts, which has technologically subordinated the country's defense innovation system and defense industry under foreign influence.

However, when examining the technology requirement process for high-tech complex product

[380] Ibid., p. 20.

systems, the majority of the R&D projects are eventually tied in with weapon system development programs. Defense R&D efforts are primarily concentrated on weapon system development programs, which takes about 63.4% of the entire defense R&D budget. The remaining resources are allocated to defense technology development programs. Throughout this process, DAPA serves as the governing institution for the development of high-tech source technology. All components of the defense acquisition management system submit each of its respective technology requirements to DAPA for further coordination and prioritization towards specific weapons development programs.[381] Such connection is reconfirmed in applied research and test development projects under defense technology development programs. In conjunction with the structural arrangements, the performance analysis of applied research and test development projects conducted in recent years show 34 out of 37 applied research projects and 15 out of 18 test development projects have transitioned to weapon system development programs. This implies that defense technology development programs are not separate from weapon systems development programs, but are essentially a supplement that mostly augments system development efforts.[382]

Lower-tiered Implementation Level Defense R&D Strategy: Civil-Military Technology Partnership (CMTP)

Civil-Military Technology Partnership (CMTP) is understood in a broader term the use of dual-use technology as an outcome of technology spinoff from the public to private sector, or spillover from the private to public sector. As described earlier in this chapter, private sector workloads and responsibilities continue to grow and overwhelm the traditional dominance of the public sector. The private sector becomes involved in the defense innovation system through participating in weapon systems development or defense technology development programs.

With the growing technological and program specific complexities in weapon systems development, introducing collaborative efforts between commercial and military technology was imperative. The guiding principles of CMTP are mandated in the Civil-Military Technology Partnership Promotion Act, revised from the previous Dual-Use Technology Promotion Act of 1997. The need to promote dual-use technology was advocated by the Presidential Council for Science & Technology at 1997 as a five-year temporary legislation to build the necessary infrastructure of dual-use technologies and invigorate national competitiveness. However, the Act narrowly defined the scope of dual-use technology, which raised the need to comprehensively expand the concept to other business sectors. In this aspect, a subsequent legislation was introduced that broadened the term to almost every business field as part of addressing technological demands raised from both commercial and military needs.[383]

381 Article 173 of the Defense Acquisition Program Management Regulation states the connection between the Critical Technology Planning Report and the Midterm Defense Plan, which indicates the eventual linkage of defense technology development programs with weapon systems development programs.
382 이재억 홍성범, 한국 국방혁신체제 특성분석, 과학기술정책연구원 정책연구 2012-23, p. 84.
383 국가법령정보센터, "민군기술협력촉진법"

Private sector participates either as technology co-developers or manufacturers in a weapon system development program, or as a co-researcher in defense technology development programs. In this case, the mode of participation determines the scope and responsibility of CMTP programs. Weapon systems development programs are composed of Critical Capability Systems and General Capability Systems. Critical Capability Systems are primarily under the technical leadership of the Agency of Defense Development considering the agency's long accumulated experience in weapon systems development programs and critical mass in research capacities. The development programs designated under this category mostly considers high priority military force capabilities determined in the JSOP and MTDP such as Intelligence-Surveillance-Reconnaissance (ISR) platforms, precision strike systems, electronic warfare, and Nuclear-Biological-Chemical (NBC) defense. Technical leadership for General Capability Systems are mostly deferred to the private sector (defense industry) on technology areas with proven developmental track records such as naval vessels, air defense artillery, ground maneuver systems, command and control (C2), and so forth. Also, considering defense technology development, although most of the critical program elements fall under the auspices of ADD, generic programs are conducted under a triple helix consortium of Industry-GRI-Universities.[384] The development of aerospace technologies is a representative program that resulted from these CMTP initiatives.[385]

Program Type		Program Lead	Programs
Weapon System Development Program	Critical Capability Systems	ADD	Strategic programs (ISR, precision strike), NBC defense, electronic warfare
	General Capability Systems	Industry	Naval combat systems, air defense, anti-tank guidance weapons, ground maneuver, etc.
Defense Technology Development Program	Critical Capability	ADD	Core technology for critical capability systems
	Generic Technology	Industry-GRI-University	Commercial off the shelf technologies
	Core Technology	ADD	Basic research

Table 10. Weapon System and Technology Development Program Leads

CMTP performances since 2006 have facilitated the establishment of technology standards between commercial and military technology. Such effort saved significant cost and created a more efficient condition for civil-military technological collaboration. The Korean government is believed to have saved approximately $23 million in procurement costs and $200K in managing technology standards through the Civil-Military Technology Standardization Program. The standardization efforts managed to standardize 8,419 types of military technology out of the total 15,914 types.[386]

A notable construct of CMTP introduced in 2008 to the Korean defense innovation system is the Advanced Concept Technology Demonstration (ACTD) program. The ACTD is suggested through a bottom-up process by a consortium of Industry-GRI-universities that applies a readily available commercial-off-the-shelf technology into a weapon system development program with a scheduled

384 한국국방연구원, 2020 선진방위사업 구현을 위한 중장기 방위사업정책 발전방안 연구, 2007

385 Aircraft development programs such as the Korea Helicopter Program (KHP) and the Korea Trainer Experience (KTX-2, later T-50), and the Korea Multi-Purpose Satellite Program (KOMPSAT) are the programs referring to CMTP.

386 조슬기나, "민군기술협력사업에 국고 1389 억원 투입," 아시아경제 2016.02.28.

objective of completing a prototype and new operative concepts within three years of program launching. The total investment into this program until 2015 was approximately KRW 53.4 billion ($50 million) for 56 research projects. The significance of the ACTD is that it presents an opportunity to rapidly transform a proven commercial technology into a defense acquisition program by circumventing the lengthy and convoluted R&D process of regular defense research programs. The concept also serves as a strong conduit to attract the private sector into the defense business with more ownership and responsibility.[387]

Project	Duration	Program Objective	Budget	Contract
Mobile Tactical Computer	2008~2009	An equipment that disseminates tactical information to construct a common operational picture to tanks, armored vehicles, self-propelled howitzers through FM radios and critical data-links	$50K	Samsung Thales
Unmanned Mine Detection Vehicle	2008~2010	An unmanned vehicle that approaches and eliminates the target mine with a visual connection with a communication buoy and returns to base	$200K	Ocean Research and Development Institute
Mobile Aviation Information Display System	2008~2009	Displays enemy EW/GCI, SAM base, flight path, stationing point, track information through commercial PDA technology	$80K	Huneed Technologies

Table 11. 2008 ACTD Selected Programs, adopted from 2010-2015 Defense S&T Implementation Plan

However, the lower-tiered structure in defense R&D is constrained by its own weaknesses lamented within the coordinating mechanisms of the CMTP. The most challenging aspect is the absence of an effective policy control tower that administers the CMTP. The complexity of technology and bureaucratic processes places additional layers in maturing the program into high visible objectives. Therefore, the roles and responsibility of a government control tower that administers and coordinates these complexities is imperative. Unfortunately, DAPA, which is the designated government agency for the CMTP, has performed disappointingly over the years in this program. When the CMTP was first launched in 1999, there were a total of four government agencies – MND, MOST, MOTIE, MICT – that participated in the program.[388] Currently, the Ministry of Trade-Industry-and-Energy and DAPA are the only two participating government agencies remaining within this construct. Other related agencies that hold competitive advantage in distinctive technological fields such as in ICT, biotechnology, and so forth, are no longer parties of the CMTP. Even in the case of MOTIE, its involvement into this program is declining since 2006 with the upsurge of more MOTIE specific R&D programs materializing. The cause of such constraints is attributed to the closed and classified nature of defense technology managed by ADD. ADD has shown reluctance to share technology information with other agencies on sensitive subject areas such as guidance missiles, propulsion, electro-optical instruments, and so forth. The incompetence of the Dual-Use Technology Promotion Center is another direct illustration of this situation. With no single government agency claiming ownership for

387 박휘락 외, 신개념기술시범제도 분석 및 효율적 운영방안 연구, 21 세기 군사연구소, 2013, p. 122.
388 The MND's responsibility transferred over to DAPA in 2006 with the restructuring of the Defense Acquisition Management System.

interagency coordination and technology transfer, the Dual-Use Technology Promotion Center has been lacking to show competence in planning and execution over collaborative programs with universities and industry. Especially, the Center being a subordinate organization of ADD further restricts the Center from reaching out to other public or private entities in terms of broadening its collaborative spectrum.[389]

The absence of a government control tower in CMTP is believed to have grave impacts on the performing outcomes of the ACTD program in general. The ACTD started with a high anticipation to apply commercially proven technology into military applications, such that it presents less uncertainties and risks in maturing the subject technology into a weapon system program. But the end results as of 2016 showed only one single research project out of the 56 projects funded under the ACTD the past ten years has entered into production and deployment. Three more projects have proceeded into the technology maturation and risk reduction phase, but it appears very uncertain at this point that the actual application of those three projects will materialize into military force needs. The reason for such poor linkage between the ACTD and military force needs is the bottom-up application process of the technology area identified. Normally, the private sector, through public-private partnership programs such as the CMTP, suggests the relevant technology to DAPA for application into the ACTD, rather than having the warfighter, who are the real consumers of the force requirement, initiating the requirement from a top-down process. Therefore, in many cases, the selected ACTD projects are technology-driven instead of needs-driven, which implies significant disconnect with real world warfighter capability requirements. Therefore, despite the low risks associated with the subject technology through the ACTD, it becomes challenging to find links to apply the technology into weapon system programs.[390]

Public authorities endeavored to involve defense R&D within the national composition in order to reinvigorate the connection between defense and civil sector R&D efforts. In February 2007, the national S&T authorities determined to include the domain of defense R&D within the National Science and Technology Commission (NSTC) by organizing the Special Committee of Defense Research and Development as a subcommittee component. The objective of including the defense sector within the NSTC was to create a more integrated construct in the national R&D architecture. Defense R&D, despite the significant national resources committed to this sector, has been dealt separately apart from the national S&T planning and coordination apparatus, thus created systemic overlaps in planning and budgeting, and structural disconnects with other relevant R&D programs. According to the initiatives, the Subcommittee is administered by the Director General of R&D Coordination under MOST, which gathers senior executives from other NSTC member agencies such as MOSF, MOTIE, and DAPA, along with specialists from academia and private sector. Supporting legislations and implementing ordnances

389 TECHNOVALUE, 민군협력사업 법제화 방안연구: 민군협력 활성화를 위한 새로운 체제 및 사업제안,” 방위사업청 용역보고서, 2008 년 12 월, p. 63.
390 김종대의원실 2016 년도 국정감사 자료.

were enforced the year prior in 2006, which prepared the legal grounds to execute the new initiative.[391] However, the actual implementation of the new initiative did not take place until 2017 when the NSTC decided to preview defense R&D programs and budgets. Although the preview process is not associated with a compulsory provision, it presents the opportunity to assess the feasibility of the respective R&D program across the board and determine necessary measures for reallocating national resources.[392]

4.6. Defense Industrial Base (DIB)

The rationale supporting the establishment and sustainment of the Defense Industrial Base (DIB), ever since its first indoctrination through the Yulgok Project of 1974, was to adopt a self-reliant national security identity against the continued North Korean conventional military threat, and to prepare against an evident U.S. military retrenchment from the Korean Peninsula. The government's strong development drive to build a robust heavy chemical industry came in conjunction with the construction of a capable defense industrial base. Throughout the scope of industrialization, the DIB enjoyed privileges through various policy instruments such as financial, technology, and workforce promotion.

4.6.1. Structure of the Defense Industrial Base

The supply chain aspect of the defense industry forms a typical pyramid structure that maintains a cooperative arrangement between the three layers of production. The prime contractor serves as the final system integrator of all components and parts, and normally handles all the system design and engineering aspects of a weapon system. The subcontractors are normally the main component suppliers of a weapon system such as engines, combat control systems, armaments, and so forth. Material and part suppliers constitute the third layer of the supply chain. The prime contractor obtains large manufacturing facilities and professional technicians that perform system design and integration work. In many cases, the prime contractors, mostly big business Chaebols, are widely diversified into other non-military business sectors, in which they show strong competitive advantage in market dominance within the respective commercial field. The subcontractors supply critical components for the final end item, therefore obtain core technology and long lasting experience in the respective field. The top two layers of the supply chain are mostly specialized as defense firms. The third layer material and part suppliers are businesses engaged in both defense and commercial sectors, and does not necessarily hold a specialized status in the defense industry. As of 2016, there are a total of 100 companies designated as defense firms, 1,322 items labeled as defense items, and sales reaching approximately $1 trillion.[393]

391 과학기술부, "국가과학기술위원회 산하에 국방연구개발전문위원회 신설," 과학기술정책동향, 2007.2.2.
392 연합뉴스, "내년부터 국방 R&D 도 국가과학기술심의회서 사전심의," 2016.5.12.
393 Defense Industry Statistics, Korea Defense Industry Association, https://www.kdia.or.kr/content/3/2/47/view.do

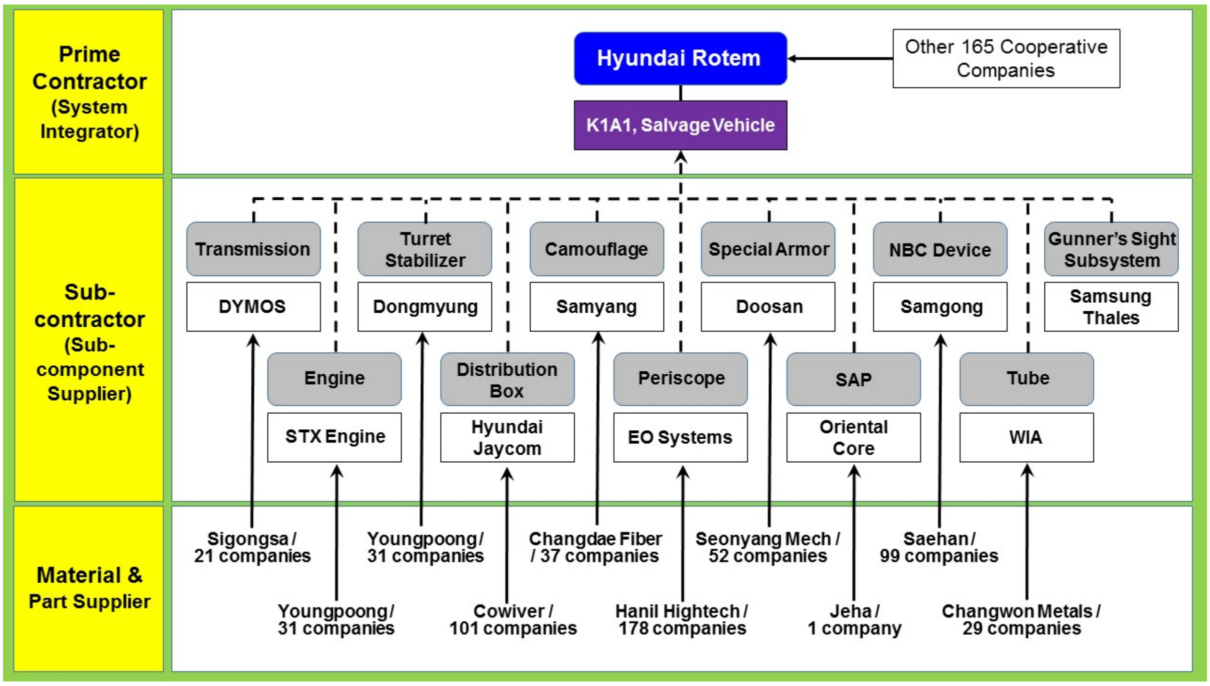

Figure 12. Supply Chain Breakdown of K1A1 Main Battle Tank (Proprietary Data of Hyundai Rotem)

The defense industry has been a beneficiary to various government protection and support programs, and was nurtured under these privileges for decades. The below table illustrates some notable defense industry promotional measures since the inception of the defense industry in the early 1970s.

Support Types	Support Institutions
Finance	Defense Duty Tax Imposed ('75) → abolished ('90) Defense Material Cost Accounting Standards ('78) Defense Industry Promotion Fund ('80) → abolished ('06), replaced by Defense Industry Promotion Credit Loans as of 2006 Value Added Profit Rate ('88)
Technology	Defense Offset Policy ('82) Specialization & Systematization ('83) → abolished ('09) Specialized R&D Center Designated ('94) Dual-Use Technology Promotion Act ('99) → Revised to CMTP Promotion ('13) Corporate led R&D Program Initiated (Program managed by Program Management Office of respective military service) Technology Innovation Support System for Small-Medium Businesses ('98)
Exports	Designation of Defense Materials and Firms ('73)
Other	Special Measures for the Law on the Defense Industry ('73) → Replaced by Defense Acquisition Program Act ('06)

Table 12. Government Support Institutions to Promote the Defense Industry; adopted from 유형곤, "방위산업 육성을 위한 효과적인 산업정책 시행방안," 방위산업진흥회, 2015.

4.6.2. Specialization and Systematization Act

Since June 1983, Article 4 of the Act on Special Measures for Defense Industry promulgated the protection and nurture of the defense industrial base through the Specialization and Systematization of defense firms. The Act, followed by an Implementation Directive, manifests the authority that the President, under close consultation with the Minister of Commerce-and-Industry and Minister of National Defense, shall designate certain defense articles and companies as specialized or systematized for defense manufacturing to create a reasonably promotional condition to advance the defense industry. The purpose of implementing the Specialization and Systemization measures was to secure a stable weapon system production infrastructure, promote defense technology development and a high skilled professional workforce, and to prevent duplicate investment and unnecessary competition. Before the policy was abolished in 2009, there were 29 specialized firms and 48 systematized firms supported under this act. The contractual arrangement established under this competition structure designates one or two system integration firms under a certain product category, or prime contractor, as specialized firms, and one or two component supplier firms, or subcontractors, as systemized firms. In this regard, big businesses such as Samsung, Hyundai, Daewoo, etc., diversified into the defense industry under huge government subsidies, and was subsequently awarded major weapon system production work. Based on this special arrangement, the competitive structure of the defense industry maintained a monopolistic and oligopolistic structure.[394] Although there were some exceptions made in terms of introducing commercial off-the-shelf technology or other civil-military technology partnership programs, the monopoly formation of the defense industry maintained adamant until the abolition of the Specialization and Systematization Act.

However, just like other long lasting programs in public policy, the Specialization and Systematization Act ran into its own limitations. The long gestation of the Specialization and Systematization regime caused evident defects in firm performance and market competitiveness. Defense firms under this regime found little incentives to award technology development and seek cost saving efforts. Especially, the protection system prevented technologically competitive firms from entering the market.[395] Prime contractors did not have the liberty to contract better improved subcomponents from non-systematized defense firms, and were forced to establish sub-contractual arrangements with designated subcontractors. Mergers and Acquisitions between defense firms were prohibited. Therefore, defense firms exiting the defense business was disapproved by higher industrial supervisory authorities.[396] Such restrictions were especially pernicious for building innovative wherewithal in complex product systems such as fighter aircrafts and unmanned systems. In order to overcome these systemic difficulties, the Specialization and Systematization regime went through four amendments until 2001, which introduced a limited competitive bidding rule on certain defense items where the commercial sector obtained higher competence, such as military vehicles, electronics, communications, optical systems, and so forth, in regards to the compatibility and interchangeability with relevant systems.[397] Eventually, with the objective to introduce an open and competitive structure

394 김종하, “한국 방위산업의 연구개발수행력에 따른 구조혁신의 방향,” 한국방위산업학회, 제 17 권 2 호, 2010, p. 154

395 신보현 외, “방산 경쟁 정책의 발전방향,” 건국대학교 무기체계연구소, 2013 년 방위산업진흥회 연구용역과제, p. 5.

396 정진태·김진호, “방위산업의 전문화·계열화 발전방안,” 국방과 기술, 2003 년 3 월, p. 31.

397 문종열, 방위산업 재정지출 성과와 과제: 방위산업 위기와 핵심군사력 해외의존도 심화, 예산현안분석 제 20 호, 국회예산정책처, 2008 년 9 월, p. 39.

in the defense industry, the government decided to abolish the Specialization and Systematization regime on 2005 based on the recommendations of the Defense Acquisition System Improvement Group. After a three-year grace period, the Act was finally abolished as of January 2009, and the defense industry has entered into an era of competition with substantially reduced privileges.

4.6.3. Financial Incentives to Defense Firms

The first financial assistance program to support the defense industry was the imposition of the Defense Tax on 1975. The implementation of the tax program was to secure national resources to finance the massive defense industrial build-up of the 1970s that was instigated by the changing dynamics of the country's military alliance relations with the U.S., raised by the concerns of the Nixon Doctrine in February 1970, along with the continued North Korean military provocations throughout the years. At first, the finances for defense industrial build-up was to be capitalized from public donations in 1974, but the collected amounts fell far less than the original expectations. Therefore, the government legislated a new tax item for national defense in July 1975 through the Defense Tax Statute, initially for a temporary enforcement until 1980, but was extended to the end of 1990 until its abolishment. The Defense Tax has substantially expanded the scope of financial resources for defense industrial development by increasing the defense budget over 30% compared to previous years.[398]

In parallel with the Defense Tax was the creation of the Defense Industry Promotion Fund in 1980. In order to facilitate the efforts in industry level R&D activities, stockpile raw materials, and maintain idle production equipment, an amount nearly KRW 30 billion (currently valued at KRW 75 billion) was endowed as the Defense Industry Promotion Fund under Article 7 of the Act on Special Measures for Defense Industry Promotion. Until its abolishment in 2006, the fund grew larger with a government endowment of KRW 110 billion and an interest earnings of KRW 30 billion. Although the original purpose was to provide finances to support various objectives, the majority of the Funds was committed to localizing core technology and critical component parts because of the resource shortages. For instance, from 2001 to 2006, the Fund endowed for expenses was programmed far shorter than the amount originally requested by the industry, accounting for an average of only 38.4%.[399] In a similar context, Defense Industry Promotion Credit Loans was a program that replaced the previous Defense Industry Promotion Fund on 2006. The program provides low interest rate loans (1%) to defense firms and subsidizes the differences of interest rates from the open market with government funds to the loaner bank. The program was to put small and medium sized defense firms as a priority to support efforts to localize the technology base of critical components and parts. Additionally, such preferential funding support would assist competitive prototyping and the development of software operating systems,

[398] The Defense Tax accounted for about 2% of the GDP and was invested entirely into force improvement programs and the defense industrial base. National Archives: http://www.archives.go.kr/next/search/listSubjectDescription.do?id=009395

[399] 권기정 외, 방산육성을 위한 정책금융 지원 방안 연구, 한국산업개발연구원 방위사업청 연구용역, 2008, p. 19.

alleviate management challenges in maintaining production facilities, and promote defense exports as well.[400]

But in reality, the majority of the loans were provided to big businesses (mostly prime contractors), in which small-medium sized businesses was granted a marginal amount. The track record of the credit loans since its inception to 2012 show a lopsided picture where the grants were given primarily to big businesses rather than small-medium firms. About $198 million out of $262 million was granted to big business, which accounts for 74% of the entire loans. Part of this result attributes to the poor R&D infrastructure of the small-medium defense firms opposed to the comparatively larger capital-intensive R&D infrastructure of big businesses. The original intention of the credit loan program was to promote the technological R&D foundations for small-medium defense firms, contrary to big businesses that already received significant government protection and support for decades. In this regard, the current pattern of granting loans more towards big businesses does not fully serve for the initial policy objectives.[401]

Type	2007	2008	2009	2010	2011	2012	Total
Big Firms	178 (67%)	259 (81%)	683 (88%)	81 (59%)	502 (72%)	464 (65%)	2,166 (74%)
S-M firms	89 (33%)	62 (19%)	94 (12%)	56 (41%)	196 (28%)	254 (35%)	751 (26%)
Subtotal	267	321	777	137	698	718	2,918

Table 13. DAPA Report to the National Assembly on Defense Industry Credit Loans (2013)

4.7. Adaptive to Change – Organizational Restructuring of the Defense Acquisition Management System

Weapon system development business was always troublesome due to its shady political connections and service rivalry challenges. However, the Defense Acquisition Management System itself, which should effectively govern the development and procurement of highly complex product systems, still maintained an inherently compartmental and disconnected structure. Among the multiple attempts to restructure the defense acquisition system, the profound changes were implemented by two working councils driven by the Presidential Office between 2003 and 2013. One was the Defense Acquisition System Improvement Group of 2005 and the other was the Presidential Council for Future and Vision in 2010.

4.7.1. Defense Acquisition System Improvement Group

Weapon systems development programs were always considered a major conduit of political corruption, thus has been intensively scrutinized when new Presidential authorities came into power. Especially the corruption incident from the Yulgok Scandal, which prosecuted a number of Defense

400 방위사업법 제 38 조 (자금융자); 방위사업청, 2016 방위산업 지원제도, p. 56.
401 진성준 의원실, 2013 년 국정감사 자료

Ministers and top brass general officers of the Korean military, has prompted subsequent administrations to initiate various reform measures to fix the deficiencies. The most notable milestone of defense acquisition system reform was the establishment of the Defense Acquisition Program Administration in 2006. The Roh Mu Hyun Administration that came into power in 2003, gave special attention to the exclusively cliquish hierarchical culture of the military and the immense influence such culture imposed on the decision making process of weapon system programs. Compounding to this situation was the absence of expertise in program management, in which the arbitrarily rotating personnel assignment system was believed to be the source of such inefficiency. Decision making and program management was predominantly monopolized by the military where civilian involvement remained minimal. Additionally, weapon systems procurement had very limited linkage and consideration to industrial competitiveness. Therefore, the contribution of the defense industry to the overall competitiveness of the national industrial architecture was rated insignificant. In order to overcome such systemic complications, the Roh Administration established the Defense Acquisition System Improvement Group under the Prime Minister's Office in 2004 after a series of debates between the cabinet ministries and the National Security Council, with intentions to substantially overhaul the defense acquisition system under the guiding principles of building procedural transparency and workforce professionalism. From March 2004 to January 2005, after nine committee sessions within the cabinet and three consultation sessions with the National Assembly, the Roh Administration recommended to build a new organization that administers the defense acquisition management system, while maintaining self-autonomy apart from the military.[402] In this regard, the Defense Acquisition Program Administration was established in January 2006.

The primary focus areas for reform were highlighted in four institutional aspects of the existing defense acquisition structure; institutional efficiency, workforce professionalization, organizational transparency, enhanced competitiveness. Firstly, institutional efficiency embodied the largest reform efforts, which included massive consolidation of overlapping organizational functions, streamlining onerous decision processes, elimination of service rivalries in force requirement planning priorities within the Joint Staff, synchronizing defense acquisition programs under the Midterm National Fiscal Policy, and so forth. Most of all, the organizational consolidation process involved the incorporation of eight (8) different agencies subordinate to the Ministry, direct supervisory units, Joint Chiefs of Staff, military services, and ADD into one single agency controlled under DAPA. The consolidation of these eight entities was believed to reduce 10% of the workforce and save about 5% in operating costs.[403] Secondly, workforce professionalization exerted efforts to assign more civilian officials specialized in defense acquisition programs instead of relying mostly on military officers that constantly serve in rotating assignments. The program duration of an average defense acquisition program was set between 7 to 10 years, whereas military officers working in rotating assignments in these programs served

402 국방획득제도개선위원회, 국방획득제도 개선방안, 2005. 1. 19.

403 The procedural aspects of consolidating various stakeholders in the acquisition process introduced the concept of the Integrated Product Teams (IPT), which incorporated the lower tiered service program offices and the higher tiered planning offices in the Ministry into a streamlined single team that administers all technical, negotiative, and contractual domains of a single program.

only a 3-year tour in maximum. Thus, there were apparent discontinuity and inconsistency caused under the incumbent personnel system. The professionalization efforts also aspired to establish a highly specialized education and training institute for defense acquisition specialists. Thirdly, instating organizational transparency strived to improve legal statutes on defense acquisition. The existing legal structure predating DAPA was based not on a formal law but a ministerial directive called the Defense Acquisition Regulation. Thus, strong regulatory implementation efforts were not enforced, where the regulation went through constant revision work in a piecemeal way without a strategic vision or guiding principle interlinking the acquisition system under the broader national innovation system. In this aspect, the legislation of the Defense Acquisition Program Act addressed the overarching boundaries of defense acquisition through strong enforcement measures. And lastly, in terms of enhanced competitiveness, the need to fix the protective and promotional measures imposed on the defense industry, represented by the Specialization and Systematization Act, subsequently led to the entire abolishment. Such measures granted open competition in the defense industry, which motivated defense firms to improve its productivity and become more involved and innovative in technology development.[404]

However, the establishment of DAPA has caused systemic challenges in terms of structural disconnect between the acquisition and operation and maintenance (O&M) authorities. Considering the breakdown structure of weapon systems life cycle costs over a thirty-year period, the general rule of thumb accounts that the system acquisition costs around 20-30%, while the operations and support piece costs around 65-80%. Thus, the opportunity to identify risk factors early in the life cycle management of a weapon system depends on how synchronized and integrated the acquisition and sustainment pieces fit together. As the acquisition process continues, it becomes increasingly difficult to influence life cycle costs for a weapon system.[405] The autonomous stature of DAPA as a separate entity from MND has detached the acquisition function from the overall defense innovation system, which uncoupled the critical components of the defense acquisition management system between the force requirement planners, acquisition authorities, and the operation and maintenance apparatus. The defense budget was unsynchronized between acquisition and O&M, where an affluent amount was allocated for new weapon system procurement while insignificant amount was negotiated for weapon system sustainment. Because of this disconnect, the total life cycle management of weapon systems confronted enormous challenges in post-deployment phase operations.[406] Such disconnect has presented difficulties in securing sustainment resources from budget authorities. For instance, the K-series Main Battle Tanks and armored personnel carriers have been suffering from repair and maintenance overload due to shortages in the O&M budget, which has been exacerbated during the recent years since DAPA's establishment.[407] In another case, the Cheonma Surface to Air Guidance Missile was indigenously developed without considering to build-up a repair and overhaul support system, which subsequently

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404 이창희 외, 최근 국방획득정책의 주요성과와 발전과제, 산업연구원 Issue Paper 2013-306, p. 35.
405 DoD Instruction 5000.02, Operation of the Defense Acquisition System, November 26, 2013, p. 28.
406 최석철, 총수명주기체계관리 (TLCSM) 집행통합 구축방안, 국방대학교 정책연구보고서, 2010, p. 9.
407 Repair and Overhaul Overload Rate of K-series Main Battle Tanks, Armored Personnel Carriers, and Self-Propelled Howitzers between 2012 and 2016 was 39%, 41%, and 36% in average over each item. 2016 Natioal Assembly Audit Updates from the Office of National Assembly Member Seo Young Kyo.

compelled the Cheonma Program Office to outsource the repair function to an unqualified private company under huge cost increases. After huge legal disputes, the military authorities finally decided to internally build-in the maintenance functions for the missiles, after significantly costing the tax payers money and time.[408]

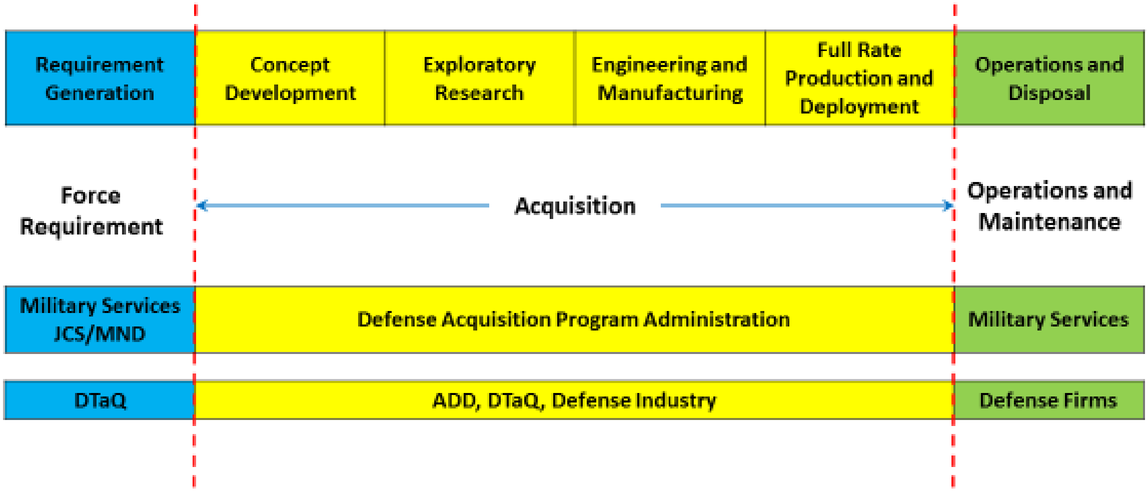

Figure 13. Structural Disconnect and Coordination Challenges in the Defense Acquisition Management System

4.7.2. Presidential Council for Future and Vision

In order to overcome the systemic challenges emerged from DAPA, the Lee Myong Bak Administration initiated a series of reform efforts through the Presidential Council for Future and Vision in 2010. The Lee Administration especially viewed the defense industry in an economic perspective, and articulated a number of policy measures to reform the defense business as a new economic growth engine for the Korean economy.[409] The Lee Administration's reform objectives were to obtain state-of-the-art advanced military technology driven not by government but by corporate sectors through increased investments in defense R&D, improve corporate competitiveness by utilizing commercial capacities in the defense sector, and promote defense exports in the global market.[410] As the President hailed from a business background of big-business conglomerates, the center piece of these reform efforts focused on restructuring the defense industry through massive M&A strategies in order to build economies of scale commensurate to compete in the international market. The vision was to create a 'total solution' defense corporation that can perform in technology development, manufacturing, and sustainment within a 'Total Life Cycle Management' architecture. The idea was motivated by the global defense business trend, whereby observing the creation of the Big 4 (Lockheed Martin, Boeing, Raytheon, Northrop Grumman) in the U.S. and the four major aerospace companies in Europe (BAE,

408 김동호, 국산 미사일 '천마' 무자격 외주업체에 정비 맡겨, 연합뉴스, 2014. 5. 9.
409 President Lee Myong Bak's Speech delivered during the KUH Surion Helicopter Rollout Ceremony, 31 July 2009.
410 대통령실, 우리나라 방위산업 새로운 성장동력입니다, 청와대 정책소식, Vol. 138, 2012.11.21.

Thales, Finmeccanica, EADS).[411]

The M&A strategies confronted huge impediments as the weapon systems development institutions subject to restructuration vehemently opposed the government initiatives. The first agenda raised during this period was the downsizing of ADD. The Lee Administration intended to relieve about 1,000 ADD researchers and transform the laboratory to a technology strategy and planning agency.[412] With the purpose of strengthening corporate R&D in defense firms, about 400 of these researchers were to be reassigned to companies such as Samsung Thales, Hanwha, and so forth. However, regarding the concerns of diminished R&D capabilities, the downsizing plan was not fully implemented and was later fizzled out to nothing after the end of the administration. The second agenda was to privatize government owned defense firms. The issue considered the selling of government shares of the Korea Aerospace Industries (KAI).[413] However, alleged preferential treatment by Presidential authorities to certain business conglomerates and the shortages of financial resources for corporate acquisition have discouraged further M&A deals in the domestic defense market. The specifics of the privatization attempt will be covered in more detail in the following chapter.

In an institutional aspect, the coordinating relationship between MND and DAPA came into question. The structural disconnect between acquisition and logistics functions, and the separation in budget responsibilities between Force Improvement Program and Force Support and Sustainment Programs have prompted Presidential authorities from the Council for Future and Vision to migrate three critical policy functions from DAPA to MND. The three considered areas were Mid-term Defense Planning and Budgeting, Defense Research and Development, and Defense Exports.[414] However, the National Assembly opposed the migration of all three responsibilities, with concerns related to an inadvertent disconnect between defense R&D and weapon systems development programs, which would still remain under the auspices of DAPA. In this regard, the eventual migration of responsibilities only involved the Midterm Defense Planning and Budgeting, and Test and Evaluation functions from DAPA to MND and JCS.[415]

4.7.3. Technology Transfer Mechanisms

Defense offsets is a major channel for negotiating the transfer of highly advanced critical defense technology from global first tier defense contractors. In general, the purchasing country fully exploits its purchasing power from defense contracts to negotiate opportunities for technology acquisition and production deals. The ideal situation on defense offset trade considers a situation where the beneficiary firm acquires the subject core technology, proceeded with a learning-by-doing effort in

411 미래기획위원회, 국방과 산업의 융합전략(안): 국방산업 G7 미래전략, 2010.6.
412 헤럴드경제, “국방과학연구소 인원 절반감축,” 2009.5.12.
413 김도균, “날아오르는 한국항공우주산업, 민간에 판다고?”, OhmyNews, 2012.7.30.
414 방사청 핵심기능 국방부 이관 본격화하나, SBS, 2010.8.13
415 김귀근, 무기체계 시험평가 기능 방사청서 국방부로 이관, 2014.11.10.

learning and accumulating the requisite production process. Afterwards, the beneficiary firm becomes a party of the global supply chain through cooperative production deals, which increases business earnings for sustained corporate operations. Such routines expand investment opportunities and generates a virtuous business cycle that encourages innovation and entrepreneurship.[416]

Figure 14. Increased Competitiveness through Effective Defense Offset Trade

The legal requirement to conduct defense offset deals was first institutionalized in 1983 as stipulated in the “Special Measures for Defense Industry” under Article 21 “Defense Offsets”. The motive to institute defense offsets was initially to build-up the domestic aircraft industry, which became the primary window for technology transfer opportunities.[417] Currently, the responsibilities for defense offsets are mandated in Article 20 of the Defense Acquisition Program Act, administered by the Defense Offset Division under the Acquisition Planning Bureau of DAPA. At first, defense offsets focused on retaining production works from foreign firms to capitalize domestic defense firms with stable manufacturing quantities, and securing overseas export opportunities. As times progressed, the focus shifted from negotiating manufacturing works to acquiring requisite technologies. Since the defense authorities have set the priorities on consolidating the foundations of defense R&D infrastructures, and to build-up indigenous technological capabilities for weapon system development, defense offset negotiations further concentrated on acquiring critical core technologies. During the early 1990s, 63% of technology transfer cases and 32% of co-production work were negotiated through defense offset deals.[418] The rule of thumb is to negotiate over 30% of the contracting value for defense offsets adhering to the listed priorities of technological and production needs. The below table depicts the priority agendas of defense offsets specified in the Defense Acquisition Program Act.

- *Acquisition of core technology*
- *Production of major components for exports*
- *Obtain technologies, equipment, facilities, and tools to support major depot maintenance work*
- *Product improvement programs*
- *Secure defense export opportunities*
- *Secure overseas maintenance and repair work*
- *Participate in major co-production and co-development projects*

Table 14. Defense Offset Priorities, adopted from the Defense Acquisition Program Regulation (2010)

416 박종호, “사례분석을 통한 부품 제작 및 수출성과 확대방안,” 2014 절충교역 발전 심포지엄.
417 법률 제 3699 호, 방위산업에 관한 특별조치법, 1983.12.31 시행.
418 조달본부, 절충교역 20 년사, 국방부, 2003, p. 25.

From 1983 to 2003, a total of 408 defense acquisition programs were associated with defense offset deals with an estimated negotiation value of $99.72 billion. About 66% was negotiated from commercial defense contracts of major end items and 25% was from co-production programs arranged through technology transfers. In terms of negotiated countries, the United States accounted for the majority of all defense offsets (53%) followed by Germany (13%), UK (9%), France (6%), and Italy (6%). Domestic defense firms were the major beneficiaries of the defense offset deals, where a dollar value of $53.18 billion (54%) out of the $99.72 billion were provided in the form of technology transfers, component production, and defense export arrangements. About 22% of the dollar value was provided to ADD, which mostly constituted of core technology acquisition, and the remaining 24% was provided to the military services as part of technical assistance to construct means for depot maintenance. Such distributing results attributes to the legal requirements for industry promotion mandated in the Special Measures in Defense Industry, which continues in the current Defense Acquisition Program Act as of 2016. In this aspect, the value added accrued from defense offsets during this period was estimated $84.47 billion, which accounts for a total of $184.19 billion in dollar value. Thus, defense offsets had impacted substantially to the technological growth of the Korean defense technological capacities and industrial development.[419]

Type		**Offset Value**		**Value Added**
Total		$99.72B	100 (%)	$84.47B
Technology Acquisition	Tech Data	$10.85B	11	$10.52B
	Tech Assistance	$33.7B	34	$32.69B
	Tech Training	$4.36B	4	$4.22B
	Subtotal	$48.91	49	$47.43B
Overseas Exports	Component Production	$19.47	20	$19.47B
	Government Designated	$12.49	12	$8.24B
	Subtotal	$31.96	32	$27.71B
Equipment and Engineering Tools		$18.85	19	$9.42B

Table 15. Defense Offset Value between 1983 and 2003. DPA Update on Defense Offsets (2003)

However, defense offsets entail restrictions and limitations in the course of obtaining critical technological capabilities. The era of complex product systems in weapon system development are generally regarded as a national security consideration for all countries in terms of sustaining its industry and technological prowess. Therefore, demands for technology transfer of state-of-the-art technology is handled under special care and sensitivity, and often hindered by export controls and technology security regimes. Such traits are especially evident in critical core technology items. According to a defense acquisition program update on the Type 209 Chang Bogo Class Submarine Program to the National Assembly in 1993, the only core technology that was actually transferred from the original manufacturer Howaldtswerke-Deutsche Werft (HDW) of Germany were two electric cable wires connected to the main propulsion battery. Other critical components such as engines, combat control systems, propulsion motor, armaments, emergency buoyancy control systems, and so forth, were not

[419] Ibid., p. 43.

included in the transfer list for domestic development, and were simply provided as components for subsequent assembly work.[420] Such restrictions appeared especially obvious considering defense offset deals with the United States, which accounted for almost 80% of foreign weapon systems acquisition.

Opposed to countries like Korea that benefits from technology transfers offered from defense offset trade, the U.S. is strongly against the idea of defense offsets and considers it a necessary evil. The U.S. Government generally considers the ramification of offset trade distorts regular business transactions, increases foreign reliance in the global supply chain, gives away critical technology to foreign competitors, and takes away U.S. jobs to foreign manufacturers.[421] When comparing through simple math between total weapon systems imports and defense offsets, the United States should proportionately account for almost 80% in dollar value in defense offsets comparative to the import value. However, the actual defense offset value of 53% falls considerably disproportionate from the 80% purchases, which represent the restrictive nature of technology transfer conditions regarding defense offsets. In real terms, technology transfers from the U.S. in defense offsets before 1997 averaged around 70%, but this level was significantly reduced to 34% afterwards. The U.S. limited the defense offset value of the KF-16 procurement, dubbed the Korea Fighter Program (KFP), to only 30% in this respect. Such restrictiveness in U.S. tech transfer conditions is reflected in the Korean defense offsets regulations as well. According to the defense offset guidelines in the late 1980s, the overall threshold for defense offsets marked over 50% out of the entire contract value for every other country, whereas defense offset threshold over U.S. contracts constituted only a portion of 30%.[422] The constraints relate to maintaining U.S. competitive advantages in an era of shrinking defense budgets and growing competition in the global defense market. Thus, the perception prevailed among defense acquisition authorities over the idea that the U.S. Government instrumented defense offsets to restrain further growth potentials of the Korean defense industry.[423]

In an institutional aspect, bureaucratic constraints structurally hindered efficient coordination efforts in successfully negotiating defense offset deals. Offset negotiations are not closely tied in with long-term strategic S&T documents. In this regard, the majority of the defense offset negotiations do not address the strategic objectives of Korea's defense S&T capacities and weapon systems development guidelines. The highest level Defense S&T Promotion Document and its Implementation Plan are not effectively employed in negotiating critical programs under consideration for defense offsets. The current disconnect between defense S&T policy making, which is administered by the Ministry of National Defense, and defense offset negotiations, which is administered by DAPA, exemplifies this disconnect. The organizational disconnect is severed by the detached coordinating

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420 동아일보, 율곡 전투기 등 기술이전 돈만 더 주고 받은 것 없다, 1993 년 10 월 3 일.

421 Bureau of Industry and Security, Offsets in Defense Trade: Twelfth Report to Congress, U.S. Department of Commerce, December 2012.

422 국방부 훈령 제 733 호, 국방획득관리규정, 제 96 조 절충교역 적용기준 및 대상

423 Since the November 1991 Defense Industry Cooperation Committee meeting, Deputy Ministers of Defense Acquisition made various attempts but were unsuccessful to relax some of the tech transfer restraints during various bilateral engagements, 김재홍, "방산기술 도입 미국장벽 높다," 동아일보, 1991 년 11 월 20 일.

relationship between the policy control tower and actual program management offices leveraging the offset deal. The Defense Offsets Division under DAPA, which holds the policy authority for offsets, does not adequately obtain the requisite experience and knowledge in the negotiation table. The officials conducting the offset negotiations mostly serve in rotating assignments, which merely counts for three years in maximum. Major negotiations are conducted by officials assigned under a specific program office, such as the Aircraft/Fighter Program Office, C4ISR Program Management Office, Guidance Munitions Office, and so forth, that manages major program milestones of a weapon systems program. However, these officials have comparatively less interest in negotiating technology offset required to support the overarching defense S&T technological roadmap. Also, the actual defense R&D authorities that consist of ADD and domestic defense firms are not closely involved in the planning and policy making phase of defense offset trade either. For example, a number of defense offset negotiation sessions with foreign governments and defense firms often ran into roadblocks when negotiating officials from DAPA did not come prepared with the full technological needs required from ADD or other corporate entities.[424]

4.8. Structural Challenges in Defense R&D and Technology Transfer Mechanisms

The past forty years, however, have demonstrated intrinsic challenges in transitioning from a low-tech conventional production structure into a high-tech complex product base for the defense industry. Almost every government administration declared its commitment, with national pride and dignity, to upgrade the defense industrial base to the ranks of global frontrunners through a politically initiated top-down scheme in the process of promoting the defense sector as an economic growth engine. But the structural impediments in R&D and competitive constraints of defense firms have obstructed further evolution of the defense industry to an advance structure.

4.8.1. Risk Averse Mentality Prevalent in Defense R&D

Organizational inertia prevalent in defense R&D seems to be part of the impediments that discourages a vibrant corporate R&D environment. Defense R&D has been primarily conducted under the auspices of ADD, and this is where ADD officials refused to transfer such responsibilities to the corporate sector. The 1980s marked the dark ages of Korean defense R&D history. As part of rationalizing government sponsored research labs and institutions early in the Chun Doo Hwan dictatorship, the government relieved approximately 800 scientists and engineers from ADD who were mainly committed to missile development programs, substantially reduced the defense R&D budget from 3.5% of the overall defense budget to 1.2%, and gave priority to foreign procurement instead of domestic development in the course of rushing into early deployment of various foreign high-tech

424 최석철, 한승만, "국방연구개발과 절충교역의 연계방안에 관한 연구," 한국방위산업학회지 제 10 권 2 호, 2003, p. 86.

weapon systems. These measures were detrimental to the Korean defense industrial base, which devastated the S&T infrastructure in defense R&D and lowered the operational rate of industrial manufacturing.[425] Chun-Doo Hwan regime came into power through a military coup in 1979. The lack of democratic legitimacy placed the regime under huge criticism by its western allies, especially the United States. In order restore trust and confidence as an authentic and legitimate military ally to the United States, it was imperative for the Chun regime to dispose of the earlier defense industrial build-up efforts that the U.S. has been vehemently skeptical against, such as missile development and allegedly a nuclear development program. At the same time, Korean leaders turned less desperate of becoming self-reliant in the defense of its own country as the new Reagan Administration assured a stronger commitment to protect U.S. allies against potential communist aggression, which alleviated the prevalent concerns of a possible U.S. military stand down from the Korean Peninsula.[426]

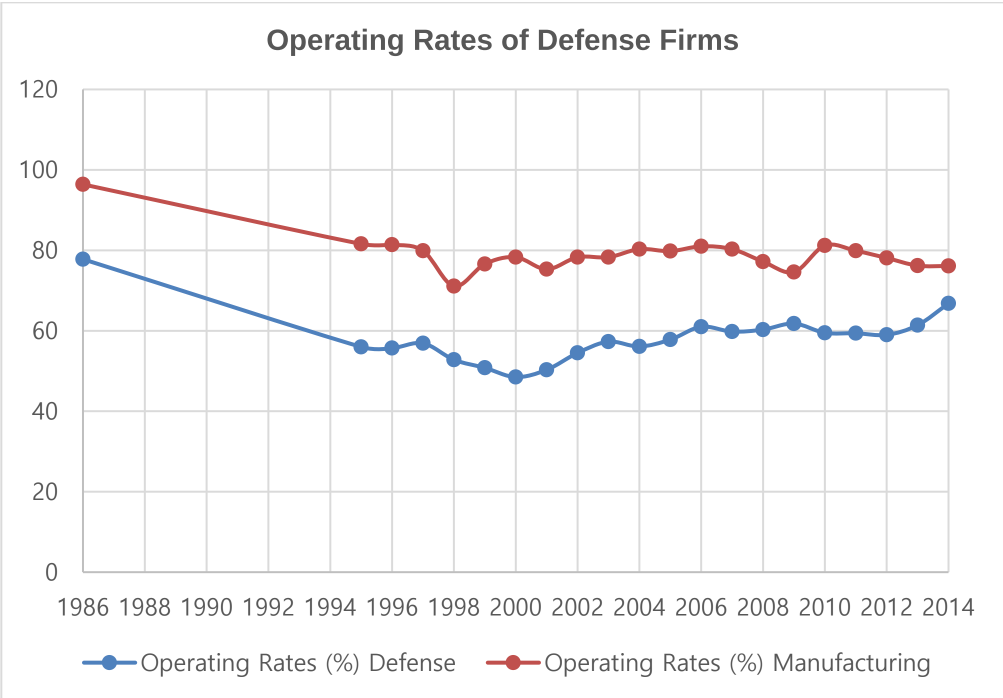
4.8.2. Rough Waters Ahead: Deep-rooted Impediments of the Defense Industrial Base

Despite the remarkable development of the defense industry during the fast developmental days, the industry conditions deteriorated in the entering years of the 1990s and afterwards. The fundamental constraint falls on market saturation and the reduced military force needs that occurred after concluding the production and deployment phase of the respective weapon system program. As the force needs of conventional weapon systems became saturated, production runs of the defense industry have plummeted to a significantly lower percentage. In this regard, Korean defense firms being overly dependent on government weapon system procurement, and not being sufficiently competitive enough to market its defense products to global defense customers, has left the defense industry gridlocked in the domestic boundaries of its business operations.[427] Hence, the root cause of the current crisis in defense industrial operations originate from the excessive investment in production capacities attributed to the disproportionate number of defense firms in the weapon system supply chain protected under the Specialization and Systematization Regime.[428]

In terms of competitive constraints, the overall management situation of defense firms shows poor business performances in operating rates, productivity, net sales, and net profits. An assessment of Korean defense industrial competitiveness in the corporate and national level compared against advanced American and Western European defense industries shows a low performing standard of 70~80%. The competitiveness level in product price is 84%, technology and quality is 87%, and product is about 86%.[429] Strong market protection and government subsidies rendered to the defense sector

[425] 이은영, ADD 무기개발 3 총사 의 핵미사일 개발 비화, 월간 신동아 2006 년 12 월호
[426] 백곰 날다
[427] As of 2010, about 90% of the net sales ($8.5 trillion) of the defense industry were from domestic sales whereas overseas exports only accounted for less than 5%, 유형곤 외, 방산수출 확대에 따른 방위산업 선진화 방안 연구, 안보경영연구원 연구용역과제, 2012, p. 48.
[428] Most defense firms protected under the Specialization and Systematization Act solely focus on the defense business, and are less diversified into other business sectors. 문종열, p. 40.
[429] 안영수 외, 2014 KIET 방위산업 통계 및 경쟁력 백서, 산업연구원 정책자료 2014-226, p. 21.

over the years presented less incentives for defense firms to innovate and improve their management practices. The operating rates of defense firms from a span of thirty years has declined from an average 77.8% in 1986 to a level under 60% in the 2000s. As shown in the table below, attributing to the saturated domestic defense market, the operating rates substantially declined in the late 1980s and continued to fall in the 1990s, while slightly improved in the 2000s. Such status shows comparatively lower performance levels than the average operating rates of other commercial manufacturing sectors, which shows an average rate of 80% during the similar period. Operating profits of defense firms also show lower returns compared to the regular manufacturing sector during the same period.[430] Such trend shows that defense firms demonstrate considerably high levels of idled production capacity, which is considered significantly high when even accounting for the economic necessity in preparation against a national emergency situation.



Year		1986	1995	1998	1999	2000	2003	2004	2006	2008	2009	2011	2012	2013	2014
Operating Rates (%)	Defense	77.8	56	52.8	50.8	48.5	57.3	56.1	61	60.3	61.8	59.4	59	61.4	66.8
	Manufacturing	96.4	81.6	71.1	76.6	78.3	78.3	80.3	81	77.2	74.6	79.9	78.1	76.2	76.1
Operating Profits (%)	Defense		4.6	6	5	6.4	3.6	3	5	5	6.1	5.7	4.5	2.3	4.5
	Manufacturing		6.9	4.9	5	6.8	6.7	7.2	5	5.9	6.1	5.6	5.1	5.2	4.2

Table 16. Business Performance of Defense Firms, adopted from KOSIS Statistics

In the technological aspects of the defense innovation systems, unlike the U.S. or other advanced Western European defense industries that conducts technology development as a priority and places system development in subsequent priorities under a Total Life Cycle System Management (TLCSM) framework, the majority of Korean defense R&D projects and associated production structure primarily focuses on system development, and places R&D in a peripheral category. As such,

430 Business Performances of Defense Firms, adopted from http://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx_cd=1703

Korea falls comparatively short in building a wide array of S&T infrastructure for critical core technologies, which compels the industry to rely heavily on foreign technology and components. Thus, the defense sector appears far less competitive against advanced foreign defense industries in many technical defense products, where the country has been placed in the lower-middle-tier within the global defense industrial landscape. Lower-middle-tiered defense industries are typically those that directly import critical military components or manufacture weapon systems under substantial technology assistance from advanced defense industries.[431]

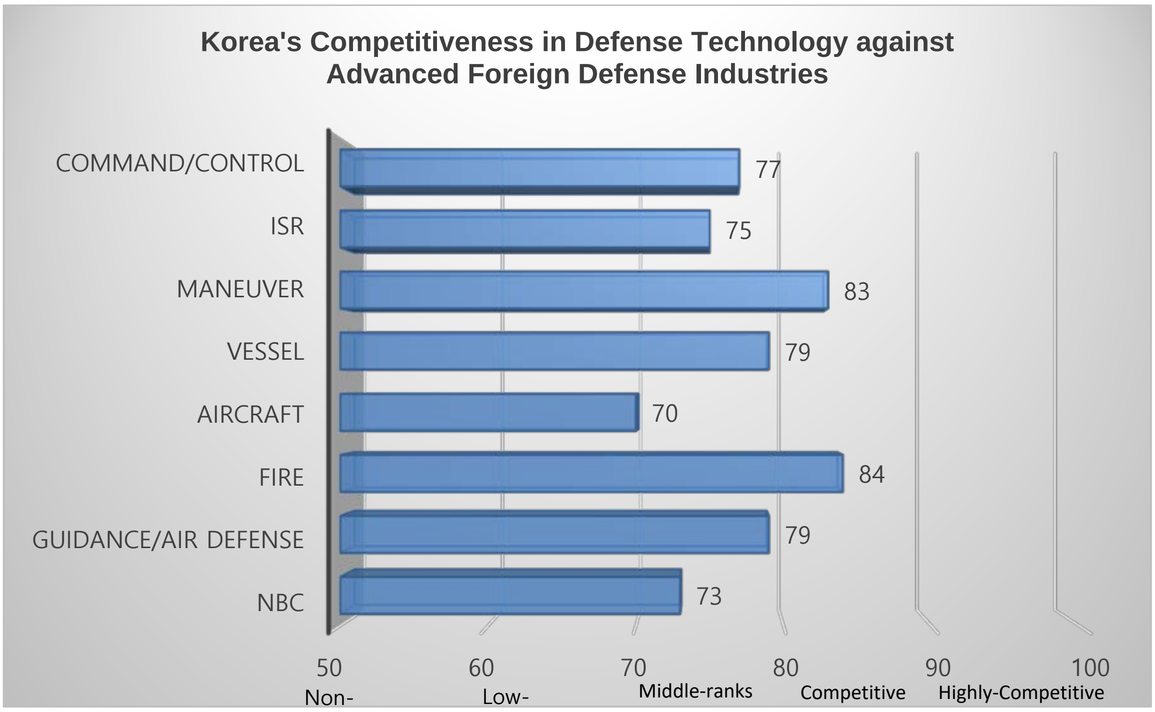


Figure 15. Defense Technology Competitiveness Compared to Advanced Countries, DTaQ (2010)

In order to overcome the quagmire of over production and redundant manufacturing capacities, corporate strategies in a normally functioning market economy would seek options to streamline the industrial structure through mergers and acquisition, expand overseas exports, introduce more intensive competition systems, diversify products, establish co-development/production arrangements, or pursue other possible options available. Considering the fact that the Korean defense industry runs as a private business operation controlled under huge government subsidies, the streamlining efforts should've been regulated via market mechanisms. But the established institutions such as the Specialization and Systematization Act and Defense Industry Promotion Act have restrictively precluded defense firms to seek rationalization efforts under their own initiatives. As illustrated in the previous chapters, American and Western European defense firms went through intensive restructuration processes over the course

431 First-tiered advance defense industries are countries like US, UK, France, Germany, Italy, and the Upper-Second-tiered, or upper-middled-tiered, are Australia, Canada, Czech, Norway, Japan, Sweden, and the Lower-Second-tiered, or lower-middled-tiered, are Argentina, Brazil, Indonesia, Singapore, Korea, Taiwan, Turkey, and the Third-tiered are Egypt, Nigeria, Mexico, etc. 김종하, "한국 방위산업의 연구개발수행력에 따른 구조혁신의 방향," 한국방위산업학회 제 17 권 2 호, 2010, p. 157.

of advancing the competitive strength of its defense industry. Therefore, the oligopolistic structure of leading global defense industries appeared as an outcome of such intense competition. But because of the rigidities and inflexibilities prevalent in the Korean defense industry under the four decades of government protection and nurturing, these alternate solutions turned hardly achievable. Corporate competitiveness of Korean firms in the global defense market was seriously challenged by the R&D arrangement between GRIs and defense firms.[432]

Continued government scrutiny and public criticism over weapon system development programs also counts as a destabilizing factor that discourages innovative entrepreneurship in the defense industry. Ever since the Yulgok Scandal in 1993, a series of irregularities and malpractices were revealed in weapon systems development, and a number of politicians, senior military officials, and business people were prosecuted for program mismanagement and corruption. Afterwards, weapon systems procurement programs and the defense industry were condemned as a source of public evil, and the self-esteem of the defense firms was seriously damaged afterwards. Especially for major defense firms managed by big business conglomerates (Chaebol), the CEOs and owner families started to disfavor the defense business, which generally performed comparatively lower than other operating sectors within its business group.[433] The significant cause for the low-preference was due to the rigid policies and regulations imposed over the entire manufacturing process. The current Defense Acquisition Program Act mandates the obligation of defense firms to disclose the production cost, financial statements, and other accounting documents to DAPA at the end of the year under the justification of transparency and efficiency. However, such information in other business sectors is normally considered corporate secrets and is rarely revealed to the public only on a necessary basis. Additionally, defense firms are subject to annual government audits conducted by the Board of Audit and Inspection (BAI) and the National Assembly, and are obliged to continuously update the progression status of its weapon system development programs to these authorities accordingly. Finally, but not the least, defense firms are subject to constant supervision by the counter-intelligence agencies such as the National Intelligence Service, Defense Security Command, and Police, because of the volume of secret information the company holds.[434] On the contrary, in the case of foreign weapon systems procurement programs, foreign defense firms are not subject to disclosing any such information that can be labeled corporate secrets, and are neither subjected to constant supervision by the Korean authorities. Despite the comparatively higher potentials of fraudulent contracts and misdemeanor in these foreign procurement cases against domestic development programs, there is no enforcement measure that can legitimately monitor these foreign programs against domestic ones. In this regard, the

432 한남성 외, 방산물자 및 전문계열화제도의 효율적인 운용방안, 한국국방연구원, 연구보고서 무 02-1801, 2002, p. 27.
433 The estimates of defense sector performance in annual sales compared to other industrial sectors as of 2011 shows a relative performance level of 4.7% against the automotive sector, 6.1% against the steel sector, 11.3% against the general machinery sector, and 12.3% against the shipbuilding sector. 장원준 외, 우리나라 방위산업 구조고도화를 통한 수출산업화 전략, p. 302.
434 채우석, 삼성이 방위산업을 포기한 이유, 글로벌디펜스뉴스, 2016 년 4 월 20 일.

control measures being imposed to Korean defense firms are comparatively harsher, and a number of firms have been expressing its willingness to exit the industry.[435]

For instance, the top two Korean defense contractors, Samsung and Doosan, have been arduously seeking options to divest its defense businesses to other companies, and to permanently exit the defense business ever since the Asian Financial Crisis of 1997. Especially, the defense sector of Samsung was traditionally considered the most diversified and comprehensive in scale and performance – spanning from command and control systems, self-propelled artillery, armor tracked vehicles, and aircrafts – and had the strongest and most respectful convictions to sustain its defense operations as part of returning its corporate achievements to the country since the creation of its defense branches in 1977.[436] Despite the relatively smaller footprint of the defense business compared to other business sectors within big business conglomerates, the frequent government audits and court appearances over various defense acquisition programs have accumulated constant work fatigue and market uncertainties among the Chaebols. Also, opposed to the 9% returns in margin rates of the defense industry announced by DAPA and other defense authorities, the actual profit margins of major defense system integrators hover around 2-3%, whereas its subcontractors perform far below this percentage. As such, the high risk factors existing both in technology development and political situation have discouraged innovation and entrepreneurship in the defense business from the past twenty years.[437] These circumstances will be covered in more detail in the following sections of this chapter.

4.8.3. Corporate R&D Efforts in Defense Acquisition Programs

Depending on the lead organization responsible for the system development phase of the acquisition cycle, weapon system development and critical technology development programs are largely divided into government managed programs (primarily organized by ADD) and corporate driven programs (including GRI-Industry-Univ. partnerships). Based on the technology readiness level, risk factor assessment, and economic impact factors, the defense acquisition authority supervised by the Defense Acquisition Program Executive Committee (DAPEC) decides the acquisition strategy of the program, whether it be government managed or corporate driven.

Until the 1990s, defense R&D in weapon systems development was an exclusive property of ADD where defense firms narrowly contributed in manufacturing roles such as in prototyping and full rate production. R&D of critical core technology and engineering design work was also primarily conducted by ADD where defense firms served in sub-contractual manufacturing arrangements. Hence, the defense industry was considered a government subsidiary in manufacturing weapon systems rather than an incubator of innovative technology and systems development. The dualized segments between

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435 김종대, 방향 잃은 방산비리 수사, 경향신문, 2015 년 3 월 16 일.

436 Samsung and Doosan each sold off its defense branches to Hanwha Corporation in 2015 and 2016, and have entirely exited the defense businesses. Interview with a former Samsung official.

437 한국방위산업학회, 방위산업 발전을 위한 국방연구개발 활성화 방안 연구, 국가과학기술자문회의 정책용역자료 2001-11, p. 30.

R&D (government-ADD) and production (industry) precluded the construction of a symbiotic defense industrial ecosystem that incorporates the total life cycle management of a weapon system including R&D, production, system upgrade, depot maintenance, and disposal. Under this arrangement, defense firms had little incentives to strive for obtaining critical core technology as a baseline capability. The negative effects of the prime contractor not holding R&D responsibilities of the subject weapon system program resulted in the technologically substandard capabilities of its subcontractors and component suppliers. In this regard, weapon systems development programs suffered from low localization rates, which forced the prime contractor to heavily rely on foreign components and technology. Therefore, defense firms not only lacked the most competitive foundations in system design and integration technology, but also failed to hold a self-reliant supply chain.[438] In reference to the continued evolution of complex weapon systems development, the government was compelled to share R&D responsibilities with defense firms in a number of naval and aircraft development programs since the 1990s. The advantages of corporate R&D efforts in weapon systems development programs contributes to reduced program cost and shortened development periods. Firms can fully materialize proven technology into a weapon system, which alleviates a number of challenges in risk management during the development process. The awarding of development firms through a competitive bid provides opportunities to save time and money for the government because it eliminates the esoteric cycle of the acquisition strategy generation phase.

Yet, firms have been reluctant to commit corporate resources into defense R&D work because of the domestic defense market presents little incentives to firms that demonstrate strong technology competitiveness. At first, the closed oligopolistic structure of the defense industry awards government contracts to a handful of defense firms protected under the Specialization and Systematization system. In this aspect, firms existing outside of the protective boundaries of the defense industry are unable to penetrate the domestic defense market. Secondly, the government does not guarantee to the development firm an appropriate compensation for development nor does it assures adequate quantities of procurement even after the successful conclusion of the systems development efforts. Consequently, the development firm bears all development and production risks, hence it becomes quite commonsensical that no firm will accept such risk factors in an unrewarding market. Thirdly, firms are concerned with the eventual ownership of the intellectual property rights in relations to the resulting R&D achievements. In this aspect, most of the proprietary rights that arise from the development project fall under the ownership of either ADD or the military authorities.[439] Such contracting behavior is quite contrary to other advanced defense industrial countries. In the case of the United States, the Department of Defense, under a Technical Advisory Group, reviews and validates the investment costs and real value of Independent Research and Development (IR&D) projects, and sets the acceptable ceiling for

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438 정진태·김진호, 방위산업의 전문화·계열화 발전방안, 국방과 기술, 2003 년 2 월, p. 38.
439 고승석 외, 방산특성을 고려한 기업의 연구개발 관리시스템 구축에 대한 사례연구: 업체주도 연구개발과제를 중심으로, 한국방위산업학회, 제 15 권, 1 호, 2008, p. 209.

compensation as a government share to the firm.[440] The institutional structure that determines the proprietary rights resulting from technology development projects becomes especially troublesome for the R&D participating entities. According to the Act on the Agency of Defense Development and the Defense Acquisition Program Act, either ADD or DAPA appear as shareholders of the proprietary rights, even if the technology or manufacturing data originated from the corporation itself. The rationale supporting this ownership structure relates to the need of maintaining confidentiality in defense R&D, in conjunction with the general perception of the government as the original investor of the R&D activities retaining such ownership. On the contrary, the rule of thumb for proprietary ownership over collaborative R&D programs administered by other government agencies such as MOTIE and the Small-Medium Business Administration, show that the participating corporations or research laboratories also hold an equal share of their respective efforts, even if the R&D finances originated from the government. Thus, the restrictions over proprietary rights on defense R&D products have the potential of conflicting with a broader and higher legal arrangement that defines intellectual property rights of publicly funded research programs. Such restriction hinders defense firms from taking leadership roles and actively promoting R&D efforts to improve its own competitiveness, the entrance of technologically competitive firms into the defense sector, and promotional effects of the transfer and diffusion of technology to other sectors of the economy.[441]

A recent survey conducted by the Korea Institute of Intellectual Property on 18 defense firms reflects such reluctance in a cost benefit perspective. According to the survey, 38.9% responded that no special incentives or awards existed for corporate led R&D efforts such as in tax benefits, financial loans, etc. 16.7% expressed frustration over the idea of the government taking full ownership of Intellectual Property Rights that resulted from corporate led R&D. In a separate survey conducted on 44 defense firms also showed similar results, where over 72% responded that the government guaranteed nothing in terms of properly compensating the development efforts of defense firm. More than 54% pointed out the situation where no implementing institution or regulation existed for properly compensating corporate defense R&D outcomes. Additionally, 36.4% expressed reluctance because of the ownership arrangements of proprietary rights, and 38.7% responded the lack of incentives that would motivate firms to engage in R&D work.[442]

Only a small number of low-tech conventional weapon systems such as ammunition or armored vehicles, or electronic communication equipment such as radars counted as product categories where defense firms were able to exert efforts in corporate level R&D. However, in accordance with the various causes described above, some programs were inadvertently shutdown with no proper government compensation at all to the development firm. For example, the K-56 Ammunition Resupply

440 Subpart 231.2 – Contracts with Commercial Organizations, Defense Federal Acquisition Regulation Supplement. 최치호, 국가연구개발사업의 성과 귀속 및 활용체계 개편 방안, KISTEP Issue paper 2013-13, p. 10.

441 산업기술혁신촉진법 13 조, 중소기업기술혁신촉진법

442 전성태 외, 방산업체 자체 R&D 투자 활성화 및 지원방안, 방위사업청-방위산업진흥회 정책용역, 2011, p. 25.

Vehicle Program showcases the event where the government did not compensate the defense firm's R&D work due to a sudden program cancellation attributed by changes in warfighter needs and defense budget shortages. The Army raised the force requirement generation of the K-56 in 1983, and the acquisition strategy was determined in 1986 as a corporate development program. The baseline configuration was to be adopted from the expanded version of the K-200 chassis, and the prime contractor role was awarded to Daewoo Heavy Industries in 1987. After a series of T&E failure and configuration changes, which substantially incurred additional development costs to Daewoo Heavy Industries, the K-56 ARV was finally determined 'serviceable for combat', and was subsequently qualified to enter into full rate production in 1998. But after conflicting assessments on its combat performance and effectiveness, and also compounded by the 1997 Asian Financial Crisis, the government unilaterally cancelled the K-56 ARV Program in 2000, without compensating the development costs incurred by Daewoo Heavy Industries.[443]

4.8.4. Overly Reliant on U.S. Technology Transfers: Indispensable but Repressive

Traditionally, Korea has been considered a big customer in the international arms market. In the case of 2014, Korea was ranked the largest importer of foreign weapons by marking $7.8 billion in contract value. This was the inevitable consequence of putting emphasis on delivering strong deterrence against North Korean asymmetric threat by introducing highly advanced weapon systems such as the RQ-4 Global Hawks, CH-47D aircrafts, among other things.[444] The predominance of U.S. defense products in the Korean force structure as well as industry level collaborative efforts reflects the geopolitical situation of the Korean Peninsula. Putting into account of the rapid economic development and technological catch-up of the Korean innovation system, U.S. assistance in technology transfers and system procurement in the early phases of the economy was critical and indispensable. However, to a certain extent, such large imports of U.S. weapon systems placed Korea's innovation engine in a predicament over the course of building fundamentals for its defense industrial sector. Majority of the weapon systems listed in the Defense Reform 2020 are high-end state of the art systems, which have to highly rely on foreign purchase. Contrary to the 'domestic development first' policy that was mandated in the 1970s, the dissipating commitment towards a self-reliant national security initiative and low incentives in technology upgrading through defense industrialization has altered major defense acquisition programs from domestic development to foreign purchase. Although the Defense Acquisition Program Act of 2005 asserts coherent weapon system development architecture focused on domestic development, the arrangement is more oriented towards economic feasibility through cost benefit analysis or military alliance considerations and not long term TRL upgrading for enhanced

[443] 이호석 외, 업체자체연구개발 실태분석 및 발전방안, 한국국방연구원 연구보고서 무 02-1783, 2002, p. 31.
[444] Catherine A. Theohary, *Conventional Arms Transfers to Developing Nations, 2007-2014*, Congressional Research Servce, December 2015, p.7.

competitiveness.[445]

According to a recent global arms trade report published by the Stockholm International Peace Research Institute (SIPRI), Korea was ranked in third place in global weapon system import between 2004 and 2008. This accounted for about 6% of the global defense import quantities behind China (11%) and India (7%). During this period, over 73% of the weapon systems purchased from overseas were U.S.-origin, thus shows an obvious bias. Especially, as Korea continues to purchase more complex product weapon systems, the lopsided procurement pattern becomes even more apparent towards the U.S.

Unit: $ million

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Canada	3	12	12	12	9	6	6	3									63
France	80	80	80	87	80	27	163	186	172	160	2		2				1119
Germany	180	161	19	25	29	30	21	294	378	415	38	70	34	26	319	33	2070
Indonesia		16	49														66
Israel	19		100										35	28	24	40	246
Italy	5																5
Netherlands	35			25	25	25		39	10		10		10				179
Russia	29			10	32	86	102										259
Sweden									3	12	12	20		24	29	11	109
UK	110	41			12	12								12	12	24	222
U.S.	935	463	268	593	873	619	1358	1233	1121	209	1188	1462	985	93	332	138	11870
U.S. (%)	67.0	59.9	50.8	78.9	82.4	77.0	82.3	70.3	66.6	26.3	95.0	94.1	92.4	51.1	46.4	56.3	73.2
Total	1396	773	528	752	1059	804	1650	1755	1683	796	1250	1553	1066	182	715	245	16207

Table 17. ROK Defense Import Breakdown by Country (SIPRI)

In a slightly tweaked perspective, Korea is ranked first place worldwide that imported U.S. weapon systems in total between 2000 and 2015. Korea spent nearly $11.9 billion in equipment purchases from the U.S. during this period followed by UAE and Australia. However, the dollar figures will most likely rise because the statistics does not account for the purchase of components, spare parts, and other services associated with the weapon system procurement.[446]

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Total	7597	5680	4958	5616	6790	6827	7481	7800	6799	6806	8098	9104	9163	7687	10470	10484	121359
Korea	935	463	268	593	873	619	1358	1233	1121	209	1188	1462	985	93	332	138	11870
UAE	15	19	18	36	380	1259	994	472	677	394	153	863	923	1063	542	895	8702
Australia	194	87	106	165	114	101	348	574	320	610	1389	1004	589	148	326	903	6977
Egypt	823	809	477	345	500	588	429	372	263	82	249	160	177	494	190	585	6542
Saudi Arabia	3	33	89	117	324	153	172	149	235	231	345	398	401	615	1383	1764	6412
Japan	442	398	426	412	352	414	444	470	659	490	381	263	243	258	458	283	6393
UK	814	1253	380	425	165	15	108	290	438	277	331	213	400	331	194	362	5997
Israel	102	115	323	104	839	1114	1110	839	663	134	41	59	107	65	121	194	5929
Taiwan	553	345	298	111	314	641	503	12	11	-	37	138	425	553	1081	681	5702
Singapore	531	59	209	47	362	530	30	8	25	772	748	492	446	670	627	65	5619

Table 18. U.S. Defense Exports from 2000-2015 (SIPRI) Unit: $ million

The justification for purchasing U.S. weapon systems primarily relates to the military alliance structure with the United States. The buzz word in this respect is 'interoperability', meaning the need to maintain commonality in command and control systems, surveillance and reconnaissance assets, strike capability, among others, all intertwined into a complex network of systems, which is the

445 For instance, only one out of the eight feasibility studies of the Korean Fighter Experiment Program was focused on technology strategy where the rest were mostly cost-benefit analysis. National Assembly KFX Seminar, Yoo Seung Min.
446 김외현, 한국, "세계 8 대 무기수입국…미국산 비중 80%," 한겨레신문, 2014.10.19.

prerequisite for effectively waging modern warfare. Because of this procurement pattern, international aerospace and defense firms considered the Korean arms market as a stronghold of the American Big 5 arms dealers, in which other firms from Europe or Israel found almost no opportunities to penetrate.[447]

Moreover, because of the complexities associated with Direct Commercial Sales (DCS) as well as the restrictive control measures imposed on high-tech U.S. defense articles, the recent trend in procuring U.S. defense systems became more reliant on the U.S. Foreign Military Sales (FMS) system. FMS comparatively comes in handy for program managers because it provides a total package approach of the respective weapon system, which includes an integrated logistic support package, education and training program in operations and maintenance, U.S. government quality assurance in system tests, evaluation, and safety, and so forth, all contracted by the U.S. Government on behalf of the purchasing country. On the other hand, FMS is also more restrictive in nature because it does not render any technology transfer arrangements, or defense offset trades, with the purchasing country, while implementing stringent technology control standards to preclude any possibilities of reverse engineering. But because of the convenience in contracting the subject weapon system, FMS contracts in Korean defense spending have substantially increased in recent years. Proportionately, FMS contracts accounted for only 14% in 2008, but reached a ratio to 66% in 2012.[448]

Contract Type	Total	2007	2008	2009	2010	2011	2012 (August)
DCS (%)	66%	37%	86%	52%	64%	61%	34%
FMS (%)	34%	63%	14%	48%	36%	39%	66%
Total	155,732	20,498	68,158	19,681	19,318	14,718	13,359

Table 19. FMS Contracts, reproduced from contract updates to National Assembly provided from the Defense Acquisition Program Administration, 2014

The biased procurement pattern towards U.S. weapon systems not only puts Korea in a less advantageous position when negotiating for better terms in the contract phase, but also applies stringent restrictions in technology security and control measures when adopting highly advanced defense technologies. Defense technology in the U.S. is considered a national security interest, where relatively lesser attention is given to corporate benefits. Thus the primary objective is to preserve critical U.S. military technological advantages. As discussed in the previous chapter, according to the U.S. export control regime, foreign countries or corporate entities must obtain authorization from the U.S. Government prior to either initiating transfer or modification of the respective defense article or services, including technology, that are subject to the U.S. Munitions List.[449] In this aspect, further exploitation of U.S.-origin defense technology with the purpose of modification and overhaul, is extremely limited. Therefore, defense cooperation in the technological realm is only feasible through legitimate means that serves for stewarding U.S. military technological advantages.[450] Especially, Korea has been scrutinized lately by the U.S. Government for either stealing or taking advantage of high-end U.S. military

447 정승임, “웬만한 무기수입은 ‘미국산’으로 통한다?,” 한국일보 2016.1.13.
448 이영하, 차성원, “FMS 방식의 해외무기 구매실태,” 계간 감사, 2013 년 봄호, pp. 62-64.
449 Section 2753 of the U.S. Arms Export Control Act
450 Fact Sheet: Defense Technology Security Administration (DTSA), The DISAM Journal, Spring 1997.

technologies for its own use in a variety of indigenous weapon systems. The items laid out by a recent publication of Foreign Policy showed suspicions on sensor devices, anti-ship missiles, and electronic weapon systems potentially developed through 'copycatting', in the midst of growing Korean defense exports to other countries.[451]

4.9. Chapter Conclusion

Korea's economic growth engine and overarching innovation systems are in its crossroads. The institutional foundations that firmly supported the nation's rapid economic growth and technological catch-up until the late 1990s ran into a roadblock after the Asian Financial Crisis, which proved the concept of a government driven fast-follower policy can no longer keep up with the innovation pace of an economy reaching its mature phases of industrialization.

Apparent handovers of publicly sponsored R&D efforts to the commercial sector resulted in a lopsided increase in experimental development and applied research, in which depreciated the significance of basic research. In this aspect, insufficient commitment to basic research resulted in the country lagging behind not only in cutting-edge advanced technology but also incapable of localizing critical core technologies required for producing components and modular products. In order to overcome technological insufficiencies, the country's manufacturing sector has become excessively dependent on foreign technology and components. As a result, expenses payed to foreign sources that substitute local production has become higher in more high tech industrial sectors. The highly dependent situation applies even more directly to the defense industrial sector.

The national innovation system of Korea, reflected through its S&T development and support architecture, shows indications of inefficiencies caused by vertically aligned bureaucratic stovepipes that consequently created barriers in flawlessly implementing interagency coordination. The structural challenges over the innovation construct of the defense R&D sector within the national innovation system extends to this argument regarding the restraints in conducting coordinated research with other GRIs. The defense R&D budget carves out almost 15% of the national R&D budget, which makes weapon system development and core technology programs the single most committed publicly funded projects where government resources are invested. However, with the center of gravity placed on weapon systems development programs, defense R&D exerts very little focus on basic research and core technology development, which becomes the reason for high dependence in foreign technology and components. The restrictive control measures and proprietary rights dictated on foreign defense technology also serves as a self-imposed constraint on localization efforts.[452] The obstructive and secretive nature of defense R&D has placed the sector disconnected from the overall national innovation architecture, which resulted in redundancies and overlaps on the distribution of resources. Despite the accession of defense R&D into the National Science and Technology Commission (NSTC) in 2007, the

[451] Gordon Lubold, "Is South Korea Stealing U.S. Military Secrets?," Foreign Policy, October 28, 2013.
[452] 송위진, 국가기술혁신체제 관점에서 본 국방연구개발의 발전 방향, 대전발전포럼, 제 18 호, 2006, p. 16.

actual incorporation between the two sectors still seems to be far off. NSTC did not have oversight on defense R&D programs until 2017 when the Commission started to preview initial planning documents. But even so with the NSTC preview process in place, strong enforcement measures have not been instituted for execution yet.

Such disconnect emerges from the upper tier of the R&D structure where the defense structure is not fully integrated into the national R&D construct, starting from the planning stage. The Total Roadmap on the National Mid-Long Term Investment Strategy (TRM), administered by the NSTC, does not include the defense sector. Neither did the TRM include the program components of the Civil-Military Technology Partnership in the lower tier structure, which is the most relevant defense program connected with R&D programs managed by other agencies. Because of these poor links, the CMTP also suffers from disassociation with civilian technologies caused by incompatible technology standards. The Midterm Defense Program, which contains the 5-year defense expenses in Force Improvement Programs, has never had any well-planned ties with government initiated R&D programs ran by other ministry-level programs either.[453] The next chapter juxtaposes this situation to the aircraft-manufacturing sector.

[453] 홍성범, 과학기술력 강화를 위한 국가과학기술자원 총동원체제 구축, STEPI Insight, Issue 60, 2010, p. 7.

Chapter 5. The Aircraft Manufacturing Sector: Background and National Level Innovation Systems

5.1. Overview of the Korean Aircraft Manufacturing Sector: Industry Performance and Characteristics

The magnitude of aircraft-manufacturing in terms of scale, scope, and technology sophistication, has branded the sector as a strategic industry where the Korean government selected and nurtured national champion firms by building capacities and technological competence in furtherance of upgrading the country's industrial portfolio. For national security reasons, military force requirements have primarily driven the market demand in aircraft manufacturing. Although the industry has recently diversified into commercial businesses based on the technological progression and achievements obtained from the past fifty years of engineering and manufacturing, commercial aviation had marginal contributions to the overall industry construction and parallel technological development. Considering the minuscule footprint of the commercial sector into sectoral development, this chapter gives higher attention on government driven military build-ups in aircraft manufacturing.

Because of the exorbitant price tag associated with military aircrafts, it is imperative to synchronize these defense acquisition programs with development and manufacturing capabilities over a mid-to-long term industrial outlook in order to sustain production lines while fulfilling national security objectives. Unfortunately, defense acquisition programs were never in synch with industrial capacities, where systemic disconnects in policy coordination caused major structural confusion in the absence of an appropriate government adjudication mechanism. Government inefficiencies impacted negatively on production line sustainment and technology accumulation. Especially, frequent delays and cancellations of military aircraft programs caused by poor interagency coordinating efforts and ineffective decision making entailed uncertainty and discontinuity in military aircraft programs. Continued disagreements between military and industrial authorities were the source of organizational discrepancies, because the military preferred rapid procurement and internationally certified products proven from various deployment records, whereas industrial authorities put high emphasis on building industry capacities. In this regard, the military always placed high priorities on foreign procurement while industrial authorities prioritized on indigenous development.[454]

Starting in the 1970s with an ambitious strategic vision to fulfill national security objectives and industrial development aspirations, the Korean government launched the aircraft industry as part of its efforts to build a sound defense industrial base. Because of its short history compared to advanced industrial countries, knowledge and investment in consideration to the domestic market demand specific to the aircraft sector was insufficient. However, with the growing military requirements in aviation assets, the prospects of industrial growth were overly covered with wishful thinking. Nevertheless,

[454] 이기상·이무영, "우리나라 항공기 산업의 발전 과제와 대책," 항공산업연구, 제 68 집, p. 14.

short-term government visions and disconnected program synergy characterized the grim reality, which encapsulates the sluggish growth of the aircraft industry to date.

Despite the series of government support packages and industrial investments, the foundations of the aircraft sector remained brittle and inconsistent. In the heist of the aircraft-manufacturing sector during the 1990s, the production output stayed at KRW 393 billion, which accounted for only 0.2% in proportion against the overall manufacturing output. Although in other domains of the industry, the aircraft sector was one of the fastest growing sectors between 1986 and 1992, marking a growth rate of 35.5% compared to 13.1% of the overall manufacturing output. Foreign exports also showed remarkable growth rates during this period, marking approximately 20.8% compared to the overall manufacturing industry average of 13.1%, which showed a fast growing business sector within the domestic economy. Nevertheless, the inside story to these statistics presents a different dimension because the total manufacturing output of the aircraft sector started in only 0.05% against the overall manufacturing sector. In this aspect, the comparative growth factors appeared relatively higher than other industrial sectors. Overall foreign exports of the aircraft sector marked 0.2% in proportion of the entire overseas exports, whereas imports of aircraft components and related technology accounted for 2.4% of the entire foreign imports.[455]

Rank	Country	2008-2009 Output			Business Area
		Business Sales ($ billion)	Proportion in Global Performance	Employment (10,000)	
1	USA	201.2	46.8%	64.3	Aircraft/Engines
2	France	53.1	12.3%	16	Aircraft/Engines
3	UK	43.1	10%	15.5	Engine/Components
4	Germany	32	7.4%	10.6	Components
5	Canada	23.6	4.5%	8.3	Mid-size
: :	: :	: :	: :	: :	: :
8	Japan	11.6	2.7%	3.1	Components
9	China	8	1.9%	-	Aircraft/Engines
: :	: :	: :	: :	: :	: :
16	Korea	2	0.5%	1.1	Trainer/Components

Table 20. Global Aerospace Industrial Ranking, adopted from Aerospace Industry Association Facts and Figures (2014), Aerospace and Defense Facts and Figures (2014)

As for the aircraft industry's current performance status, the picture is nowhere different to the performance feature represented 25 years ago. As shown in Table 1, aircraft manufacturing in Korea constitutes only 0.5% of the global aircraft manufacturing output, in which the military sector comprises 69% ($1.35 billion) of the total industrial output compared to 20 – 30% of other advanced industrial countries. Unlike other competitive business areas such as automobiles ($119 billion), general machinery ($48 billion), and shipbuilding ($37 billion), the annual sales of the aircraft-manufacturing sector meagerly shows less than $2.1 billion.[456]

[455] 산업연구원 항공기산업 분과위원회, 2000 년대 첨단기술산업의 비전과 발전과정-항공기산업, 1994 년 12 월
[456] Korea Aerospace Industries Association, 2010 Aerospace Industry Performance Statistics, February 2011.

Million US Dollars

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Production	1,269	1,110	1,009	1,152	1,202	1,366	1,243	1,187	1,398	1,515	1,861	1,945	1,970	2,430	2,358	2,697	3,606	4,343	4,886
Domestic Sales	3,112	1,972	1,831	2,005	1,744	2,468	1,951	2,226	2,911	4,161	4,393	3,765	3,170	5,141	5,930	5,193	5,766	6,408	7,215
Exports	212	313	258	312	371	340	292	371	389	472	597	772	760	1,000	1,019	1,366	1,652	1,985	2,563
Imports	2,055	1,175	1,080	1,165	913	1,442	1,000	1,410	1,902	3,118	3,129	2,592	1,960	3,711	4,591	3,862	3,812	4,050	4,892

Table 21. Aircraft manufacturing Performance Statistics

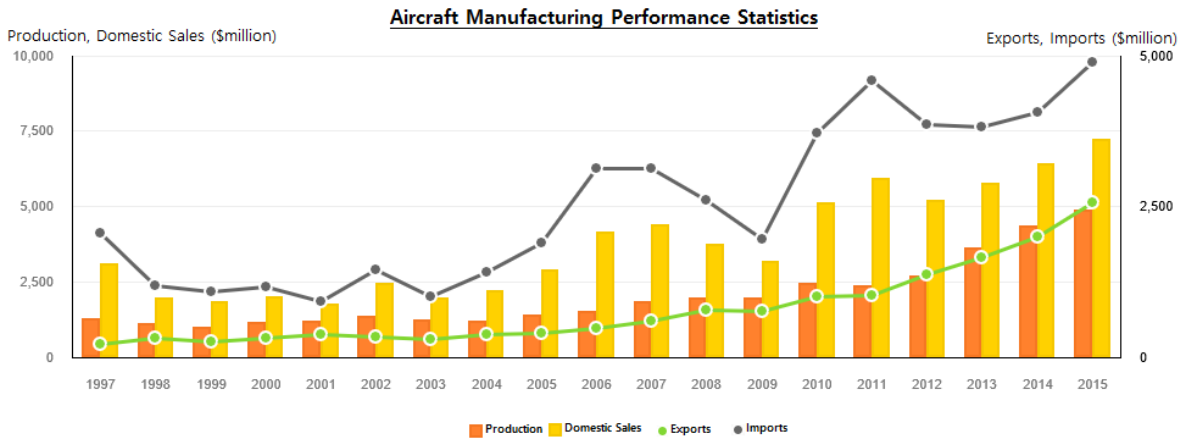

Figure 16. Aircraft manufacturing Performance Statistics, 산업통상자원부 항공산업 전망 통계

Production capacity continues to grow, especially starting with 2010 as the industry initiated a number of government projects such as the Korea Utility Helicopter and T-50 Golden Eagle Advanced Trainer. Production capacity remains over $20 billion a year. The commercial sector also shows a parallel growth rate, which proportionately reduced the industry's excessive reliance over military programs. Commercial production output contributes nearly 40% where the military sector contributes about 60% of the total industry output. However, there are apparent trade gaps in the balance sheet between imports and exports. As of 2015, overseas exports of Korean aircraft products mark about $25.6 billion whereas imports of foreign products mark around twice as much of overseas exports ($49 billion), showing a near trade deficit of $24 billion.

The aircraft-manufacturing sector strived to diversify its military focused business programs to accommodate more commercial aviation outputs. Military programs are excellent force multipliers because it attracts government resources and technology development efforts sufficient to build up scale and capacities for a technologically complex capital intensive program. Considering the 20-year life cycle of a military aircraft, the production output rapidly recedes after the initial batch of production concludes. Therefore, in order to sustain the production capacity, it is crucial that the industry diversifies into other sectors of aircraft manufacturing, namely in the field of commercial aviation.

Programs	Program Cost ($ million)	Output percentage (%)
T-50 Production	367	18.6
FA-50 Development	68	3.5
KHP Development	240	12.2
KT-1 Production	76	3.8
F-15K Subcomponents	32	1.6
Commercial Aviation Components	468	23.8
Engine Maintenance	267	13.5
Airframe Maintenance	152	7.7
Space Programs	124	6.3
Unmanned Aerial Vehicles	4	0.2
Other	172	8.8
Total	1,970	100

Table 22. 2009 Aircraft Production Output, 항공우주 제4권 1호, 2010, p. 10.

In this regard, aircraft maintenance, which considers maintenance work performed on engines and airframes, has become a growing business sector in this field. The total output in this sector in 2009 marked $420 million, or about 22% of the entire production output, and growing. Thus, the growth potentials of the Maintenance, Repair, and Operations (MRO) market are auspicious. In a related performance report, because of the scale and complexity of aircraft manufacturing, the field is considered less profitable in operating returns compared to other machine sectors such as automobiles or general machinery. However, the sector definitely appears to be in a growth pattern in comparison to other machine sectors. Contributed from these prospects of growth, aircraft manufacturing is generally considered a likely growth sector despite its relatively small scale.

Business Area	Profitability		Growth Potentials	
	Operating Profits Ratio	Net Profit Ratio	Growth Rate of Sales	Growth Rate of Operating Profits
Aircraft	2%	2%	10%	32%
Machinery	8%	5%	5%	10%
Automobile	5%	5%	3%	4%

Table 23. Profit rates and growth rates of domestic manufacturing industry, 항공기산업 경쟁력 강화방안 (산업은행 2009)

Because of the fact that military programs dominate the Korean aircraft-manufacturing sector, the industry's production output had fluctuated based on program schedules. According to Figure 2, there were two primary periods when the industry plummeted into negative growth rates. The industry became stagnated by the Asian Financial Crisis of 1997 as commercial aviation was directly impacted from the crisis as well as the military sector went through extreme budget cuts and program cancellations. It was a period when major military aircraft programs entered into finalization phase. After a slight recovery from the crisis, the industry entered into another recession in 2002 after the supplementary production of the KF-16 (KFP-II) and the KT-1 program concluded, compounded by decreases in exports due to strong exchange rates of the Korean Won.

Other than the two turbulent seasons, the industry generally performed with an annual growth rate averaged around 6.9% throughout the years. The essential cause of these industry performance outcomes are attributed to the fluctuating demand pull of the domestic market. Without a sizable commercial aviation supply chain, the industry mostly relies on military programs, which immediately becomes short of business after program deliveries conclude. Based on these growth patterns, a conservative assessment conducted by the Seoul based Aerospace Industry Research Institute forecasted the production output of the industry would grow to $3.3 billion until 2020, about threefold since the time of the analysis was conducted in 2009. The estimates were under the premises that the government continues to support the industry by complying with its policy commitments to nurture the sector sufficient to compete with global standards.[457]

The industry's first boom period in 1996 was attributed to the production outrun of the Korea Fighter Program (F-16 license manufacturing). After a steep decline due to the Asian Financial Crisis, the growth rate recovered in the early 2000s as the government decided to produce 20 additional KF-16 fighters to sustain the production line of the aircraft industry. After undergoing continued fluctuation in production and growth rates, the industry reached its second boom in 2005 and 2006 as the number of government orders for the T-50 advanced trainer started running in and component exports generated from the F-15K offset and other commercial aviation programs accelerated industry growth. However, the industry growth rates entered into another steep decline as the T-50 production concluded. Since then, the Korea Utility Helicopter program (Surion) entered the engineering and manufacturing phase with a prototype introduced in 2008, followed by full rate production afterwards. The military aircraft programs wait listed for either development or production to date include utility helicopters (KUH Surion), FA-50 light attackers, Light Attack/Commercial Helicopter (LAH/LCH), Mid-tier Unmanned Aerial Vehicle (MUAV), Korea Fighter Experiment (KF-X) and so forth.

457 최영진, 이인규, 이경태, "국내 항공산업 통계자료의 시각으로 분석한 항공산업발전기본계획," 항공경영학회 추계 발표 논문집, 2010, p. 67.

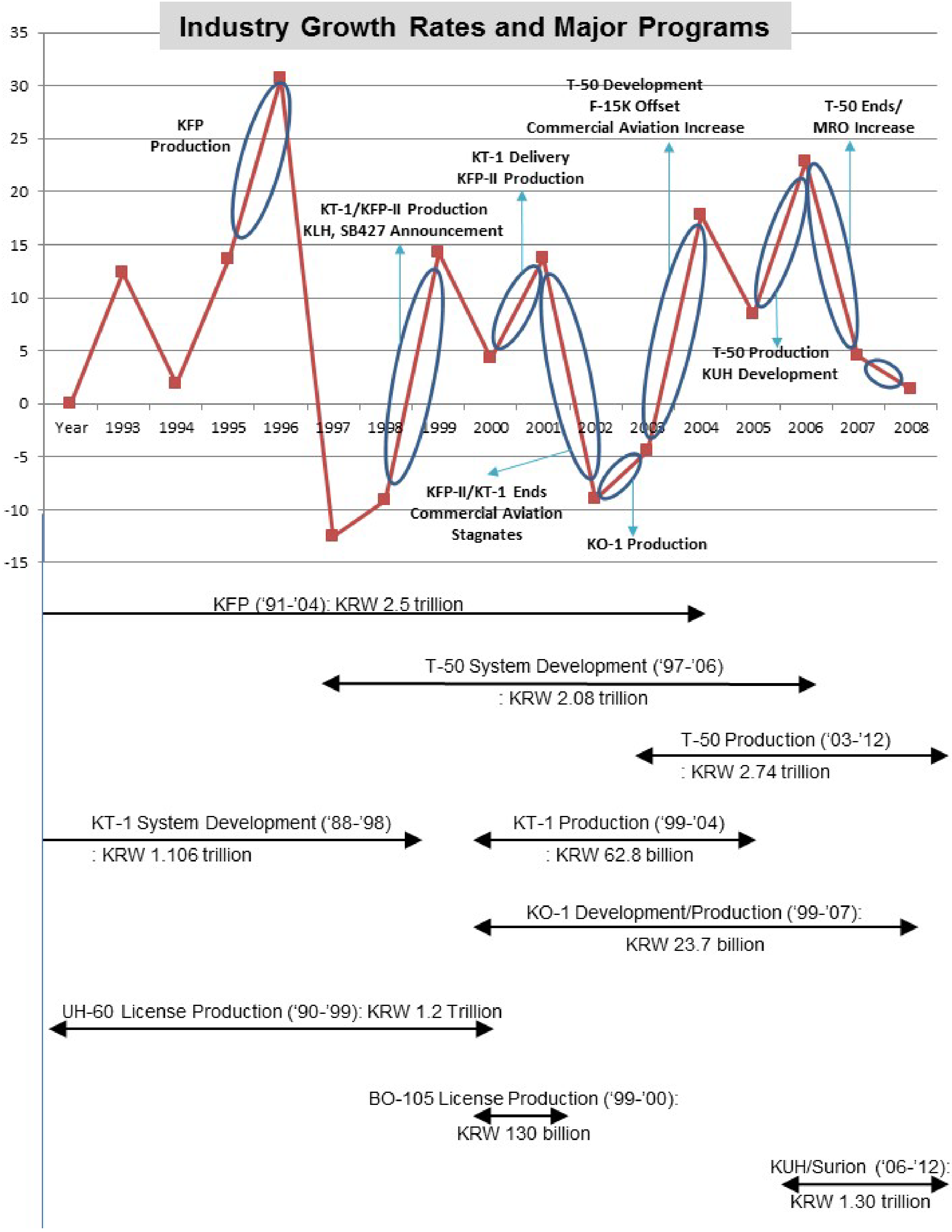

Figure 17. Industry Growth Rates and Major Programs,
Reproduced from 항공산업 통계, Korea Aerospace Industries corporate materials

5.2. Technological Competitiveness

In a nutshell, the Korean aircraft-manufacturing sector show high competitiveness in manufacturing air frames and fuselage, and product assembly works but show low technical competence level in system design and development. The overall competence level was built up from license production and subcomponent production arrangements with advanced aircraft manufacturing firms from the U.S. and

Europe in the 1980s and 1990s.

In between the capacity build up process, Korea started to develop its own indigenous version aircrafts in fixed wing and rotorcraft such as the KT-1 Basic Trainer, T-50 Advanced Trainer, and the Surion Utility Helicopter. From this point, the country accumulated experiences and skillsets in a wide range of technical fields from concept/system design to production technology. According to a technical survey conducted by the Defense Agency for Technology and Quality in 2012, the country's overall product assembly and manufacturing works reached almost 90% in technology competitiveness levels compared to global advanced technical standards. On the other hand, system integration technology was comparatively rated 60%, system design 70%, test and evaluation 70%, flight safety certification 35%, and so forth.[458]

System design capacities were acquired through the development of major military aircrafts in conjunction with a series of feasibilities studies over developing midsized business jets and associated safety certification systems. In this regard, interpretation techniques to comprehend aircraft system design and manufacturing works have stood on an equal footing with global standards, but the optimization technology in relations with system design and integration works still remain in mediocre levels.

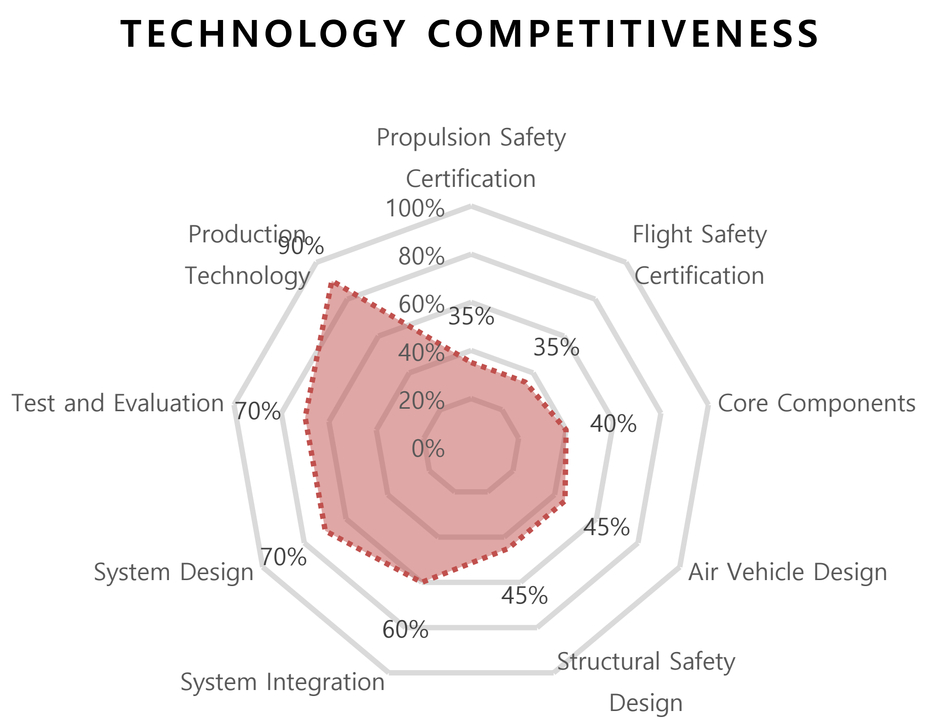

Figure 18. Technology Competitiveness of Korean Aircraft Manufacturing Compared to Advanced Industrial Countries

According to a 2010 study conducted by the Korean National Defense University over military

[458] 한국산업기술진흥원, 2011 산업기술로드맵: 항공산업, 지식경제부, 2012. 3., p. 70.

aircraft-manufacturing sector, the sectoral effectiveness and impact towards the overall national industrial output shows some varying indicators in terms of production, value added, importation, and employment. Considering production aspects, the aircraft-manufacturing sector show similar indicators to other general manufacturing sectors, while show high performances against service sectors. In the value added category, aircraft-manufacturing exhibits similar standards towards other general manufacturing sectors, but falls substantially behind the service sector. Under the import inducement category, aircraft-manufacturing displays the highest rate compared to other industrial sectors overall. Such aspect is a result of high dependence on foreign technology and components, which comes in line with the technology competitiveness standards featured in the above diagram. However, the highly advanced and complex nature of aircraft-manufacturing supported by broad production networks consequently induces higher employment levels compared to the general manufacturing sector. In order to overcome the weaknesses identified in this analysis, the study recommends to increase domestic R&D instead of overseas direct equipment purchases, and to expand localization rates of core technology and components. Giving priority to contracting domestic support industries through various public sponsorships in the form of easing technology transfer and diffusion processes was recommended as a viable solution.[459]

	Production Inducement Coefficients	**Value Added Inducement Coefficients**	**Import Inducement Coefficient**	**Employment Inducement Coefficient**
Aircraft Manufacturing	2.0764	0.553	0.447	12.3
General Manufacturing	2.072	0.556	0.347	5.4
Service Sector	1.712	0.819	0.181	16.4
Construction Sector	-	-	0.268	11.6
Overall Industry	1.937	0.666	0.334	10.4

Table 24. Inducement Coefficients Compared with Other Industrial Sectors
Source: 국방대학교, 함정 항공전력 방위력개선사업의 경제적 효과분석, 2010년 10월.

Before diving into industry specifics, the next section looks into the unique developmental trends by reviewing the history of aircraft manufacturing in Korea.

5.3. Daybreak of the Korean Aircraft-Manufacturing Industry: Individual Rushes by Military Services

A typical development pattern of post-World War II aircraft manufacturing for catch-up industries can be highlighted in three categories. One is the Japanese case where the U.S. Military designated major Japanese industrial sites as forward operational depot level maintenance services, which resulted in building major technical infrastructure required to enter into the aircraft market.

The second case is where developing economies such as China, Taiwan, and Brazil, have accumulated aircraft related technical skills and knowledge first through building other sectors of the

459 국방대학교, 함정 항공전력 방위력개선사업의 경제적 효과분석, 방위사업청 연구용역보고서, 2010년 12월 10일, pp. 144-148.

economy, and later entered into the aircraft manufacturing business. A last but very rare case is when developing countries like Indonesia entered into the global value chain first without the required infrastructure, with hopes of business opportunities spilling over into other sectors of the economy under the premise that there would be sizeable foreign direct investments and outsourcing programs from multinational corporations and prime contractors.[460] The Korean case is more of a mix between the first and second case, where the required knowledge and skills were transferred through U.S. military channels in the early phase, but did not evolve into a business enterprise until three decades later.

5.3.1. Colonial Gestation and Occupational Foundations

The early start of the Korean aircraft industry finds its origin from the Japanese Occupation period, when Japanese aircraft manufacturers sought asylum from continued aerial bombardment threats of the U.S. military during the Pacific campaign of WWII. On July 1942, the Japanese Governing General founded the Chosun Airplane Production Company (朝鮮飛行機製作所) at Pyeongyang, and on October 1944, the Japanese Occupation Force Command partnered with a local Korean company to create the Chosun Airplane Manufacturing Corporation (朝鮮飛行機工業株式會社) south of Seoul, which mainly focused on manufacturing airplane components.[461] Actual production of an aircraft as a major end item did not happen until the Japanese Imperial Navy established the Chosun Aircraft manufacturing Corporation (朝鮮航空工業) at Busan area in February 1944, as part of relocating the manufacturing facilities of the Nakajima Aircraft Company (中島飛行機株式會社) from mainland Japan. The Chosun Aircraft Manufacturing Company produced three airplanes for the Imperial Navy.

Unfortunately, after the end of the Second World War and the ensuing disarmament of the Japanese Imperial Army by the US occupation force, these aircraft companies were dissolved and the production skills and knowledge acquired from this brief manufacturing experience never continued into the liberated Korean economy afterwards.[462] A small portion of the technicians from these companies were later employed into the maintenance depots of the Korean Air Force and Navy but the numbers and contributions to the technical foundations remained marginal. Additionally between 1946 and 1949, the U.S. Far East Command and the American Mission in Korea turned down the Korean Government's request for larger military aid, including aspirations for building a modern air force, concerning an escalation of hostilities in the Korean Peninsula.[463] Thus, as soon as the supporting public entity pulled out its resources from the program, the skills and technical pool created during last

[460] Jorge Niosi and Majlinda Zhegu, "Multinational Corporations, Value Chains and Knowledge Spillovers in the Global Aircraft Industry," International Journal of Institutions and Economies, Vol. 2, No. 2, October 2010, p. 113.
[461] 조태환, 한국의 항공기 개발 역사를 돌아보며, KSAS 매거진 제 3 권 1 호, 2009 년 1 월, p. 16.
[462] Airportal webpage, Ministry of Land, Infrastructure, and Transportation, http://www.airportal.co.kr/life/history/unh/LfUnhUr005.html, accessed September 8, 2015.
[463] Steven L. Rearden, History of the Office of the Secretary of Defense Volume I: The Formative Years 1947-1950, Historical Office of the Secretary of Defense, Washington, D.C., 1984, p. 265.

three years of the occupation had rapidly disappeared with no further chances of technical sophistication.

As a typical progression of technology development and maturation, repair and maintenance work provided the technological foundations of the earliest Korean aircraft manufacturing before the Korean War, although the size and scope were considered insignificant, in which was simply regarded as machinery and tools. The Japanese trained technicians were neither qualified nor technically compatible to repair aircrafts of US-origin because of the different aircraft design configuration and structure. Language barriers also presented significant challenges to these technicians since all technical manuals were written in English. Small repair shops organized under flight lines, merely capable of conducting preventative maintenance and field level maintenance work, was the actual reality of the South Korean technological background in aircraft manufacturing opposed to the corps of technicians readily organized under the North Korean People's Army and skillfully trained in various engineering specialties.

Air Force: Setting the Foundations

The introduction of aircraft manufacturing technology came into reality by the breakout of the Korean War when the Korean Military tremendously expanded its air component with the assistance granted by the US Government. From a mere size of only twenty trainers and liaison aircrafts, including 10 North American T-6 Texan advanced trainers acquired from Canada, the Korean Air Force grew to a size of 110 aircrafts at the end of the war, with 79 fighter bombers under one organized fighter wing and three combat squadrons equipped with F-51D Mustang Fighters. Technical manuals of US aircrafts were passed down to Korean technicians by the grant assistance provided by US military advisors stationed in each fighter wing as flight instructors and technical advisors.

Also, in the process of enlarging the engineering corps in aircraft repair and maintenance to fulfill the urgent needs of technical expertise in the military during the Korean War, the military mobilized scientists and engineers from local colleges in order to facilitate the learning efforts. As part of this recruitment process, on 20 December 1950, the Korean Air Force mobilized 423 scholars and engineering students from colleges to fill in critical technical billets at Engineering Departments of the Air Force Headquarters and repair depots, which later contributed to the modernization of the Korean Air Force. The scientists and engineers recruited during the Korean War period later served in influential positions throughout the Korean society such as Prime Ministers, S&T Ministers, college chancellors, and so forth.[464]

During this period, the Korean Air Force became keenly aware of the apparent gap in air power between the South and North, thus drafted the Air Force Three Year Build-up Plan in late 1951 with an objective to build an air force of 300 F-84 Thunder-Jet fighter aircrafts organized under 4 combat fighter wings until March 1955.[465] Support elements for this force structure included ground based command

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464 조태환, p. 19.

465 http://www.archives.go.kr/next/search/listSubjectDescription.do?id=008670&pageFlag=

and control facilities, airborne reconnaissance and control, transport, supply and maintenance, and various organizational components to train the future workforce of the Korean Air Force, at which the total program would gross about USD 80 million. However, the economic insolvency of the Korean Government compelled the Korean Air Force to seek funding support through U.S. grant aid channels, which at first was not supportive at all of such ambitious progression. The objective of U.S. military grant aid to Korea at the time was to build one combat fighter wing and ten military bases. In the meantime, the U.S. Air Force will reinforce into the Korean Peninsula in times of escalated hostilities. After a series of negotiations and executive level exchanges, the two countries reached to a compromise in December 1952 and agreed to build a much more advanced tactical strike capability in the Korean Air Force, of which accomplished the original goal drafted by the Korean Air Force.[466]

The most significant turning point during the warring period in terms of acquiring aircraft manufacturing knowledge and skills was the establishment of the aeronautical repair depots. At first, the 80th Aeronautical Maintenance Depot established in 1951 during the heist of the Korean War was the conduit where the country acquired the skill base for knowledge and experience in repair and overhaul by performing maintenance work on the P-51 Mustang fighter and Cessna L-19 liaison and observation aircraft. The U.S. military through its advisory elements stationed in Korea provided substantial technical knowledge and skills for performing depot level maintenance work on the P-51 Mustangs during this period. The significance of the technology transfer was attributed to the transitioning of the U.S. Air Force fighter aircrafts from turboprop engines to jet engine fighters, enabled by the introduction of the F-86 Saber Fighter. Thus, the technology for turboprop P-51 Mustang Fighters became rapidly obsolete in the U.S. Air Force, but still considered critical to fight the war in the Korean Peninsula, which consequently facilitated the decision of the top U.S. military brass to transfer substantial P-51 related technology to the Korean Air Force.[467] The 80th Aeronautical Maintenance Depot furthermore consolidated the disseminated technical training functions from various airfields in 1952, with the main effort absorbed from the 22nd Air Reconnaissance Squadron.

By the time of 1953, technical standards of military depots reached the level capable of performing maintenance work on the L-19 Bird Dog liaison and observation aircraft including engine overhaul works. Several replication works on the design and configuration of the L-19 followed until October 1953 when the Air Force Technical Engineering School revealed the first Korean designed and manufactured twin seated trainer aircraft called Rebirth (復活號). The various engineering backgrounds from technicians educated and trained by the Aeronautical Department of Seoul National University were the leading figures at the Air Force Technical Engineering School that had the technical expertise to manufacture aircrafts. But most of the repair tools and parts during this period were provided through U.S. military grant aid channels, thus the Korean Air Force was not in full shape to repair aircrafts under

466 국방군사연구소, 국방정책변천사 1945～1994, 1995.
467 오원철, 한국형 경제건설 제 5 권, 기아경제연구소, 1996, p. 474.

its force structure at this time. In order to overcome its excessive reliance on U.S. military assistance, the Air Force Technological Research Laboratory was created under the depot to localize the manufacturing of these tools and parts, in conjunction with conducting research on special purpose equipment or devices. In early 1962, under the full assistance provided by the U.S. military, the largest maintenance depot in East Asia at the time was constructed at Daegu Air Base, and was named the 81st Aeronautical Maintenance Depot.[468] At this point, the 81st Aeronautical Maintenance Depot obtained the skill level of repair and overhauling of L-19 aircrafts, which later was awarded depot level maintenance work from the U.S. Air Force on aircrafts with similar nomenclatures, which was previously subcontracted by Japanese or Taiwanese firms as regional maintenance points.[469] This was the first time the Korean aircraft manufacturing establishments contracted foreign sources orders, thus a source of revenue generated outside of its routine boundaries.

With the engineering skills accumulated from the decade long experiences in repair and overhaul work, the 81st Aeronautical Maintenance Depot, in 1972, managed to localize the manufacturing of the two-seated Plazmany PL-2 trainer aircraft, named Sparrowhawk (*Saemae*) in Korean.[470] The significance of this achievement was that the PL-2 Sparrowhawk became the first metallic aircraft manufactured by Korean engineers. The 81st Aeronautical Maintenance Depot manufactured four Sparrowhawk prototypes, but the program did not mature into full rate production and deployment.[471] The Sparrowhawk, just like many other locally manufactured aircrafts that came before, simply remained as a prototype, although the achievement was highly appreciated in terms of advancement in repair and overhaul work. Nevertheless, Sparrowhawk never entered into full rate production and deployment into the Korean air fleet.

Navy: Lonesome Aspirations to Build an Independent Air Wing

However, the situation developed slightly different for the Korean Navy. As briefly mentioned from previous paragraphs, the technical assistance provided by the United States military was essential in the earliest stages of aircraft manufacturing in Korea. However, the contribution was often contradicting, and in sometimes restrictive. The US efforts in military assistance was merely focused on maintaining the status quo in the Korean Peninsula, therefore was reluctant to provide a capability to the South Korean military considered substantially offensive. Although the US military provided unconditional technical support during the Korean War, the volume of support obviously dissipated after the end of the war. This was especially apparent in building-up the Korean Navy. The U.S. Naval Advisory Group, which was the service component that provided advisory services to the Korean Navy, focused more on building naval vessels such as littoral combat ships whereas gave little, or almost no

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468 Ibid., pp. 475-477.
469 김성배, 항공기산업 발전을 위한 절충교역제도 활용전략, 국방논집 44, 1998 년 12 월, p. 258.
470 신인호, “훈련기에서 전투기까지: 세계 12 번째 항공기 개발국가로 우뚝서다,” 과학과 기술 2010 년 8 월, p. 50.
471 국방부, 국군 50 년사 화보집, p. 181.

attention to naval aviation for the Korean Navy, since aviation assets were generally considered a more offensive capability. Neither did the Korean Government considered to build naval aviation capabilities.[472]

Interestingly, despite the lack of higher state level assistance, the Korean Navy in the 1950s demonstrated stronger willingness to build a more indigenous aircraft manufacturing capacity than other military services. The efforts were mainly based on collecting scrap components and pieces from disabled US military aircrafts gathered from crashed combat sites, and from Army and Air Force warehouses that stored grounded aircrafts disposed to become scrapped. During this period, the Korean Navy initiated several attempts to overhaul airframes for modified end-use purposes, including the rebuilding and modification of a crashed and destroyed Texan AT-6 into an amphibious aircraft named 'Sea Eagle' (海鷲號). With the help of 14 technicians formerly trained by the Japanese military aviation authorities during the Colonial periods, the Texan AT-6 was overhauled with additional aluminum floats and transformed into the first amphibious patrol seaplane of the Korean Navy. Several modification works followed until 1954 when the Korean Navy designed a patrol aircraft called 'Sea Vigilance' (誓海號) or codenamed 'SX-1' that used a spare engine from a L-5 liaison aircraft with additional airframe pieces collected from Japanese sources.[473] Unfortunately, with a lack of anti-salinity coating technology, Sea Vigilance suffered serious corrosive damages from the salty seawater, and was disposed of after nine month of its commissioning.

Utilizing the manufacturing experiences acquired from the two programs, the Navy created its first fully designed and armed amphibious aircraft called 'Command of the Sea' (制海號) or 'SX-3' out of the wreckages collected from a L-19 aircraft, which successfully completed its maiden flight on March 30, 1957.[474] The significance of SX-3 was that it applied anti-salinity coating works adopted from coating technologies for vessels, thus made it capable of effectively performing maritime patrol missions with improved resistance against seawater.[475] Based on the design and manufacturing skills acquired from the SX-3, the Navy produced a replicated version titled 'Control of the Sea' (統海號), or SX-5 and deployed it for patrol and reconnaissance missions on December 1958.[476] The Korean Navy during this period did not have the resources to sponsor research and development for its aviation fleet. The defense budget allocated for naval research primarily focused on repair and depot maintenance of combat vessels, whereas aviation assets received no official budget at all. Furthermore, the majority of U.S. military aid on the transferring of technical knowhow and depot structures related with aircraft technology was concentrated primarily on the Korean Army and Air Force, whereas aircraft

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472 박동찬, "주한미군사고문단(KMAG)의 한국전쟁 인식과 대응," 군사 제 79 호 p. 112

473 http://demaclub.tistory.com/2791

474 A preceding program titled 'SX-2', which was a landbased aircraft, concluded unsuccessful as it was crashed during test piloting in 1955.

475 https://milidom.net/warhistory/4690

476 Dongailbo, naming ceremony for single propeller aircrafts (Control of the Sea) produced by naval engineers, 1958. 12. 24.

technological assistance to the Navy was almost nonexistent. In order to overcome these circumstances, the Chief of Naval Operations, Vice Admiral Jeong Geun Mo, announced a series of Navy Directives to establish the Navy's Aviation Research Division under the First Research Department of the Naval Science and Technology Laboratory. The Division continued to develop air assets under the leadership of Lieutenant Commander Cho Gyeong Yeon, the pioneer figure of Korean naval aviation that previously administered the manufacturing of all naval aircrafts mentioned above. The technicians under the Division attended training programs provided by the Army and Air Force technical schools and maintenance depots to learn the technical skills and experience passed down from the U.S. military. The laboratory was more of a technical schoolhouse to train the Navy's maintenance workforce rather than conducting genuine R&D work, thus was not a scientific research branch in reality and neither did it receive formal funding from the central government. These difficulties compounded the very existence of the research lab, and in 1958, the research lab was forcefully closed and consolidated its functions to the Navy General Maintenance Depot.[477]

Naval aviation in the 1950s was at first under the control of the fleet command and not a separate entity capable of conducting independent missions until the establishment of the Fleet Aviation Service on October 1957. The aviation service operated five aircrafts – SX-3, SX-5, three L-19 aircrafts assembled by the Navy – which performed patrol, rescue, airlift, and training missions. However, the U.S. Military Advisory Group known as KMAG refused to provide additional logistical support for these aircrafts, and later demanded to dispose of all aircrafts that did not qualify U.S. government technical standards. The primary reason was based on concerns over public safety, mostly under the perspectives that the U.S. did not wanted to hold responsibility over substandard aircrafts with no proven safety measures. All five aircrafts operated by the Fleet Aviation Service were US-origin defense articles, collected and assembled from disposed aircrafts, but did not obtain proper licenses or qualify under the technical standards of the US Government.[478] In order to avoid the entire destruction of its aviation assets, the Navy decided to transfer all aircrafts and its maintenance units to the Korean Coast Guards on February 1961, and shut down the Fleet Aviation Service in 1963. The aviation fleet of the Korean Navy did not return to the Navy's organizational branch a decade later until 1973, when the Navy reintroduced the Naval Aviation Service into its operational routines.

5.3.2. Ambitious but Mediocre Transition into an Intermediate Level Manufacturer (1970s ~ 1980s)

Aircraft manufacturing in the 1970s was initially coupled together with missile development. On 15 September 1972, the Presidential Office drafted a secret missile development plan, covered under the name of "Aircraft Industry Promotion Plan." The intent was to obtain a technological capability to

[477] http://gdnews.kr/news/article.html?no=2877
[478] 해군본부, 해군항공 50 주년을 맞이하여, 2006.

build an intermediate-range rocket until 1974, intermediate range surface-to-surface guidance missile until 1976, and a long-range surface-to-surface missile until 1979. The short-term target program was to build a missile with similar performing features to the Nike Hercules surface to air missile used by U.S. and NATO armed forces. The primary forces driving this program originated from the continued North Korean offensive ground threat in the midst of a potential U.S. military retrenchment from the Peninsula. Thus, the need to build a self-sufficient defense capability was becoming an urgent priority for the Korean government at the moment. In order to execute this secretive mission, huge volumes of resources were committed to acquire equipment and tools for research, test flight, manufacturing facilities for propulsion systems, and so forth. The Daejeon Machinery Depot at Daejeon drew 500 scientists and engineers to support this ambitious development task.[479]

Because of the low technical skills and infrastructure at the time, most of the technology was acquired through U.S. military aid programs. For instance, a team of ADD researchers was dispatched to learn aircraft design skills and related aeronautical engineering information at Northrop and McDonnell Douglas. Essentially, the purpose was to acquire requisite knowledge to indigenously build surface-to-surface missiles, since the propulsion related aerodynamics between aircrafts and missiles were basically identical. About 20 box loads of technical documents and engineering dynamics were obtained at the end of the research.[480] At this point, the U.S. Government also provided a team organized under the Advanced Research Program Agency (ARPA), also known as the Hardin Team based on the name of the project leader Clyde Hardin. The U.S. Army Guidance Munitions Laboratory located at Huntsville Alabama provided additional support by allowing ADD scientists to visit as resident researchers and learn the engineering essentials to build missiles. The Korean government also dispatched a team of engineers from ADD to the McDonnell Douglas Huntsville facility, the original equipment manufacturer of the Nike Hercules Missiles. Throughout this effort, Korean scientists obtained critical designing knowledge in wind tunnel, inertial navigation and aerodynamics, and so forth.[481]

However, after six months into acquiring design information and learning technical skills at various U.S. institutions, the U.S. government started to impose restrictions over the development process, with concerns of Korea developing offensive capabilities that have grave potentials to change the balance of power of East Asia. Especially, the suspicion that the missile development program could eventually evolve into a nuclear program has prompted the U.S. Government to place more scrutiny over the technology transfer and assistance efforts. In this aspect, the U.S. started to put restrictive measures in transferring sensitive technology through the Joint U.S. Military Assistance Group under the U.S. Embassy (JUSMAG-K). Officials from JUSMAG-K were stationed in the Daejeon Machinery Depot to make sure the missiles did not exceed 180km in range. Such restrictions later evolved into a

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479 과학대통령 박정희와 리더십, p. 485.
480 조한대, "박정희 지시로 쥐도 새도 가족도 몰랐던 미사일 개발," 중앙일보, 2015.1.28.
481 대한민국 역사박물관, 국방과학기술 발전을 이끈 주역들 구술채록사업 결과보고서, 2015 년 12 월, p. 23.

diplomatic treaty governed under the United Nations called the Missile Technology Control Regime (MTCR), which restricts member states to develop missiles with an effective range farther than 180km.[482]

5.4. National Level Innovation Systems

5.4.1. Legislations and Administrative Support Systems of the Aircraft Industry

Legislative establishments sustained the developmental pattern of aircraft manufacturing. The legislative support initiated by Aircraft Manufacturing Program Act of 1961 promulgated by the Ministry of Transportation focused on repair and air traffic-control rules. The aircraft industry before the Aircraft Industry Promotion Act of 1978 was mostly considered a public service field for managing transportation needs instead of a science and technology sector attuned to industrial development.

Therefore, the supervising agency was initially the Aviation Bureau under the Ministry of Construction and Transportation. The 1961 Act evolved into the Aircraft Industry Promotion Act, and the administrative authorities transitioned into the Ministry of Industry and Commerce in 1978. It was in this legislation for the first time when aircraft manufacturing became labeled as a strategic industry with objectives to broaden the scope of the country's S&T competency. Supervisory jurisdiction was further transitioned over to the Defense Industry Division of the Machine Industry Bureau under the Ministry. The Aircraft Industry Promotion Act evolved over the years into the Aerospace Industry Development Promotion Act of 1987 and has been updated to reflect the developmental changes in technology and industrial circumstances ever since.

Legislative Intent and Objectives of the Aerospace Industry Development Promotion Act (AIDPA)

The legal basis of aircraft manufacturing until the late 1960's was the Aircraft Manufacturing Program Act, which was first introduced by the Japanese Colonial Government in 1938. This law had very restrictive limitations in terms of promoting aircraft manufacturing and development, in which it merely administered in-country production certification and licensing procedures to manage safety and control transportation in the airspace. There were no subsequent implementing ordinances that supported the law, in which the law did not further mature into an institutional system. Thus, the fact that the Ministry of Transportation assigned as an implementing agency of this law instead of major industrial authorities such as the Ministry of Commerce and Industry or the Ministry of National Defense shows aircraft manufacturing was not considered a business area.[483]

Aircraft manufacturing did not become a serious industrial sector until the mid-70s when the country started to initiate a number of self-reliant defense build-up schemes. Enacted in December of 1978, the *Aircraft Industry Promotion Act* replaced the nominal Aircraft Manufacturing Act of 1961. The

[482] 엄정식, "미국의 무기이전 억제정책에 대한 박정희 정부의 미사일 개발전략," 국제정치논총 제 53 집 1 호, 2013, p. 171.
[483] 항공기제조사업법, 1961.

declaratory objective was to develop technological capacities sufficient to build an indigenous fighter aircraft with state of the art avionics until the mid-1980s.[484]

Within the Aircraft Industry Promotion Act, the main effort was concentrated on the localization of equipment manufacturing in support of a burgeoning defense industry. The primary efforts included aircraft component localization, building foundations for a professional technological workforce, financial subsidies to nurture industrial strength, and so forth. Other defense industry related promotion acts followed legislation as well. The driving force behind these legislations was to enhance the technological capacities for building a sound self-reliant defense industry with hopes to spill over into the overall manufacturing industry. Series of companion legislations were introduced during the span of ten years with the objective to build an indigenous defense industrial base. Other legislations introduced in this category were; Machinery Industry Promotion Act/Shipbuilding Industry Promotion Act/Science Education Promotion Act (1967), Steel Industry Promotion Act/Petrochemical Industry Promotion Act (1970), Textile Industry Modernization Promotion Act (1979), Electronic Industry Promotion Act (1981). However, the aircraft industry was not able to take off on its own compared to other industrial sectors, where the technology and infrastructure did not fully grow into a competitive and the Promotion Act had to remain as a separate legislation ever since. The supportive legislations of other industrial sectors, after having matured into a competitive business enterprise, consolidated into the Industrial Development Act in July 1986. Nevertheless, because of the underperforming business accomplishments of the aircraft sector in technological and industrial competitiveness, the Aircraft Industry Promotion Act continued to remain as a separate legislation.[485]

Aerospace became the buzzword of the era in the mid-1980s after the Presidential Candidate of the ruling Democratic Justice (Minjeong) Party included aerospace industrial promotion as a campaign commitment during the Presidential Election of 1987.[486] To support Roh's campaign strategy, the "Special Research Committee for National Development in the New Millennium" under the ruling party initiated special initiatives to construct an 'Aerospace Industry Policy Driving Committee' in February 1986, and passed the bill sponsoring this idea at the National Assembly in December of 1987. The legislation consolidated the dispersed government authorities to the Ministry of Commerce, and Industry to underscore the importance of aerospace as a technologically intensive business field opposed to the previous notion of the industry as a service-providing sector (transportation airlines). The bill also included strategies to indigenously develop combat aircrafts until year 2000, and support the education of aeronautical scientists and engineers at the university level, including the renowned engineering departments of Seoul National, Inha, Korea Aerospace, KAIST, etc.[487]

In order to address the pending challenges in aircraft manufacturing, the Aircraft

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484 유경현, "항공기로까지 가는 방위산업," 동아일보 1978. 1. 9.
485 임달연, 한국항공우주사, 한국항공대학교 출판부, p. 440.
486 경향신문, 우주항공개발 적극육성, 경향신문, 1986. 10. 28.
487 Before the 1987 legislation, aircraft-manufacturing responsibilities were assigned redundantly to public transportation authorities and industrial authorities. 매일경제, 2000 년까지 전투기 독자설계, 1987. 10. 1.

Manufacturing Act restructured into the Aerospace Industry Development Promotion Act (AIDPA) in December 1987, with a long term objective to bolster the technological competitiveness of the industrial base in par with other business sectors such as in electronics and automobiles. The intent was to efficiently sponsor and promote research and development in aerospace related science and technological fields to a level capable of contributing to the national economy. The Ministry of Commerce and Industry (MOCI)[488] was assigned the supervisory role to administer the AIDPA. In addition to the preceding Aircraft Industry Promotion Act of 1978, the AIDPA included additional elements to foster interagency cooperation as well as guiding principles to connect critical collaborative networks between the R&D consortia and business enterprises. According to the new Promotion Act of 1987, the implementing agency shall draft a mid-term development plan that encapsulates government assistance in building a sound and competitive aerospace industry, and establish an interagency supervisory committee that reviews and determines the growth directions of the industry. Especially, the AIDPA legislation sponsored the establishment of a government-run institute in the field of aerospace related science and technology. The Korea Aerospace Research Institute (KARI), which used to be a research branch under the Korea Institute of Machinery and Materials specializing in aeronautics, branched out in 2001as a separate entity solely focusing on aerospace policy and engineering.[489] The AIDPA 1987 also lowered the entry barriers of companies entering the aircraft industry by streamlining the corporate registration process from the previous multi-layered procedure into a single effort operation. This provision in the Act provided fodder for more corporate investments and motivated new entries into the aircraft-manufacturing sector, mostly pertaining to big business conglomerates. This action made all business entities with a keen interest in entering the domestic aircraft industry to freely join and compete. The AIDPA also streamlined overlapping functions by consolidating different verification and validation procedures such as performance tests and quality tests into a single process. Previously, performance tests were under the responsibility of MOCI, whereas quality tests were under the auspices of the Ministry of Transportation and Construction. The AIDPA placed these two functions into a centralized control under the MOCI. In February 1988, as the government labeled the aircraft industry as a technological field that can strategically lead the economy into the new millennium, MOCI drafted the "Strategies to Reinforce the Competitiveness of Aircraft Manufacturing" as a detailed execution plan to implement the AIDPA. Considering the competitive edge of the country still maintaining a comparative advantage in cost, the authorities intended to gather experience in business deals through building capabilities for original equipment manufacturing (OEM).[490]

Nonetheless, the efforts were easily said than actually done. The enforcement of the AIDPA was always compartmentalized and mostly remained declaratory in nature without seeing much tangible

[488] Ministry of Commerce and Industry (MOCI) later evolved into the Ministry of Commerce, Industry, and Energy (MOCIE, 1996), Ministry of Knowledge Economy (MKE, 2008), Ministry of Trade, Industry, and Energy (MOTIE, 2013).
[489] 항공우주산업 개발촉진법
[490] 매일경제 88 년 2 월 9 일, 항공부품 OEM 식 생산 2 천년대 수출산업 유도

actions in terms of nurturing domestic aircraft manufacturing firms or boosting corporate R&D efforts. Authorities did not provide substantial support as stated in the legislative actions or in the pressroom when presenting illustrious and flamboyant speeches about the auspicious initiatives programmed for the industry's future. The following section describes some of the major policy initiatives stated in the legislation and opposing criticism.

Supporting Institutions of the AIDPA: Aerospace Industry Development Policy Council

A notable element that differentiates the AIDPA from the previous promotion act was the institutionalization of an interagency policy coordination forum at the highest level possible under the Presidential monitoring radar called the Aerospace Industry Development Policy Council (AIDPC). The Council attempted to effectively coordinate the dispersed industrial and technological capacities of aircraft manufacturing residing in different government agencies and business sectors. Before the AIDPC, there was an ad-hoc interagency coordinating body called the Aircraft Industry Promotion Committee, with a primary interest over the localization of the F-16 fighter, first established in May 1985, which formed the basis of the ADIPC. The purpose of the Committee was to find new business areas in aircraft manufacturing after the production of the Korean Air's F-5E/F fighter concluded in 1983. The committee was formed by a collaborative effort between the industrial agencies, which composed of the Economic Planning Board, Ministry of Commerce and Industry, Ministry of National Defense, and so forth. Government run think tanks and research labs such as the Korea Development Institute, Korea Institute of Defense Analysis, Korea Institute of Industrial Economics and Technology, Korea Advanced Institute of Science and Technology, etc., supported the organization of the Committee. The Vice Minister of the Economic Planning Board chaired the committee.[491] Later in 1985, the committee gathered into its membership the domestic aircraft industries such as Korean Air, Samsung Precision Engineering, Doosan Machinery, and so forth, to develop collaborative strategies for promoting the country's aircraft-manufacturing sector to a higher competitive level in par with global standards.[492] However, with the growth prospects of aircraft manufacturing based on the significant demand-pull initiated from the Eight Major Aircraft Development Programs in the late 1980s, the government strongly perceived the need to establish a standing coordinating mechanism that effectively incorporated inter-agency differences under a common objective of building a synchronized industrial capacity in aircraft manufacturing. Thus, after the legislation of the AIDPA, the ad-hoc construct of the committee directly transitioned into the Aerospace Industry Development Policy Council.

The AIDPA of 1987 assigned the Ministry of Commerce and Industry (MOCI) to draft and implement an industrial development masterplan every five years, and provide an intermittent progress update to the Aerospace Industry Development Policy Council at the end of the calendar year. The

491 매일경제, "정부 항공산업 중점 육성," 1985.6.21.
492 매일경제, "재계, 항공산업 공동참여 모색," 1985.9.19.

Prime Minister presides over the Council and gathers fifteen (15) interagency members related to industry and S&T responsibilities. The council serves to decide on the industry development masterplan drafted by MOCI and mitigate nonperforming program elements within the process of implementing the masterplan. The Council has discussed a number of strategic industry development agendas that included R&D and manufacturing strategies for rotor wing and fixed wing aircrafts, industrial restructuring, international cooperation for technology transfer, and so forth. Below are the key policy areas discussed under the auspices of the Council.

Dates	**Major Agendas**
3 July, 1997	- Development Strategies of the Korean Trainer Experience-2 (KTX-2, T-50) - Program Updates of the Midsized Regional Airliner Development
22 April, 1999	- Review and Approval of the 1st Aerospace Industry Development Plan - Government Support Plan for Aerospace Industry Restructuring - KTX-2 Program updates and government subsidization options
8 January, 2001	- Implementing details of the Aerospace Industry Development Plan - Industry Restructuration Updates and Government Support Plan
19 March, 2003	- Korea Multi-Purpose Helicopter (KMH) Program Development Strategies (Draft) - KTX-2 System Development Updates and Full-Rate Production Plan
8 July, 2005	- KMH Program Updates - Prospects of Overseas Exports and Subsequent Marketing Strategies
21 January, 2010	- Aircraft Industry Development Master Plan (2010~2019)
8 November, 2010	- Designation of Ten Core Technology Items and R&D Strategies - Development Strategies for Local Clusters and Functional Technologies - Updates on Major Aircraft Development Programs
18 November, 2013	- Program Updates and Development Strategies of Next Generation Regional Airliner - Korea Fighter Experiment (KF-X) Development Strategies (Draft) - High Speed Vertical Takeoff and Landing (Tilt Rotor) Unmanned Aircraft - Common Development of Light Armed/Commercial Helicopter Program

Table 25. Agenda Items of the Aerospace Industry Development Policy Council, Ministry of Industry, Trade, and Energy update to the National Assembly, April 2014.

The entitlement of the Council came through confusing and inconsistent terms as it evolved from various attempts to create control tower over the domestic aircraft-manufacturing sector. The previous attempts to create an Aerospace Industry Planning Group under the President's Office in the mid-80s, and the undertakings to construct a Policy Council under the auspices of the Prime Minister, all count to these efforts. The convening of its first meeting was not an easy task either. Despite the designation of the Council in the AIDPA of 1987 and its more detailed description in the ensuing implementation ordinances of 1990, the first Council meeting was not held until July of 1997 due to the difficult accommodating circumstances in and out of the aircraft industry. Perceiving the need to establish a powerful coordinating mechanism that should mitigate the overlapping bureaucratic frictions and industrial performances, the Presidential Office proposed to establish an Aerospace Industry Planning Group in 1990, in support of the AIDPA.[493] However, the Planning Group did not materialize

[493] In 1990, the Implementing Ordinances of the AIDPA ambitiously stated a very rosy business prospect of the aircraft sector, with high hopes that the industry will generate an annual revenue of KRW 9 trillion within the next decade, 매일경제, 항공산업 참여 적극유도, 1990. 1. 11.

until April 1993 when the government included the condition for the Aerospace Industry Planning Group in the "New 5-year Economic Development Roadmap" as a companion government project formed in conjunction to serve another industrial objective of boosting the domestic automotive industry.[494] Nonetheless, the initiative remained declaratory in nature and was not effectively implemented to fulfill its original policy objectives. The Council was frequently under criticism by various government auditing agencies for simply serving as a figurehead to decorate fashionable economic growth aspirations without presenting any concrete plans or effective solutions for industry development and promotion. Especially, the assignment of the Prime Minister as the presiding chair of the Council contained misleading connotations in various aspects. At the time of its inception, the number of interagency coordinating forums chaired by the Prime Minister sprang up like mushrooms after rain, accounting for a dozen policy areas including finance, medical, industrial sectors, education, and so forth. Thus, the multitude of auxiliary responsibilities, in conjunction with the main profession of the Prime Minister, diluted the significance of these interagency forums, including the Aerospace Industry Policy Council.[495]

It wasn't until 1999 after the Asian Financial Crisis when the Council started to work on some serious business that had a real impact on the domestic aerospace industry. The second AIDPC meeting convened in 22 April 1999 endorsed the Aerospace Industry Development Framework Plan and the restructuring of the domestic aircraft-manufacturing sector. It was here where the consolidation and divestment of aircraft manufacturing branches of the three Chaebol firms – Samsung, Daewoo, Hyundai – was resolved into a single corporation called the Korea Aerospace Industries (KAI). The government support packages, including tax breaks, subsidies, and designation as a specialized defense firm for aircraft manufacturing, were discussed and voted in this session.[496] During the April 1999 session, the Council also decided on the additional production of KF-16 aircrafts as an extended effort to sustain the production line of the domestic aircraft-manufacturing sector. The KF-16 additional production was in odds with the Air Force's Fighter eXperiment (FX-I) program. The KF-16 fighter was produced under license between Samsung Aerospace and General Dynamics from 1991 to 2000, which later merged into Lockheed Martin, whereas the FX-I was the Air Force's future capability force build-up program after the KF-16, which considered foreign procurement instead of indigenous development. After concluding the final production of the KF-16 aircraft in 2000, the domestic aircraft-manufacturing sector had no further workloads to sustain its production lines before the initiation of the T-50 advanced trainer program in 2005. In this regard, the domestic industry was demanding the government to manufacture additional KF-16 in order to endure the 5-year production gap between 2000 and 2005. Compelled to exercise an austere budget plan under the Asian Financial Crisis, the government was

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494 매일경제, 항공우주산업 적극 지원 청와대에 기획단 설치, 1993. 4. 2.
495 임규진, 이용재, "유명무실한 위원회 많다." 동아일보 1997.4.18.
496 Minutes adopted from the 22 April 1999 Aerospace Industry Development Policy Council.

falling short of options to support both programs.[497] Meanwhile, the Ministry of National Defense ostensibly welcomed the idea of manufacturing additional KF-16s for sustaining domestic industrial infrastructures, but in closed doors behind the scene, it vehemently opposed the allocation of defense budgets for this idea. At this time, MND absorbed the largest hit in budget cuts in the aftermath of the Asian Financial Crisis, and was determined to defend the remaining allocated budget to execute its 5-year Midterm Defense Plan. The KF-16 production was introduced as a hot agenda item at the AIDPC. Here, the decision was to rebalance the budget from the Ministry of Commerce, Industry, and Energy in support of producing twenty (20) KF-16 aircrafts worth KRW 1 trillion, while the Air Force reorganizes its fighter wings to receive the additional aircrafts. The defense budget for the FX-I remained intact.[498]

Afterwards, the Council was actively involved in the decision making of major defense programs such as the Korea Multi-Purpose Helicopter (KMH) Program, Korea Fighter eXperiment (KFX), Unmanned Aerial Vehicle Programs, and so forth. In 2010, the Council played a major role in developing the follow-up plan of the 1999 Aerospace Industry Development Framework. The updated 2010 version highlighted the country's strategic vision towards upgrading the domestic aerospace industry, the development of major aircraft technology areas, and the promotion of local clusters in the course of building a robust aircraft-manufacturing sector. Subsequent chapters will further describe the programs and initiatives resolved from the Council in more detail.

Supporting Institutions of the AIDPA: Aerospace Industry Development Framework Plan

After the legislation of the AIDPA of 1987, there were efforts to draft a long term roadmap that provided guiding principles to foster the domestic aircraft-manufacturing sector. However, the drafting of this document was not materialized until July 1997 when the agenda was discussed during first convening meeting of the AIDPC. The agenda was subsequently discussed in an interagency workshop in October the same year that invited the stakeholders from industry, GRI, and academia. After a period of deliberation, the Aerospace Industry Development Framework Plan (hereinafter Framework Plan) was endorsed by the Prime Minister in April 1999 during the 2nd AIDPC Plenary Session.

The Framework Plan of 1999 was the first documented government initiative to foster the domestic aerospace industry, which included the sectors of both aircraft manufacturing and space technology. The strategic objective was to upgrade the country's industrial sectors to a structure suitable to assimilate knowledge intensive high-tech business fields. The Plan also served for self-reliant defense by localizing the production base of critical defense capabilities associated with military aircrafts such as in composite materials, avionics, armaments, aeronautics, propulsion dynamics, and so forth. The mid-term objective was to build technological and industrial capacities in maintenance, repair, and

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497 최상연, "KF-16 추가 생산 논란," 중앙일보, 1999.5.13.
498 김성걸, "KF-16 추가생산 파문: 불거진 로비의혹, F-X 사업은 어디로," 신동아 1999 년 6 월호.

overhaul (MRO), diversify into commercial aviation manufacturing, and obtain capacities for quality control and safety certifications. The suggested timeframe for these objectives took a two phased approach, in which followed; 1) 2005 for component localization and industry reorganization; 2) 2015 for mid-sized regional jetliners and combat aircrafts (fixed and rotor wing). The guidelines for consolidating the scattered industrial capabilities into a single corporate entity, which subsequently created the Korea Aerospace Industries (KAI), was raised in companion with the on-going restructuring efforts by the Corporate Restructuring Committee under the Financial Supervisory Commission. Lastly, bolstering the triple helix of industry-GRI-academia technological partnership through robust coordinating networks in the regional industrial belts of Sacheon-Changwon-Gimhae Cluster constituted the core of the Framework Plan.[499]

A decade after the 1999 Framework Plan, industrial authorities perceived the need to review the outcomes of the Framework Plan and provide a new and upgraded strategic guideline to foster the domestic aerospace industry. The successful development of the KT-1 Basic Trainer, T-50 Advanced Trainer, KUH Surion Helicopter, and the twofold growth in industrial outputs ($600 million in 1999 to $1.3 billion in 2008) triggered the government to follow-up with a more grandiose plan to exploit the growing performances of the aircraft industry. In this sense, with a vision and objective to become the 7th biggest country in aerospace (Global 7), the upgraded 2010 Framework Plan announced four strategies and thirteen priority projects to advance the competitive capacities of the industry. Especially, the 2010 Framework Plan presented two notable components. One was the designation of 10 core technologies in order to boost the competitiveness of the local industry to a competitive level in par with global standards. The second component was the building of regional innovation clusters based on industrial specialties of each respective region. Interagency coordination and incorporating industrial capacities by mapping the technological fields was the implementing instrument to stimulate technological development and innovation.[500]

The fostering of 10 core technologies was intrigued by the need to localize critical design and components derived from these technologies in order to become a competitive contestant. The technologies were generally considered state-of-the-art, for which countries imposed more restrictive measures in technology transfers through exercising stronger IPR control. Depending on the distinctive characters of each technological fields, the authorities designated the Ministry of Knowledge Economy (commercial aviation), Ministry of National Defense (military aircrafts), and Ministry of Land, Infrastructure, and Transportation (aviation safety certification) to effectively manage the development efforts.[501]

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499 산업자원부, 국방부, 과학기술부, 항공우주산업개발기본계획, 1999 년 4 월.
500 지식경제부, 항공산업개발기본계획, 2010 년 1 월
501 지식경제부, 10 대 항공핵심기술 선정 및 항공분야 R&D 추진방향, 2010 년 11 월

Technology Systems	Core Technologies			Implementing Field
System Integration	1	SC	Integrated Design Features	High Efficiency Air Vehicle Design
				Next Generation Eco Friendly Air Vehicle
Cabin Design Convenience	2	UR	Convenience/Comfort Improvement in Cabin	Noise Reduction
				Ergonomic Design
Flight Safety Design	3	UR	Improved Flight Safety, T&E Technology	Antifreeze Substance
				Ground Test Equipment for Dynamic System Design
Airframe Structure	4	UR	Composite Materials, Airframe Structure	Composite Material, Integrated Structure Technology
				Advanced Material Components Molding Technology
Avionics/Flight Control	5	UR	Next General Avionics	IMA Based Avionic System
				Information Fusion Technology
	6	SC	Intelligent Autonomous Flight	Auto-pilot system
				Integrated Flight Control
	7	UR	Weapons Integration	Armament Integration
High Performance Mechanics/Electrics/ Auxiliaries	8	UR	Higher Performance Subsystems/Auxiliary Components	Higher Performance Landing Gear
				Precision Electric Hydraulic Actuator
				ECS Package
				Air Data Sensor / Integrated Design Architecture
				Fuel System Precision Control
				Hybrid Active Control Rotor System
High Efficiency/Eco Friendly Propulsion	9	SC	Eco Friendly High Efficiency Propulsion	Multiplex FADEC Technology
				Interlocking Engine Starting System with Gearbox
				High Temperature Turbine Cooling System
				High Performance Eco Friendly Combustion Chamber
				High Performance High Powered Electric Propulsion System
				Eco Friendly Hybrid Propulsion
MRO	10	UR	Performance Improvement / Overhaul	Airframe/Component Repair
				Airframe/Cabin Overhaul

Table 26. Ten Core Aircraft Technology Areas *SC: Strategic Core, UR: Urgent Requirement*
Source: Ministry of Knowledge Economy, November 2010

The building of regional innovation clusters specialized in aircraft manufacturing roamed local governments in the early 2000s as part of jumping on the government-driven *Balanced Regional Development Strategies*. The Roh Mu Hyun Administration enacted the Special Act on Balanced National Development in 2004 to readdress the economic imbalance between regions and enhance regional competitiveness in tandem with the quality of life of local residence by supporting development initiatives that fully reflects specific regional strengths. The government designated specialized innovation clusters to facilitate the development of these industrial hubs.[502] By taking advantage of local aircraft manufacturing capacities dispersed in each respective regions, the local governments strived to win the government's designation as an innovation city or become part of the innovation cluster. In order to avoid unnecessary competition and redundant investments, the government drafted the "Aircraft manufacturing Industry Regional and Functional Development Plan" appended to the 2010 Framework Plan.[503] The regional plan highlights three developmental phases based on regional metropolitan councils divided into specialty areas of aircraft manufacturing, R&D, and MRO.

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[502] Special Act on Balanced National Development, Korea Legislation Research Institute.
[503] 지식경제부, 항공산업 지역별 기능별 발전계획, 2010 년 11 월.

Category		Location	Areas of Specialization	Supporting Reasons
Aircraft manufacturing	Priority Base	Gyeongnam	Aircraft, Engines, Airframe	Production/Export, KAI
	Supporting Base	Busan	Airframe, Materials, Machinery	Production/Export, KAL
		Gyeongbuk	Avionics	Production, electronic cluster
		Jeonbuk	Composite Materials	Carbon materials, components
MRO	Priority Base	Busan	Commercial, Military	KAL Depot Facilities
		Chungnam	Military, Commercial	Air Force Depot Facilities
	Supporting Base	Chungbuk	Commercial	Cheongju Int'l Airport
		Gyeongnam	Military	Production/Export, KAI
		Daegu	Military	Air Force Depot Facilities
		Incheon	Commercial	Incheon Int'l Airport
R&D	Priority Base	Daejeon	Government R&D	GRI infrastructure (ADD, KARI)
	Supporting Base	Gyeonggi	Corporate R&D	High caliber research workforce
		Jeonam	Test & Evaluation	Flight Testing Center

Table 27. Regional Aerospace Industry Development Plans *Source: Ministry of Knowledge Economy, November 2010*

5.4.2. Aircraft Manufacturing R&D Policies and Technology Transfer Mechanisms

In the case of big players in global aerospace, a streamlined R&D apparatus that incorporates the critical functions of both public and private capacities supports the industry. Such arrangement generates optimal synergetic outcomes that enhance competitiveness in the international market. In the case of Korea, most of the R&D efforts are state-driven with marginal contributions from the corporate sector and university laboratories. However, the national level R&D arrangement in aerospace shows substantial overlaps and redundancies, which often becomes a source of systemic coordination challenges with duplicative R&D projects programmed under different bureaucratic supervision.

Research Institutions and Regulations

Korea's government sponsored research institute for aerospace related technology is represented by the Korean Aerospace Research Institute (KARI) under the Ministry of Science and Technology (MOST) and the 3rd R&D Institute of the Agency of Defense Development (ADD) under the Ministry of National Defense (MND). Corporate R&D also constitutes the third pillar of the domestic R&D apparatus. KARI mostly handles commercial aeronautical and space related R&D whereas ADD's 3rd R&D Institute primarily focuses on defense programs.

Throughout the process of carrying out aerospace R&D, ADD has contributed the majority of capacity building. In the course of conducting basic and applied research, concept formation and exploratory development, followed by the actual weapon system development phase of system development, ADD acquired critical aircraft-manufacturing infrastructure through building wind tunnels for running structural aerodynamic experiments. Based on various experimental database composed of empirical codes provided under aid from the United States in the 1970s, ADD launched the Aerodynamic Integrated Design Program (AIDP) to start shape designs and measuring fluid dynamics for developing missiles and air vehicles. As the only laboratory in the country that owned a wind tunnel test equipment, ADD performed a number of collaborative research with corporate industry and other engineering laboratories at local universities.[504] These capacities contributed greatly to developing indigenous aircrafts such as the KT-1, T-50, KUH, etc.

As of 2010, KARI employs a total of 320 scientists and engineers with an annual research budget of KRW 70 billion whereas ADD's 3rd R&D Institute employs around 500 scientists and engineers with an annual research budget around KRW 300 billion. Therefore, the total manpower in government sponsored research pool entirely dedicated to aeronautical engineering is about 800 with an annual budget of KRW 370 billion.[505] This level is comparatively smaller in scale than other second tiered countries in aerospace R&D. Therefore, a well streamlined concentrated effort across each sector of the public sphere that incorporates the business sector and university level academia is imperative to productively employ scarce public resources.

However, despite the comparatively small scale in R&D investment, the efforts to mobilize such limited resources are unsynchronized and not well-coordinated into a coherent fashion. The efforts are mostly dispersed between KARI and ADD, which precludes the concentrated potentials of government research productivities. Most of the research projects conducted under these two agencies appear to have overlaps in infrastructure and facilities (85%), equipment (82%), technology (61%), and manpower (60%).[506] Government R&D in aerospace conducted in other contending tiered countries such as Brazil, Taiwan, and Sweden are sponsored under a single state-led entity, which allows those countries to contrive consistent efforts in developing complex aeronautical outcomes. In the Korean case, there are a number of government entities that share a vested interest in the aerospace sector – in addition to the Ministry of National Defense and Ministry of Science and Technology, other public entities such as the Ministry of Trade, Industry, and Energy, the Ministry of Land, Infrastructure, and Transportation, the Meteorological Administration, and so forth. Most of the public R&D launched from these agencies are not well coordinated with each other, which is the cause of the serious overlaps and redundant spending in government resources. In this regard, the intervention and adjudication of a national level coordination body would've been deeply appreciated in the course of preventing such wasteful spending in duplicate programs. As a matter of fact, based on the Aerospace Industry Development Promotion Act of 1989, the Aerospace Industry Development Policy Council (AIDPC) was chartered to effectively carry out this coordinating role amongst the stakeholders in aeronautical sciences. In addition to the AIDPC, competing priorities in national S&T projects should be mitigated through the National Science and Technology Council (NSTC). Unfortunately, neither of these two coordinating forums effectively performs its adjudicating role in aerospace related R&D projects. In the meantime, the institutional arrangement in the national S&T regime still instigates each respective

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504 안동만, "ADD 의 연구개발과 국내 항공우주공항(산업)의 발전," 항공우주학회지, 제 28 권 제 8 호, 2000, p. 141.

505 2011 National Assembly Audit Report over the Agency of Defense Development

506 The R&D projects are named differently but the essential concept of most projects are identical. 안영수, "항공우주 국가 R&D 의 현주소와 개선방안," e-KIET 산업경제정보, 제 70 호, 2001.10.8.

government agencies to go separate ways in aerospace R&D projects. The *Act on Special Measures for Defense Industry* justifies and sponsors military projects managed under the auspices of the *Midterm Defense Plan* by the military sector (MND and DAPA). The *Framework Act on Science and Technology* allows the S&T apparatus to go its own way under the terms of the *Mid-Long Term National Aerospace Plan*. Dual use technologies related with aircraft-manufacturing is jointly managed by MND, MOTIE, and MOST based on the *Civil-Military Technology Development Promotion Act*. However, these legislations impedes inter-agency coordination, and justifies each government entity receiving separate R&D funding under less coordinated supervision.[507]

The less motivated commitment of the aerospace R&D workforce and their tendency to move into other promising business sectors is also a growing concern in improving the technological competitiveness in this sector as well. The mode of technology transfers from the two GRIs is facilitated through technology transfer centers ran by these organizations. However, the overall performance of these technology transfer activities does not sufficiently fulfill public expectations. According to a recent audit report conducted by the Korea Research Council of Public Science and Technology over the technology transfer performances of KARI, organizational efforts to transfer technology to private industry were rated inadequate and lacked any structural contents throughout the transfer process. KARI had no designated branch that supervises the technology transfer process, at which most of the transfer details are negotiated directly by the project offices. ADD had a designated organization called the Civil-Military Technology Cooperation Center that handled technology transfers and commercialization projects with local industries and universities, thus was rated better in performances than KARI in this aspect. However, both organizations were charging excessive amounts of royalty fees to private corporations over the application of publically sponsored R&D projects. The fixed royalty fee estimates is about 40% of the technology development costs, which makes technology transfer unaffordable to small and medium enterprises.[508] Also, the two organizations appeared to show less enthusiasm in registering technology patents against independent publications. As stated in previous chapters, patents are considered an important component that facilitates technology transfer and diffusion while preserving the property rights of the original developer. Meanwhile, in the case of public research outputs from ADD in 2004, out of the KRW 41.6 billion invested by the government in basic research, ADD researchers avidly published 394 research papers in academic journals, while registered only 35 patents.[509] The motivations of ADD researchers actively seeking publication opportunities in individual academic journals were broadly based on the intent to find university professorships in local colleges. The degrading treatment of ADD researchers compared to the social treatment offered in university professorships was the main cause of such research patterns.[510]

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507 이승리, 바람직한 우리나라의 항공우주 산·연·정 협력체계에 관한 연구, 한국항공우주연구소, 2000.1., p. 62.
508 특허청, 항공우주분야의 기술이전과 특허청의 역할, 2005 년도 항공우주기술 특허연구회 자료집, p. 118.
509 Ibid., p. 120.
510 Interview with a retired ADD researcher, 15 September, 2014

Government regulations for managing aircraft manufacturing R&D programs mostly refer to the Defense Acquisition Management Regulation, but in some prominent programs such as the T-50 Advanced Trainer or Korea Utility Helicopter Program, a separate and more specific regulation is enacted through legislation to serve for each program's objective. Regulations for research and development were not completely established until the early 2000s. Before initiating the indigenously developed KT-1 Basic Trainer Program, most of the in-country aircraft manufacturing programs were license productions, in which most of the development technologies introduced from advanced foreign sources were already proven by global standards. Thus, critical development phases regarding test and evaluation in previous aircraft manufacturing programs was neglected and not fully inserted into the transitioning phases from concept development to production. In this regard, the technologies utilized for the KT-1 Program entered into the aircraft production phase without being fully tested and certified.

During the Full-rate Production Phase of the KT-1 Basic Trainer Program, there were a number of confusion and complications caused by vague and less established regulations in government led R&D programs throughout the years of 2000-2004. The problem occurred in the phase transitioning from Prototyping to Low Rate Initial Production (LRIP), where the program development matrix did not clearly define the authorities and decision point to enter into LRIP. With the intent to deliver the KT-1 trainer early to the ROKAF, the authorities skipped LRIP and directly entered into Full Rate Production. Thus, a number of problems caused by less conformed technology and insufficiently tested systems led into significant periods of program delays and cost increases, which resulted in changing the design features of the aircraft in multiple occasions. In order to avoid the earlier mistakes made from the KT-1 Program, the Bureau of Audit and Inspection (BAI) recommended overhauling the Defense Acquisition Management Regulation to specify the detail procedures of T&E and the transition to full rate production in the R&D phases of aircraft manufacturing programs.[511]

In this regard, insufficient authorities to effectively wage inter/intra-agency coordination efforts consequently resulted in the sectoral deficiency in system integration technologies. The aircraft manufacturing sector has accumulated acceptable knowledge and experience in building various military aircrafts throughout the short thirty-year history of license production and component localization. However, the integration of advanced avionics, weapon system mechanics, and aerodynamic applications add substantial layers of complexity into the country's desire to become a major contender in the global aerospace market. The government, especially the Agency of Defense Development, claims to obtain the requisite technological capacities to build this mission equipment for aircraft manufacturing. But reality kicks in where workshop level coordination falls increasingly insufficient when attempting to create collaborative arrangements for these matters. ADD has been severely criticized for keeping these technological assistance to itself while being inherently reluctant

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[511] 김성배 외, 항공기 무기체계 연구개발규정 개선방안, 한국국방연구원 연구보고서 무 04-2010, 2004, p. 23.

to provide the needed technological assistance to industries.[512]

Defense Offset Trade: Primary Vehicle for Technology Transfer, Diffusion, and Knowledge Accumulation

During the initial years of its execution in the 1980s, defense offsets was a principal vehicle to sustain the defense industry via securing production deals from foreign defense contracts. Thus, the majority of the efforts were concentrated in concluding on subcontracts for outsourcing production of aircraft parts and components. In the following decade, the national objective focused on the acquirement of advanced technology to indigenously develop major weapon systems such as the supersonic advanced trainer aircraft (KTX-2: T-50 Development). In this sense, the majority of the acquirement efforts through defense offsets not only focused on introducing fighter capability, but also concentrated on acquiring aeronautical technology to bolster the aircraft-manufacturing sector. Offset arrangements for defense exports were very rare during this period. Defense exports were included as a negotiation subject only after the new millennium when the domestic industry started to pursue international markets to expand its business operations.[513]

In an overall effort of capacity building, defense offsets were proportionately concentrated in the acquisition of core technology (48%), defense exports (32%), and the acquisition of equipment and components (20%). However, corresponding to the complexity and sensitivities of high technology, foreign firms have been reluctant to transfer technologies through offset trade arrangements, at which foreign governments also imposed restrictive control measures in transferring high tech knowledge. Thus, recent trends in offset trade alternatively focused on combining core technology acquisition and defense exports through manufacturing critical components for overseas exports. Such practices present opportunities in easy market access for firms, but embodies repercussions in terms of favoritism in vendor selection. Also, in case the technology recipient firm does not follow up with continuous technology development efforts, the technology transfer deal may end up as a one-off event.[514] The following section describes offset trade cases that contributed to capacity building for the aircraft manufacturing sector.

Unit: $ million

Total	Technology Acquisition	Subcomponents			Equipment/Component Acquisition
		Subtotal	Defense Products	Commercial Products	
14,644 (100%)	7,045 (48%)	4,703 (32%)	3,129 (21%)	1,574 (11%)	2,896 (20%)

Table 28. Defense Offsets by Type *Source: DAPA Acquisition Planning Bureau documents, 2011.*

In the subject of technology acquisition through defense offsets, the priority was focused on acquiring core technologies in areas of configuration design, flight performance analysis techniques, and key design phases in building concepts and structure. The aggregation of technology transfers

512 김종원, “KFX 집중분석: 최고 전문가 사업단 필요하다,” 아시아투데이, 2014.4.15.
513 조달본부, 절충교역 20 년사, 국방부, 2003, p. 23.
514 Defense Acquisition Program Administration documented information on defense offsets, 2011.

acquired from various aircraft related offset programs, ranging from license production of KF-16 fighters, UH-60 medium lift helicopter, and a number of avionics modules and components, contributed to building technological capacities in this aspect. The primary beneficiary from this defense offset arrangement were government research institutes, notably the Agency of Defense Development (ADD).

Program	Acquisition type	Technology Acquired	Application
KF-16	License Production	Applied into KTX-2 Advanced Supersonic Trainer (T-50) Conceptual and preliminary design technologies Test, evaluation, and interpretation skills Quality assurance in component manufacturing	Direct application into KTX-2 development considering technology data for system design and component manufacturing.
Hawk-67 Advanced Trainer	Direct Purchase	Design technology for wing design Software development knowhow for flight simulation	System design and integration work in designing and manufacturing wings, aerodynamics for flight simulation
CN-235 Transporter	Direct Purchase	Composite materials, airframe structure design Conceptual design for flight control systems	Cooperative R&D relationship established with Spain CASA
P-3C Surveillance Aircraft	Direct Purchase	Wind tunnel simulator manufacturing technology	KTX-1, KTX-2 preliminary design and wind tunnel test
UH-60 Helicopter	License Production	Various display devices, design technology for mission hardware and software	Localization of display devices, KTX-1 avionics
Tactical Avionics	Direct Purchase	Design technology on electronic antenna Electronic wave transmission/receiver and remote control design technology	Direct application into KTX-1 avionics design and integration

Table 29. Technology Acquisition through Defense Offsets

The KF-16 offset originally started from the license production deal concluded between General Dynamics and Samsung Aerospace in aircraft structure, and Pratt & Whitney and Samsung Aerospace in engine structure. The manufacturing technology for aircraft components and parts had collateral influence in broadening the production capacity of the domestic industry in terms of technology accumulation and manufacturing skills. The technology and manufacturing experience acquired from the KF-16 offset program had direct contribution to the KTX-2 advanced trainer (T-50) program. The technology acquired from the defense offset arrangement of the Hawk-67 Advanced Trainer Program was in wing shape design, which facilitated the conceptual design and system development process in the aircraft wing sector of the KTX-2 program. The technological knowhow for composite materials and advanced composite structure was acquired from the partnership established between CASA and ADD from the CN-235 program. These were the representative offset cases that had substantial impact on technology acquirement for the fixed wing sector.[515]

The by-products of defense offset were the learning and production opportunities conferred in component manufacturing and depot maintenance. Contrary to defense offsets in technology acquisition, which mostly benefited government research institutes, offset arrangements in component manufacturing and depot maintenance mostly benefited technology competitiveness of defense industries or depot maintenance capacities of military services. Between a stretch of a decade until the early 2000s, defense offsets generated around $900 million worth of overseas export deals, which

515 조달본부, 절충교역 20 년사, 국방부, 2003, p. 48-50.

created approximately 11,500 jobs in domestic manufacturing. Improved capacities in domestic depot-level maintenance have assigned critical maintenance needs that would've otherwise been awarded to overseas repair work to domestic depots run by the respective military services. Such condition substantially shortened cyclical lead time in repair and overhaul routines for military aircrafts, which saved cost and set conditions to perfecting technological expertise.[516]

Program	Technology Acquired	Application	Beneficiary
LYNX Helicopter	Design and production technology for landing gears	Landing gear design for KF-16, UH-60, KTX-1, and overseas exports of $64M	Hyundai WIA
CN-235 Transporter	Cabin elevator for Airbus A-320	Import substituting effect of $60 million	Hankuk Fiber Glass
AH-1S Attack Helicopter	Component production worth $58M	Aluminum extruded material certified for exports ($13M worth)	Samsung Techwin, DHI
P-3C Surveillance	Outer wing production technology	Overseas export worth $27.8 million	KAI, KAL
HARPY UAV	Avionics and engines	Test equipment and depot maintenance technology	Air Force
UH-60 Helicopter	Assembly drawings of CT7/T700 engines, technical documents for repair and maintenance	License for CT7/T700 depot maintenance (applied to KTX-1/2), overseas export of $83M	Samsung Techwin, KAL
C-130 Transporter	Test and assembly work for engines, repair technology for propeller and transmission, repair technology over 70 types	Improved repair and overhaul capabilities	Air Force
Air Combat Maneuvering Instrumentation	S/W source code, technical data for depot maintenance	Armament related avionics	Air Force
Electronic Countermeasure	Technical data for depot maintenance	Airborne Self Protection Jammer (ASPJ)	Air Force
KF-16 airframe	Technical data for depot maintenance, wing shape production	Aircraft repair and maintenance work, $79M worth overseas export	Air Force, Samsung Techwin,
KF-16 engines	Technical data for depot maintenance, investment casting technology	F-100-229 repair and maintenance work, overseas export worth $34M	Air Force, Samsung Techwin, Kor-Lostwax

Table 30. Defense Offsets for Component Manufacturing and Depot Maintenance

F-15K Offset Program

The F-15K offsets embody significant implication to the conventional wisdom on offset trade as well as to the overall governance structure of international technology transfers through defense offsets. Therefore, it was worth describing the F-15K offset portion as a separate section to review the details of the technology transfers, government policy, interagency coordination, and so forth.

The initial phase of offset trade negotiations concluded in December 2000, but the defense authorities abruptly changed the offset criterion by including technology transfers to prepare for the indigenous development of the Korean Fighter Experiment (KFX). Afterwards, in early 2001, the program management office included secondary requirements for technology transfers that considered advanced avionics, aeronautical engineering, armaments, system integration design and technology, and

[516] Ibid., p. 53.

so forth.[517] The defense acquisition authorities applied a 70% rate in defense offset during the F-15K defense offset negotiations, increased from the former 30% rate, in order to acquire core technology and advanced manufacturing skills. The offset percentage against aircraft procurement eventually increased to 85%, which accounted for nearly $3.5 billion in dollar value. In a general sense, the defense offset trade obtained from the F-15K program alone acquired technologies and equipment in avionics, armaments, weapon control, flight control, etc., with a transfer value worth $1.5 billion.[518] In terms of component manufacturing, the offset volume secured a collaborative production volume of nearly $1.4 billion in value, which provided for over eight years' worth of production contracts with an additional employment effect of 300,000 jobs. Lastly, to facilitate a fluent follow-up support in logistics and depot maintenance work, the offset arrangement provided a workload of $573 million in engine, plating, and structure reinforcement.[519]

One representative technology where a domestic firm obtained international recognition and became a critical part in the global supply chain was in digital imagery displays. LIG Nex1 acquired both critical technology and subcontract production licenses to manufacture Head Up Displays (HUD) from the U.S. avionics giant Rockwell Collins through the F-15K offset program. The case is a representative example where domestic defense firms acquired critical technology in parallel with production subcontracts as a buy-back deal generated through defense offset arrangements. Based on the initial offset deal arranged in 2003, LIG Nex1 obtained the requisite production technology and secured a workload of 42 HUD sets delivered to the Air Force until 2007. Furthermore, after learning from the production experience, LIG Nex1 qualified all quality tests required from Rockwell Collins and became designated as a regional supply partner for HUD sets. This was a combined result of government efforts to acquire technology through defense offsets as well as firm level endeavors to enhance competitiveness by investing in equipment, facilities, and further compliance with product quality and management conditions.[520] Afterwards, LIG Nex1 received full contract awards from Rockwell Collins and secured an export volume of 156 HUDs in total until 2013.

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517 안승범·양욱, "F-15K Slam Eagle: 동북아 최강 다목적 전투기, 승리의 날개를 펴다," KODEF 안보총서, 2007, p. 115.
518 오태식, "F-X 사업을 통한 절충교역과 산업적 기술적 효과," 항공산업연구 제 61 권, 2002, p. 28.
519 DAPA report to the National Assembly on F-15K defense offsets, August 2014
520 박종호·박동환, "실증적 사례분석을 통한 절충교역 성과확대 방안," 한국방위산업학회, 제 22 권 제 2 호, 2015 년 6 월, p. 82.

Subject	Transfer Technology	Subject	Transfer Technology
Flight Control	Fly-by-Wire Integrated Servo Actuator	System Design/ Integration	Electronic Mock-up and Weight Systems RAM Analysis Systems engineering Weight System Prediction
Avionics/ Weapon Control	Head Up Display Mission Computer Data-Link S/W Design NVIS Test Equipment Interference Blanking Unit and Radio	Aerodynamics	Flight Performance High Angle Aerodynamics
Armaments	1. System Integration 2. Launcher Technology 3. Air-to-Air Missile	Structural Design	Smart Structure Design Damage Assessment Molding Composite Materials Design
Test & Evaluation	EMI/EMC Equipment/Technology Environmental Equipment/Technology Telemetry System Design	Propulsion System	Electronic Engine Control Device Engine Air Intake Design/T&E Small Engine Design Gas Turbine Engine Design
		Total	27 Technical Subjects

Table 31. Technology Transfers through Offsets from F-15K Program
Source: 2014 DAPA Updates to the National Assembly

The Korean Government has been asserting that the substantial volume of technology transfers acquired through the F-15K Offset Program has upgraded the technological and manufacturing level of the Korean aircraft-manufacturing sector sufficient enough to produce a combat aircraft commensurate to an F-16 fighter.[521] However, the exact degree of learning skills required to absorb the transferred knowledge, and translate such knowledge into a new engineering design concept to develop an indigenous capability is still in question.[522] Starting in the fall of 2014, the failure to acquire critical technology through another defense offset trade from the third round F-X Program (F-35A) for the indigenous develop of the Korea Fighter Experiment (KF-X) has ignited another layer of controversies over the technological competitiveness of the domestic aircraft-manufacturing sector. Comparing the political discourse between 2004, where the government claimed the F-15K program successfully negotiated technology transfer deals through offset that far exceeded the initial objective, and 2014, where the government fell under intense criticism for not obtaining the adequate skillsets to properly

Technology Standardization in Aircraft Manufacturing

Because of the vast numbers of components, modules, and systems, along with the sensitivities in terms of quality assurance for aviation safety measures, only approved materials and components that went through proven certification processes by publicly recognized authorities are allowed for usage in aircraft manufacturing. In this aspect, the scope of aircraft certification covers the entire life cycle of design, manufacturing, and operation. ISO/TC 20 (International Organization of Standards Technical Committee on Aircraft and Space Vehicles) administers the global technology standards in materials, components, and equipment related with the manufacturing of aircrafts and space vehicles. The expected outcomes of technology standardization through implementing the ISO/TC20 standards

[521] 조달본부, 절충교역 20 년사, p. 62; 국방부, 차기전투기: 시작에서 계약까지, 2002.
[522] In 2014, defense acquisition authorities were under severe public criticism over the failed negotiations in acquiring four critical technologies from the U.S. Government as part of the FX-III (F-35A) offset arrangements.

consequently advance into cost reduction and enhanced production efficiency. The technical standards applied across relevant manufacturing sectors enable better quality control in supplied commodities, which reduces operating costs in areas of de sign and manufacturing activities. Additionally, unified standards saves significant money in repair and maintenance costs throughout the operating cycle of a product between different manufacturers in each respective countries.[523]

As a late comer in aircraft manufacturing, technology standardization and certification systems in Korea did not come into fruition until the mid-1980s when the country started license manufacturing F-5E/F fighters and UH-60 helicopters. Government directed efforts on technology standardization propelled the standardization process over the aircraft-manufacturing sector. The establishment of Korean Industrial Standards (KS) in the 1970s facilitated quality improvement in Korean manufactured products, which enhanced product compatibility towards international standards, substantially increased industrial exports overseas, and further upgraded the technological competitiveness of the domestic economy. At this point, Korea adopted most of its early stage technology standards from the Japanese Industrial Standards, and re-engineered it suitable into Korean standards. The Korean Agency for Technology and Standards under MOTIE administers the KS certifications. On the other hand, the Ministry of Land, Infrastructure, and Transport (MOLIT) administers the technical standards and certification on aircrafts and associated components.

The standardization process in aircraft manufacturing was initiated in 1975 by an academic forum called the Korean Society for Aeronautical and Space Sciences (KSAS) where the organization shared the workload with other industrial entities. Standardization processes were primarily assigned to the Aviation Subcommittee under the Industrial Standards Council, which updates and verifies the KS engineering standards every five years. The main responsibilities and tasks of the Subcommittee are as follows.[524]

- Standardization of Aircraft Repair and Maintenance Work
- Localization of Aircraft Parts and Components
- Establish Foundations for Aircraft Assembly and Manufacturing
- Promote Indigenous Development

MOTIE and the MOLIT share the chairmanship of the Aviation Subcommittee, and is supported by experts appointed from corporate industry and academia. The inspection criterion of standard parts is stipulated by law reflected from internationally compatible standards, which is thoroughly implemented in various international trade and transactions. Especially, technically advanced countries strongly assert other countries and manufacturers to provide safety confirmation

523 Dale K. Gordan, “The Past, Present and Future Direction of Aerospace Quality Standards,” Quality Progress, June 2000.
524 임달연, 항공우주사, 한국항공대학교출판부, 2001, p. 457.

documentations that comply with Aircraft Certification Systems (ACS). Standard parts in this system refer to those certified under a nationally accredited institution that requires the highest level of reliability and safety. The United States sets the international technical standards through the Federal Aviation Administration. European countries also follow the U.S. standards as well. It is only through this approval process where aircraft parts and components become officially certified onto international standards. As a late starter in aircraft manufacturing technology, Korea has been complying with the technical standardization orders of the United States since 1993 as reflected within the Inspection Criteria for Aircraft Standard Parts administered by Korean Agency for Technology and Standards.[525]

Based on the Convention on International Civil Aviation of 1944, all countries under contract with the International Civil Aviation Organization (ICAO) must establish its own institutional framework to enforce internationally agreed standards and recommended practices regarding the certification requirements for airworthiness standards.[526] The certification process include the entire life cycle of an aircraft system including Type Certification (Design Phase) – Production Certification (manufacturing phase), airworthiness certification (operational phase). Korea implements the international norms and regulations of civil aviation through the Aviation Act and its implementing ordinances, as well as other associated laws and regulations such as the Aviation Safety Act and Military Aircraft Airworthiness Certification Act. The Korea Aerospace Research Institute performs the quality certification piece whereas MOLIT conducts the airworthiness certification process.

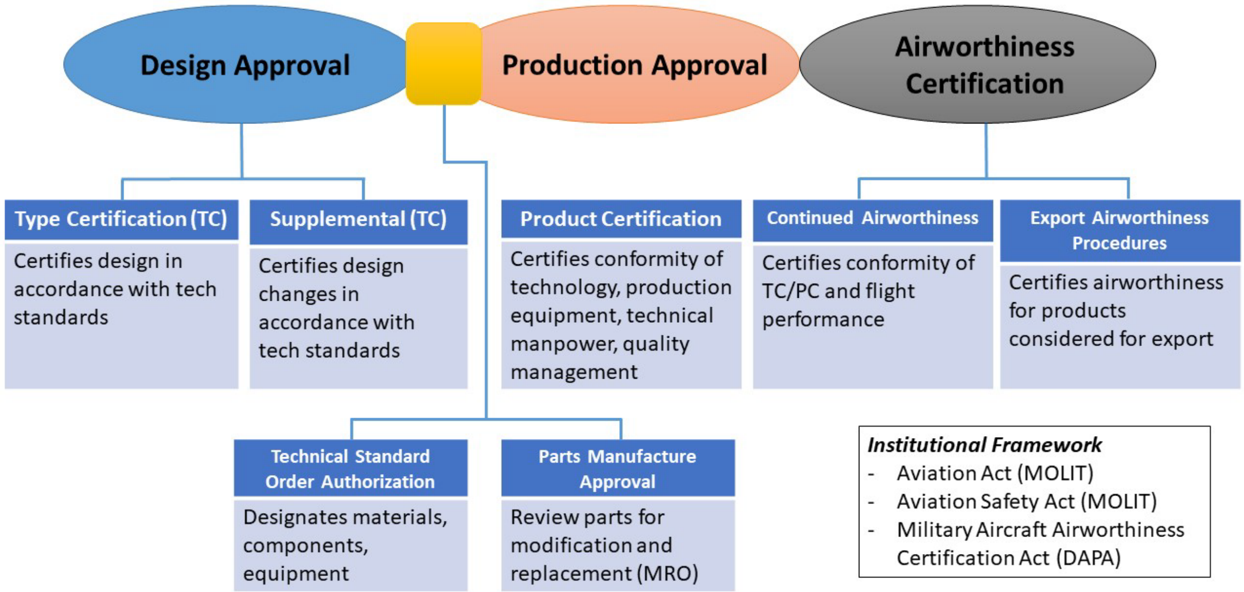

Figure 19. Aircraft Certification Process

However, most of the component manufacturers in Korea consists of small and medium sized firms that do not hold an effective quality management system. These firms lack an integrated control

[525] Ministry of Land, Infrastructure, and Transport, Procedures for Aircraft Technical Standard Order Authorization, OD 20-1, April 15, 2013

[526] Annex 8 – Airworthiness of Aircraft, The Convention on International Civil Aviation, 2016

structure that effectively accumulates the requisite knowledge and experience for capacity building in this field.[527]

Another critical part of standardization in aircraft manufacturing is airworthiness certification. Airworthiness attests the suitability of an aircraft for safe flight, in which the certification process is conducted by the national aviation authority respectively. Airworthiness certifications in military aircrafts were relatively lenient compared to the civilian aviation sector. Safety standards and technical specifications on military aircrafts were domestically oriented, at which public perspectives over the need to pay attention to global standards considering overseas export opportunities remained marginal. The motivation to establish airworthiness started in 2008 when the Korean Aerospace Industries (KAI) successfully negotiated the export of KT-1 Basic Trainers to the Turkish and Indonesian Air Force. In the meantime, the Turkish Air Force demanded documentations for airworthiness certifications of the KT-1 before concluding the contract.[528] From thereon, the defense acquisition authorities rushed into creating airworthiness certification standards through collaborating with existing government institutions and international networks.

In order to address the standardized certification needs, the Defense Acquisition Program Administration (DAPA) legislated on 1 August 2009, the Military Aircraft Airworthiness Certification Act, followed by its Enforcement Decree the same day. DAPA organizes the Deliberative Committee on Airworthiness Certification that gathers the expertise from the military MOLIT, R&D, academia, and so forth to coordinate policy, certification criterion, airworthiness planning and validation, interagency mitigation, and so forth.[529] In accordance with established laws and regulations, the government assigned the Air Force as the supervisory agency that administers standard airworthiness certifications on military aircrafts. Additionally, the Air Force and Defense Agency for Technology and Quality are assigned as specialized organizations that review functional details in areas of aircraft structural design, analysis, verification, compatibility, and other support areas. The technical basis of airworthiness certification standards derives from the U.S. DoD's MIL-HDBK-516 airworthiness criteria.[530]

Whatsoever, the short gestation period to build a competent standardization institution consequently constructed a system that needs some serious reorganization efforts. Different certification authorities in technology standards and airworthiness between MOLIT, MOTIE, and DAPA created inconsistencies in interagency policy formulation and coordination challenges in constructing a competitive aircraft-manufacturing sector. The structure of the defense acquisition system restricts a clear coordinative relationship between defense acquisition apparatus and the operations and sustainment component. DAPA is the designated authority for defense industrial standards, but DAPA's

527 서성호 외, 항공기 부품 생산 및 품질인증: 동향 및 전망, 한국과학기술정보연구원 2013 정보분석 보고서, p. 54.
528 방위사업청, "군용항공기 감항인증에 관한 법률안 입법예고," 정책브리핑, 2008.7.17.
529 Article 7, Military Aircraft Airworthiness Certification Act.
530 국방부령 제 684 호: 군용항공기 비행안전성 인증에 관한 법률 시행규칙

administrative authorities in defense program management does not extend to product support management, which is within the defined area of expertise considering the operations and sustainment phase administered by the military services. Industrial standards and airworthiness certification should effectively cover the entire life cycle of the aircraft, but DAPA's limited authorities in military aircraft standardization only covers less than 30% of the total life cycle cost.[531] Such difficulties create challenges in building most up-to-date certification standards.

Based on a 2011 survey performed over the industrial standards of the aerospace industry, about 18.8%, or 98 items, of aerospace industrial standards were deemed incompatible to international criterions. Without sufficing international standards, it would be extremely challenging for the respective product group to become marketable in international transactions. For instance, about 5% of the Korean Industrial Standards in aircraft technology applied Japanese Industrial Standards. However, approximately 13 technical items were considered obsolete, and were already eliminated from the Japanese Industrial Standards.[532] Therefore, without updating the Korean Industrial Standards in aerospace to international criterion, the domestic industry will continue to import foreign products against domestic products.

As discussed in previous chapters, however, poorly coordinated interagency R&D programs and certification standards demonstrate insufficient government staffing in high profiled national defense projects. Especially, the consequences of constant overlaps and redundancies between military and commercial programs in aircraft manufacturing eventually resulted in inefficient spending of government resources while contributing marginally into innovation or technological development. Airworthiness and safety certification efforts were no way different from these instances. Airworthiness and safety certifications require a total life cycle management approach, which encompasses major life cycle components in development, production, and deployment. However, the reality show policy disconnects and unstructured performances in interagency coordination levels. In early 2016, the auditing agency revealed that a number of aviation safety projects launched by MOLIT did not go through proper feasibility reviews and did not comply with existing national standards established by MOTIE. Thus, substantial amounts of the taxpayer's money, surmounting about KRW 390 billion, were wasted in inadequately examined programs. The worst case example was the employment of the Advanced-Surface Movement Guidance and Control Systems (A-SMGCS), which is a combination of systems displaying actual airport traffic for airport controllers. The near KRW 20 billion invested in building up the system was wasted due to the system not complying with domestic and international standards.[533]

Despite the amount of government funding provided for manufacturing military aircrafts,

[531] 유형곤, 미래지향적 표준업무 발전방향에 관한 연구, 안보경영연구원 방위사업청 용역과제, 2011.8, p. 69.
[532] 김두만 외, "항공우주분야 표준화 구축을 위한 조사연구," 기술표준원 정책용역과제, 2011.10.25, pp. 198-211.
[533] 뉴시스, "감사원, 국토부 항공안전 R&D 에 수백억 헛돈 써," 2016.2.18.

insignificant accomplishments in indigenous technology development resulted in immaterial construction of technology standards. Most of the technology standards developed from military aircraft production were merely measurements for functional components, thus considered as technology descriptions or specifications instead of actual certifiable technology standards. The standards established by aircraft manufacturing companies were used for firm level internal usage that did not have close linkages to national standards. Most Korean aircraft manufacturing firms showed low enthusiasm in either utilizing or developing indigenous standards. The overarching cause of such slow progress in building a viable technology standard system is due to the matter of the domestic industry mostly relying on technology and components imported from foreign sources. High percentage of domestic companies is subcontracted by major global aerospace giants such as Boeing, Pratt and Whitney. In this regard, it makes more sense for domestic firms to comply with firm specific standards used by these global firms in order to sustain its business operations instead of contributing to the development of domestic standards.[534]

The existing Aviation Safety Act also conflicts with the operation of the indigenously developed KUH-Surion helicopter employed in non-military sectors including public usage by the government. Only the National Police is allowed to operate two KUH-Surion helicopters for surveillance and transport missions. This was made possible because the end-use purpose of the NPA helicopters was considered an extended function of routine military duties. The cause of the problem originates from different airworthiness standards implemented by DAPA (military) and the MOLIT (commercial), which are not interchangeable to each other. The only case permitted for an interchangeable solution within the boundaries of current law is when the two different entities participate in a joint fashion during the initial design phase of the aircraft. If not, then it would be almost impossible to accredit the KUH-Surion helicopter under commercial standards.

Certification of radio communication equipment onboard the aircraft is also subject to different safety standards as well. Radio communication equipment validated by military standards are allowable in military, police, and coast guard helicopters, but prohibited in other public sector utilities such as in forestry or firefighting because of differences in safety standards. On the contrary, radio equipment introduced from foreign sources are qualified in both military and commercial standards. The different safety standards and certification methods in air worthiness and radio communication prevents the ROKG to fully exploit both domestic and international markets that should sustain and further expand the production capability of the ROK domestic aircraft industry.[535] Korea is ranked the 7th largest holder of military helicopters and 35th in commercial helicopters. Projection of the domestic helicopter market for the next twenty years, considering the replacement cycle of the current helicopter fleet, is between a 60-80 demand pull of rotor wing aircrafts to fulfill various purposes. Thus, without any significant

534 김병철 외, 항공우주분야 표준 수요조사 및 정비방안, 국가기술표준원 용역과제, 2015.10.30. p. 85.
535 나기천, “군경 외엔 못쓰는 반쪽헬기 수리온,” 2014.10.27.

legislative changes made to the current law, then the Korean public sector will inevitably have to purchase helicopters from foreign sources instead from its domestic industrial capacities. This is the result of insufficient policy coordination among government agencies and pure negligence of due diligence despite the fact the issue has been raised by various players throughout the development of the aircraft.

5.5. Structural Constraints

Because of the small scale and constraints in building technological capacities, a strong and consistent government industrial policy over aircraft manufacturing was critical. However, government policy decisions in this sector constantly suffered from indecisiveness and inconsistencies, which obstructed the aircraft-manufacturing sector from building the required foundational capacities.

5.5.1. Indecisiveness and Inconsistencies in Government Defense Acquisition Policies

During the early phases of the Aircraft Industry Development Promotion Act of 1978, the government directives were to select a handful of major business conglomerates with specialized manufacturing assignments as an ingredient to nurture technological competitiveness and corporate capacities. In this aspect, Korean Air was assigned primarily with airframe manufacturing and Samsung Aerospace was assigned with engines. However, with the industry growing and diversifying in scale and scope, in addition to new entrants into the domestic market, the assignment was rearranged based on the Specialization and Systematization Act. After the astonishing turnaround of Samsung Aerospace being awarded the KF-16 license production program in the summer of 1991, the specialization construct was reframed as Samsung Aerospace for fixed wing fighter aircrafts, Korean Air with helicopters, and Daewoo Heavy Industries with light rotor wings.[536] This arrangement was revisited in 1993 as Samsung Aerospace was awarded to manufacture the T700 engine for the UH-60 Batch-II program. Initially, the Batch-I program was awarded to Korean Air, where the company manufactured both airframes and engines under license from Sikorsky and General Electric. But the Ministry of National Defense abruptly changed the engine manufacturer to Samsung Aerospace in November 1993 for the second batch program. The primary reason was to consolidate all aircraft engine manufacturing programs under a unified company (Samsung Aerospace and its subcontractors) to cut costs and to better implement the specialization and systematization policies with a long-term product life cycle perspective considering improved efficiencies in repair and maintenance work.

At first, the engine manufacturing work for the Batch-II program was to continue the Batch-I contract between Korean Air and General Electric, which was to manufacture 81 engines for the Army's Heavy Helicopter Program. Samsung Aerospace participated as a subcontractor for Korean Air during

[536] 이철호, 차세대 전투기 (KFP)-헬기산업(HX) elelaehf 국내 항공산업 날개 편다, 중앙일보, 1991.6.11.

the Batch-I engine program and was able to localize the production of 16 components.[537] Apparently, Korean Air challenged the new contract arrangement over engine manufacturing and refused to hand over the technological skills and experiences transferred from General Electric during the Batch-I program, claiming that Korean Air already invested about KRW 15.2 billion with a program achievement of localizing 36% of the T700 engine. In order for Samsung to enter into a new technology assistance agreement with General Electric, there would be about KRW 10 billion in unnecessary program costs incurred from redundant investments.[538] On the other hand, the counter-argument from Samsung and the Ministry was that Samsung already obtained the requisite technological readiness levels from the experiences of manufacturing and maintaining over 2,000 engines the past 16 years. Also, Samsung disputed the original contract that awarded Korean Air to manufacture the T700 engines defied the essential principles of Specialization and Systematization in the first place. Therefore it was highly necessary to restore this construct for better efficiency purposes.[539] The cause of such confusion and unnecessary cost increase was the inconsistencies in policy making from the defense acquisition authorities. Also, the underperforming coordination mechanism between the Ministry of National Defense and Ministry of Commerce and Industry is believed to have substantially attributed to such turmoil as well.

The Korean F-4 Phantom-II Upgrade (KPU) Program was another case where indecisiveness, inconsistencies, and poor interagency coordination work of public authorities emerged as causes of major business losses and developmental setbacks. The development of the program in 1989 originated from the need to improve aircraft performance and life cycle extension of the Korean Air Force's F-4D/E Phantom Fighter before the final delivery of the KF-16 fighter. The first batch of F-4D/E Phantoms were delivered to Korea in 1969, so the aircrafts were already reaching close to the end of its lifespan in the late 1980s. The program objective was to improve avionics, armaments, and structural reinforcements to a performance level equivalent to the F-16 with a durable lifespan until 2012 for retirement. The role model of the KPU was the German F-4 ICE upgrade performed by DASA, which included the installation of the AN/APG-66 radar and AIM-120 AMRAAM missiles.[540] The program was raised by the Agency of Defense Development and not the Air Force. ADD's perspective was to utilize the KPU Program as a stepping stone to follow the regular learning path for late comers as it provided opportunities to gather knowledge from tech transfer deals and system upgrade experience. On the contrary, the Air Force strongly pushed for modernization programs instead of extending the F-4's service life. Considering the F-16 program (KFP) still under progress at the time, the Air Force did not want to divert the resources into the KPU.[541] Also, the Air Force favored a more advanced fighter because the F-4E presented very questionable performances in air-to-air dogfight against the MiG-21

537 김형선, "UH-60 헬기 엔진 생산업체 대한항공서 삼성항공으로," 한겨레, 1993.11.23.
538 매일경제, "삼성에 면허이전 거부," 1993.11.23.
539 김형선, "헬기 생산업체 변경 파문예고," 한겨레, 1993.11.23
540 Peter Davies, USAF McDonnell Douglas F-4 Phantom II, Osprey Publishing, 2013, p. 60.
541 161st National Defense Committee Proceedings, Hearings from the 14th National Assembly, 1993.5.10.

during the Vietnam War.[542]

The Ministry of National Defense awarded the contract to Samsung Aerospace in 1992 with an estimated program budget of USD 400 million. Major program milestones were to perform the required SLEP (Service Life Extension Program) works on two prototypes until 1994 and on the remaining 40 aircrafts until 1998. Big players in the international market such as the German DASA and McDonnell Douglas competed for the KPU, but Samsung Aerospace eventually collaborated with Rockwell International to perform the avionics upgrades and SLEP works. But the constraints imposed on technology transfers over sensitive weapon system source codes and Rockwell's corporate proprietary rights precluded Samsung Aerospace from acquiring the necessary technology for the KPU. The restrictive technology transfer circumstances also aggravated the price tag of the program where the worsened cost-benefit situation turned the fate of the KPU Program close to cancellation in March 1994. At this point, Samsung Aerospace already committed a KRW 60 billion since 1990 in equipment and services in preparation of the KPU Program, and was on the verge of losing the entire investments.[543] After avoiding near program cancellation, only a portion of the planned F-4D/E air fleet were programmed for minor avionic upgrades with AN/AVQ-26 Pave Track laser targeting pods, along with the Lockheed Martin/Rafael AGM-142 Raptor/Popeye standoff missiles.[544]

Criticism over the KPU Program primarily focused on the fact that the government neither saved program costs from downsizing the program, nor did the military find adequate resources to finance subsequent fighter modernization programs in the aftermath of program cancellation. Even to this date of May 2017, over 70 F-4E Phantoms are operational under major fighter wings of the Korean Air Force. The F-4Es will still stay in service until 2025 when the KF-X Indigenous Fighter will replace the Phantom-IIs, serving 13 years more than the expected life span of the original KPU Program.[545] In the 1990s, McDonnell Douglas, the original equipment manufacturer of the F-4 Phantom-IIs, already discontinued the production of concurrent spare parts or contractor logistics support. In order to support the shelf life of this old aircraft, item managers, air repair crews, and military logistics authorities extensively searched for spare parts worldwide, and also localized the production of about 120 aircraft components to sustain the life span of the Phantom-IIs.[546] The monolithic and rigid component procurement methods, which accounted on old competitive bidding contracts, also aggravated the fluent sustainment efforts of the Phantom-IIs.[547] The cancelling of the KPU Program also eliminated the opportunity to accumulate knowledge and experience for developing fighter aircrafts. System upgrade

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[542] The main air fleet of the North Korean Air Force at the time was MiG-21; Michael Haskey, "The F-4 Phantom vs. the MiG-21," Warfare History Network, published online on July 20,m 2015, http://warfarehistorynetwork.com/daily/military-history/the-f-4-phantom-vs-the-mig-21/
[543] 정선섭, "삼성 울곡손실 막대," 경향신문, 1994.3.19.
[544] John Fricker, "Boeing /McDonnell Douglas F-4 Phantom II Current Operators," World Air Power Journal, Vol. 40, Spring 2000, p. 70.
[545] 정성택, "KFX 날개도 펴기 전에 난기류…플랜 B 가동하라," 동아일보, 2015.11.14.
[546] 송현숙, "F-4 팬텀 부품을 찾아라," 국방일보, 2009.9.14.
[547] 손혁기, "F-4 팬텀기 부속구매," 대한민국 정책뉴스, 2005.1.31,

and system life extension programs are considered a prerequisite to gather critical knowledge base before launching a full scale indigenous fighter program. The highly anticipated KPU was considered to provide the springboard for local industries before committing itself into license manufacturing of the KF-16 fighter program.[548] Discontinuation of aircraft manufacturing caused by policy disconnects between warfighter requirements and corporate objectives are a critical factor that hindered sustained industry growth. International technology transfers through license production or co-production programs were a major source of technology acquisition in the early years of industry development. Between the mid-1970s to the mid-1990s, a total of $330 million was spent as royalties to pay for the technology transfer deals of five major aircraft development programs.

Aircraft Type		Program	Contractor	International Partner	Program Date	Transfer Type
Rotor Wing		500MD	Korean Air	Hughes	1976 – 1988	License
		UH-60	Korean Air	Sikorsky	1991 – 1998	License
		BK-117	Hyundai	Kawasaki	1989 – 1994	Co-production
		Bo-105	Daewoo Heavy Industries	MBB	1990 – 2000	License
Fixed Wing		F-5E/F	Korean Air	Northrop	1980 – 1985	License
		F-16	Samsung Aerospace	Lockheed	1994 – 1999	License
Engine	End Item	T700	Samsung Techwin/Korean Air	General Electric	-	License (UH-60)
		F-100	Samsung Techwin		-	License (F-16)
	Parts	PW4000	Samsung Aerospace	Pratt and Whitney	-	
		J79/85	Samsung Aerospace	General Electric	-	Subcontract /Maintenance
		A250	Samsung	Allison	-	Subcontract

Table 32. Major Aircraft Development and Manufacturing Program. Reproduced from 산업연구원, 21세기를 향한 항공기산업 발전방향, 1994; 2000년대 첨단기술산업의 비전과 발전과제 – 항공산업 (1994)

As shown in the table above, there was a 2-year gap in helicopter production between the 500MD Program and the UH-60 Program. However, the actual gap between the two programs was nearly 8 years after the ceasing of the main production facility at Korean Air. In the case of fixed wing production, there was nearly decade long gap between the F-5E/F Program and the F-16 Program. Because of such discontinuity in government launched programs, Korean Air did not see much future opportunity in the aircraft-manufacturing sector, and decided to eliminate all production facilities in order to concentrate on other business operations.[549] Therefore, the knowledge for technology and skill sets acquired through the 500MD and F-5E/F program experience did not fully accumulate and transfuse into the succeeding programs. In the case of the BK-117 helicopter development, there were no follow-up program that would've continued the development efforts because of the consolidation of the aircraft-manufacturing firms after the Asian Financial Crisis. Thus, the aircraft industry was not able to fully seize the momentum of exploiting the knowledge accumulated from these experiences.

A bit different but similar case was the F-5E/F local assembly. The program was a representative example where the development authorities launched a highly ambitious program that had no strategic vision towards both military force build-up and economic spin-offs. The local assembly of the F-5E/F

548 김대성, "기술축적 안되 자력개발 역행," 매일경제, 1994.3.5.
549 김종대, "부활호에서 T-50 까지 그리고 KFX 를 향해: 한국의 항공산업," 신동아 제 636 호, p. 90.

concluded with insignificant efforts of tech transfer or diffusion, in which the R&D and manufacturing capacities has short-lived an unsustainable life span. Because of the disconnect and unsustainability of the F-5E/F, the subsequent KFP or KTX programs had to start from scratch because the production experience from the previous program marginally transcended into ensuing fixed wing programs. The country's attempt to build a combat aircraft started with the license production of the F-5. In 1979, Korean Air was awarded the main assembly of the airframe through manufacturing licenses arranged with Northrop, while Samsung Precision Industries (later Samsung Aerospace) license produced the General Electric's J85 engine. Korean Air was recognized as the country's most advanced aircraft manufacturing firm at the time based on the license production of 500MD Helicopters, depot maintenance work awarded from US Pacific Air Force's F-4D Phantom-II and C-123 transport aircraft.[550] From 1982 to 1986, Korean Air locally manufactured a total of 68 F-5 fighters (localized variants called KF-5E/F) at the firm's Kimhae Technology Center. The first 30 aircrafts were localized by assembling directly imported subcomponents from Northrop, whereas the remaining 38 aircrafts were manufactured using localized components developed by Korean Air.[551]

The reason for the early shutdown of the KF-5E/F program was because the aircraft was not the fighter variant the Air Force preferred in the first place. The F-5 was an augmented version of Northrop's T-38 Talon jet trainer. In this aspect, it wasn't the ideal pick to cope against a large conventional army that was militarily supported by another world super power. The force requirement of the Air Force in the late 1970s was to compete against the North Korean MiG-21 jet fighter. In order for the Korean Air Force to obtain air dominance against the maneuverable speed range and armaments of the MiG-21, a jet fighter that had at least the effectiveness commensurate to the F-4 Phantom-II, the A-7 Corsair II, or the F-16 Fighting Falcon. The KF-5E/F was already considered obsolete against the contemporary Soviet MiG variants. The Air Force wished for the F-4E Phantom-II, and laid out a plan to license manufacture the F-16 in the 1980s. But this scheme was rejected by another group of Air Force officers that advocated the F-5E/F variants. At the time, the US government and Congress banned the introduction of the F-16 capability to Korea with the concern for an implied escalation of a Korean arms race.[552]

General Joo Young-Bok, the 13th Air Force Chief of Staff from 1974 to 1979, eradicated the force improvement plan drafted by his predecessors, and programmed the Air Force's future force structure centered on the F-5 capability. For a comparatively smaller force in size, numbers really mattered for the Korean Air Force. The relatively cheaper price of the aircraft and the fact that the F-5s were widely in use by the Korean Air Force was the main reason for General Joo to select the F-5 over the F-4s or other fighter capabilities. But most of all, it was known that the vast affordability of the F-5

550 이성희, "대한항공, 36 년만에 군용기 창정비 4000 대 출고," 경향신문, 2014.10.8.
551 김광모, "국산전투기의 수출: 항공기산업 전망 밝다," 경제풍월 제 195 호, 2015 년 11 월.
552 The concern of providing the South Korean Air Force with F-16s was over the potential of the Soviet Union arming the North Korean Air Force with the highly advanced MiG-23. Don Oberdorfer, "Carter Rejects Plan on Early F16 Sale to Korea," Washington Post, November 23, 1978.

allowed the Korean Air Force to expand the force structure of the Air Force.[553]

However, the overall technological and industrial contribution of the F-5 license production was insignificant. The government forcefully compelled Korean Air to proceed with the manufacturing work, but did not adequately compensate the firm with the developmental risks at all. Korean Air invested a net worth of KRW 70 billion in facilities, equipment, and engineering tools in the process of manufacturing the F-5 aircraft. In addition to the upfront costs, the unit cost of the aircraft increased about 30% during the localization process, but the government never compensated the losses to Korean Air. Because of such harsh circumstances, only 43% of the airframe subcomponents and 17% of the engine subcomponents were localized.[554]

Also, because the F-5 was already an obsolete version in the mid-1980s when the final unit rolled out of the production line, the Air Force did not follow-up with additional production. Furthermore, by defying all odds, the government consequently selected Daewoo Heavy Industries for the basic trainer program (KT-1), and Samsung Aerospace for the advanced trainer program (KTX-2), instead of Korean Air as the lead corporation in the field. In a systems engineering aspect, Korean Air's KF-5E/F did not go through a single refurbishment work until 1993. In comparison to Korean Air, the Taiwanese Aero Industry Development Center (AIDC) went through about 113 system design changes over its F-5 fighters, which enabled the country to accumulate the experience in system dynamics and implement applicable changes to the aircraft.[555] Therefore, after assembling 68 aircrafts under license, while having to absorb all the developmental risks breaking out, but not being recognized for these developmental efforts, and eventually being eliminated from subsequent development opportunities, Korean Air abolished the KF-5E/F production line and decided to concentrate in manufacturing helicopters afterwards.[556]

Another recent case where a defense firm took its own initiative in a certain weapon system development program, but was not awarded the final contract is shown in the Active Electronically Scanned Array (AESA) radar project for the Korea Fighter Experiment (KF-X) Program. The AESA radar is a highly advanced radar system that detects multiple targets simultaneously and allows ships and aircrafts to broadcast stronger radar signals than conventional radars while still remaining stealthy. The significance of AESA radar development was not only confined on the radar itself, but was linked with other critical performance systems of the KF-X program such as data-links, electronic counter measures, and sensor modules (IRST, FLIR, MAWS, IFF, etc.).[557] The development program of the radar itself is government led, where ADD partnered with a foreign firm, most likely negotiating terms for collaborative development with Swedish SAAB as of December 2015, for system development. The

553 Normally, an aircraft is associated with a group of crews that support airframe maintenance, armaments, avionics, safety, and various other support functions, which enables the air force to expand the organization.
554 공군본부, 항공산업 육성방안 연구, 1984, p. 56.
555 임상민, "세계의 항공우주산업: 대만," 항공우주 매거진 제 85 권, 2004, p. 10.
556 박영출, "재계 인물현대사: 수송한국의 거목 조중훈(14)," 문화일보, 2004 년 2 월 28 일.
557 안승범, "동상이몽의 KF-X AESA 레이더, 디펜스타임즈, 2015 년 9 월호.

domestic defense contractor is responsible for low rate initial production, and the subsequent full rate production of the radar. Although the defense firm is not entirely awarded the R&D portion of the program, the defense firm takes substantial responsibility in radar manufacturing and demonstration work.[558]

Considering the radar business requires highly sophisticated skills and expertise due to the complexities of the system, the experience factor in corporate R&D was heavily weighted for contractor selection. In this regard, a domestic firm called LIG Nex1 was regarded the strongest candidate for the AESA development project as the company gathered significant experience in the radar business in the past, specifically regarding AESA related technology for nearly a decade. LIG Nex1 was the partner company of ADD that conducted the first and second phase feasibility studies from 2006 to 2013, and was in the course of conducting the test development phase of the AESA project from 2014 to 2019. The corporate R&D budget LIG Nex1 invested into this program until 2016 was approximately KRW 14 billion.[559] Also, LIG Nex1 extensively conducted collaborative research with the Electronics and Telecommunications Research Institute (ETRI) on the X-band 30W GaN Photovoltaic Devices, which is a technical level highly pertinent to AESA development and also known to have longer detection ranges than the AN/APG-63(v)1 radars installed inside the F-15K.[560]

However, the defense acquisition authorities identified an alternate company, Hanwha Thales, instead of LIG Nex1 as a preferred bidder for the AESA program, and asserted the decision was weighted on all aspects of corporate capabilities including technology readiness levels and development cost.[561] Hanwha Thales, previously Samsung Thales but acquired by Hanwha in 2015, claims to have built-up significant radar related capacities throughout the history of the firm, which include Search and Detection Radars for the Cheonma Air Defense Artillery System and Active Protective System, Improved Multi-function Radar Systems for Cheolmae-II (M-SAM), and so forth. Hanwha Thales was given higher grades in the score card regarding its experience in and relevance with other systems integration work related with the KF-X. Most evidently, Hanwha Thales was awarded the Mission Computer module development and Large Area Display (LAD) module program for the KF-X as well, which must be critically interlinked with the AESA radar.[562] But Hanwha's actual experience and expertise in AESA radar development remained questionable compared to that of LIG Nex1, which continues to raise skepticism in program success even in October 2016.

5.5.2. S&T verses Industrial Authorities

In 1991, MOST initiated a development project, dubbed the G7 Project, to join the ranks of

558 KF-X program update to the National Defense Committee, November 2015.
559 김태훈, "KF-X 선수교체로 사라진 490 억 그리고…," Seoul Broadcasting Station, 2016 년 5 월 1 일.
560 AN/APG-63(v)1 radar is not a AESA radar, but considered the previous stage radars in the degree of completion, 2015 Seoul Air and Defense Expo LIG Nex1 promotion booth.
561 제 94 차 방위사업추진위원회, 2016 년 4 월 20 일.
562 박수찬, "KF-X 핵심 대화면시현기도 한화탈레스 수주," 세계일보, 2016 년 5 월 4 일.

advance technical countries in high-tech industrial sectors. The strategy included 184 R&D subjects under 11 S&T categories that included information technology, new materials, machinery and automation, aerospace, electronics, maritime engineering, environmental sciences, and so forth.[563]

The program budget of the G7 Project grew up to approximately KRW 420 billion between 1992 and 1994, with an overall program estimate of KRW 3.48 trillion until 2001. The pool of S&T workforce committed to this project was about 11,052 researchers from 327 GRIs and university laboratories. The implementation scheme was arranged through linking the triple helix of public-private partnership between industry, university, and GRIs.[564] Especially, the G7 Project endowed Samsung Aerospace Inc. with public funding for subcategories regarded most pertinent to aeronautical engineering under advanced manufacturing systems such as automation, precision machinery, and system design.[565] Defense acquisition priorities and R&D policies constrained potential growth opportunities of the aircraft-manufacturing sector. The military favored foreign system purchases instead of initiating indigenous development projects because of reasons justified by the immediate need to deploy warfighter needs to cope against imminent North Korean hostilities. Defense R&D projects is complex, exceedingly capital intensive, and requires a high degree of knowledge and expertise throughout a protracted period of time. Defense R&D programs have a high possibility of failure, and there is no guarantee a R&D project will successfully materialize into an actual weapon system program. Even so, it is extremely challenging to maintain a strong supply chain of an indigenous weapon system, especially with complex defense systems, within the forecasted life-cycle because it relates to business survivability to firms supplying the components and auxiliary parts. Large scale defense R&D programs were abruptly canceled and replaced by foreign systems. The Maritime Operations Helicopter Program (AW-159 Wildcat), Army Attack Helicopter Program (Apache / Scout Helicopter), Air Force Electronic Countermeasure Training Program are the typical examples of these kind of patterns where proposals for indigenous development were overridden by foreign capabilities. Due to these reasons, domestic defense firms slowly disengaged and diversified its businesses out from military contracts, or in some cases completely exited the defense market.[566]

The comparative cap of indigenous development programs in contrast to foreign procurement also remains as a big hurdle. Unlike countries such as Israel, Japan, and Taiwan where indigenous R&D is given preference over foreign procurement for the sake of sustaining a competitive defense industrial base, Korea was not always loyal and respectful to building its local defense industrial capacities. The general threshold is to limit the overall R&D and production cost to 130% in comparison to direct foreign procurement when making domestic R&D decisions. Considering not only the high risks associated with development, but also the fearsome challenges to maintain a healthy supply base,

563 매일경제, “차세대 G7 프로젝트 선정 착수,” 1991. 5. 24.
564 매일경제, “G7 프로젝트 중간점검: 연구성과 산업화로 직접연계,” 1994. 7. 9.
565 매일경제, “G7 프로젝트 35 개기관 신청,” 1991. 11. 18.
566 조성식, “위기의 방위산업, 박정희는 그렇게 하지 않았다,” 동아일보 2016. 5. 24.

constraining both development and production costs within 130% compared to foreign direct purchase is an insurmountable task. In this regard, high-risk development programs such as aircrafts or complex subsystems are always ruled out and the eventual contract is awarded to foreign systems.[567]

5.5.3. Alliance Politics, Tech-Transfer Restrictions, and American Dominance in the Korean Defense Market

The U.S. has been exhibiting inherently ambivalent behaviors in its cooperative relationship over defense technology transfers and industrial exchanges with Korea. U.S. technology assistance was undoubtedly a critical catalyst of capacity building during the early years of Korea's defense industry. However, as Korea's industrial capacity reached the level global competitiveness, U.S. military assistance policy steered to more restrictive control over technology transfer arrangements. On the contrary, major U.S. defense firms still regarded the Korean defense market as a lucrative business opportunity. In order to address these two conflicting dimensions of defense industrial cooperation, the U.S. technology security policy served as a pivot that leveraged these differing aspects. Thus, considering the vast volume of defense articles and technology provided from the United States, Korea's been constantly subject to restrictive control measures under the U.S. technology security regime. Most of the controversial items considered aviation assets such as in avionics, engines, and sensors. Such restriction has posed significant challenges in pursuing pure indigenous solutions in areas related to aircraft manufacturing. But under the same motives and circumstances, such condition worked ironically for U.S. government and industrial entities in the process of retaining predominance in the Korean defense market.

On 6 January, 1991, after four years of negotiations, Korea and the United States signed a provisional memorandum entitled the Patent Security Agreement (PSA), which was enforced as one of a series of restrictive control measures over defense technology development between the two countries.[568] Korea had to provide assurances that it will protect sensitive U.S. military technology in order to become an eligible party to receive or share such technology. The core concept of the agreement was to reciprocally safeguard patents that contain applications for defense purposes. Thus, if one party of the PSA registers a specific technology under defense applications, the other party shall provide the same level of protection on the subject technology in return. Under the PSA, Korea was able to receive a number of military technologies from the U.S. for domestic R&D purposes. In the case of re-engineering or exporting the subject technology to a third party, the applying party must obtain prior authorization from the other country that holds the property rights over the subject technology. Even when the subject technology obtains authorization, the applying country must pay a certain amount of

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[567] Chin-Young Hwang, The Aircraft Industry in a Latecomer Economy: The Case of South Korea, University of Sussex PhD Dissertation, May 2000, p. 104.

[568] The official title of the memorandum is the "Agreement between the Government of the Republic of Korea and the Government of the United States of America for the Safeguarding of Secrecy of Inventions relating to Defense and for which Applications for Patents have been made".

royalty fees to the parent country. The General Security of Military Information Agreement signed in 1962 and revised in 1989 serves for the same purpose of the PSA. These agreements originated from different interests evolved between the two countries. In the mid-1980s, Korea was in need of state-of-the arts military technology in order to build-up its military forces as well as its defense industrial foundations. The United States was in need of expanding its alliance network that would support the Strategic Defense Initiative (SDI) against the Soviet Union and the communist bloc. Therefore, there existed a common interest between both parties in establishing such technological arrangement, which embodied significant restrictions for the recipient country, mainly the Korean government and its defense industries. The preceding memorandums and the PSA established between the two countries have provided access to advanced state of the art defense technology to Korea. However, further technological exploitation was extremely limited because of the restrictive nature of these arrangements that restrained modification and overhaul work over these technologies. Moreover, starting in the late 1990s, Korea has been subject to a number of technological scrutinizations by U.S. defense technology security authorities over suspicions of reverse engineering copied from U.S sources. Especially, the growing concern of Korea becoming a global contender in the international defense export market has exacerbated this threat perception within the U.S. Government and its defense industry.

For instance, in June 2011, the export of an airborne electronic warfare system to the Pakistani military called ALQ-200K manufactured by a local Korean defense contractor called LIG Nex1 was frustrated by the U.S. Department of State with suspicions of reverse engineering U.S. origin defense technologies as well as concerns of transferring sensitive defense technology to a potentially rogue state such as Pakistan that's been building military relationship with China. The ALQ-200K jammers were to be loaded on F-16 fighters operated by the Pakistani Air Force (PAF). At the time of system design of the ALQ-200K jammers, LIG Nex 1 confidently believed the technology was indigenously developed and free of any technical restrictions based on the claim made by ADD that the product evolved from indigenous development efforts. However, it turned out the technology was a complete product manufactured from U.S. sources, which subsequently resulted in complete humiliation of Korean defense products in the international defense export market.[569] An interesting story subsequent to the State Department's denial of issuing export license to LIG Nex1's ALQ-200K sale to Pakistan came in a completely opposite narrative. The State Department approved the sale of the U.S. firm ITT-Exelis' airborne electronic warfare pod ALQ-211 (v)9, which is considered an improved version of Korea's ALQ-200K, to the PAF for operations into its F-16 fighter fleet.[570] The basis of the export approval completely contradicted the rationale of denying the Korean case, which argued the Korean export may lead to a possible leakage of airborne jammer technology to Chinese authorities. Thus, it was quite evident the U.S. Government was exhibiting concerted efforts to obstruct the growth of a

[569] Lee Sun Hyuk, "Suspicious of stolen technology, U.S. suspends weapon exports to Korea," The Hankyoreh, 21 Nov, 2011.
[570] Aviation Report Global, "Pakistan Air Force to Receive ALQ-211(v)9 Electronic Warfare Pods from US," 5 July, 2011.

potential competitor in the international market, such as the Korean industry.

Another yet controversial technology security case that hindered Korean officials in pursuing further utilization of U.S. origin defense technology regards the alleged unauthorized examination of the Lockheed Martin Tiger Eye Infrared Search and Track sensor attached to the F-15K Slam Eagle. In August 2011, a U.S. Government delegation claimed the possible compromise of U.S. controlled sensitive sensor technologies of the Tiger Eye targeting pod by Korean Air Force technicians who had malicious intents of reverse engineering. The U.S. Government places anti-temper seals to prevent illicit transfer of sensitive U.S. defense technologies against third countries in order to protect U.S. national security interests as well as the technology competitiveness of its defense industry. The case was not fully resolved and was escalated to the higher Ministerial-Secretarial level, in which both the U.S. Secretary of State and Secretary of Defense strongly complained the possibility to their Korean counterparts in a high level bilateral venue.[571] It was later revealed that the U.S. defense authorities had strong suspicions against the Agency of Defense Development over the attempted opening of the anti-tampered secure box of the sensor. U.S. officials expressed concerns over the continued public description `of ADD's experience in reverse engineering U.S. technology such as the Korean version of the Nike-Hercules air defense missile system.[572]

In reference to the two memorandums on technology security arrangements between Korea and United States, compounded by the number of controversies over tech-security compliance, the U.S. authorities strongly recommended the establishment of a defense technology security regime within the Korean Government, and the creation of a bilateral forum that discusses and coordinates tech security agendas. In this aspect, under the legislated jurisdiction of the National Assembly, the Defense Technology Control Bureau was established under DAPA in 2014 as well as a bilateral forum between the two countries called the Defense Technology Security Consultative Meeting (DTSCM).[573] In parallel to these controversies, U.S. authorities exerted efforts to retain its competitive advantage in the Korean defense market by leveraging their tech security concerns. What was quite notable was when the Korean Government decided to choose a foreign platform against a U.S. weapon system, which raised grave concerns within U.S. defense industrial authorities considering the possible Korean defense market drifting away from traditional U.S. predominance. As described in Chapter 4, U.S. defense articles enjoy a commanding lead in the Korean defense market attributed to the on-going military alliance structure under strong justifications of building stronger strength in command control interoperability.

However, the sudden agreement in 2005 between the two countries to transfer wartime operation control from the Commander of U.S. Force Korea to the Korean military created new circumstances of the alliance to relinquish the former patterns of giving preference over US defense

571 김종대, "서울에 온 미국의 안보장사꾼," 한겨레, 2012.7.26.
572 황일도, "한국형 전투기 개발 미국의 몽니," 주간동아, 2011.12.4.
573 안성모, "너흰 팔면 안돼, 우리 것 사기만 해," 시사저널, 2014.1.14.

products in weapon systems procurement. It was a time of retrenchment and disengagement from the conventional belief of which the withstanding 60-year alliance system was about to change. Such aspect was evident in the Korean Government's unsuspected decision to partner with Eurocopter regarding the Korea Helicopter Program in 2005. A similar observation was the competition between Boeing's E-737 and the Israeli Elta System's G-550 over the Airborne Early Warning and Control Program (E-X) in 2006. Although the Korean Government eventually selected the Boeing proposal, the entrance of a third country contender in the U.S. dominated Korean defense market was certainly perceived as an absolute threat to U.S. defense authorities.[574] The huge price tag associated with these aircrafts made these two programs the most lucrative weapon system procurement at the time for the global defense industry, and the significant fact that the Korean Government no longer rendering its absolute loyalty to US products subsequently compelled US officials to ease existing regulative control measures over Korea in its defense export control system. In this sense, several restrictions in terms of export procedures stipulated in the US Foreign Military Sales (FMS) system were removed, for which Korea was given an upgraded status commensurate to NATO member states as well as Australia, New Zealand, and Japan (NATO+3).[575]

Another similar case during this period was the US government decision to approve the export of four RQ-4 Block 30 Global Hawks to Korea in 2011. Before the decision, the Korean Government requested earlier in 2005 to approve the sale of the surveillance drone as part of building up its intelligence, surveillance, and reconnaissance capacities. However, the restrictions stipulated in the Missile Technology Control Regime (MTCR) precluded the overseas export of the Global Hawk.[576] For the same reason, countries like Japan, Singapore, and Australia were not able to acquire this enduring capability. Despite the restrictive clauses of the MTCR, the US authorities strived to lift the ban by categorizing the Global Hawk as an intelligence, surveillance, and reconnaissance platform and not an offensive strike system.[577] The US defense industry's deep involvement in this endeavor further facilitated the export approval process. With the continued rigidness of the US Government over the release of the Global Hawk, Seoul was considering an alternate option such as Boeing's Phantom Eye, AeroVironment's Global Observer, and the Israeli Heron-TP or Hermes 1500.[578] The restrictive clauses of the MTCR were harming U.S. industries while other MTCR countries such as Russia and China were finding loopholes to avoid the constraints in other ways. Thus, it made little sense for US authorities to comply the MTCR while others were finding circumventing routes for its industries, which is another representative case of industrial concerns overwhelming conventional policy lines.[579]

574 김종대, "실속 없는 무기구매국 지위향상은 미 방산업체 작품," D&D Focus, 2008.5.

575 조성식, "한미정상회담 성과물? 무기구매국 지위격상 진실," 신동아, 2008.6.

576 The MTRC restricted sales of space launchers, cruise missiles, and UAVs that can be used to deliver weapons of mass destruction. The Global Hawk falls under Category I of the MTCR classification. Stephen Trimble, "Arms agreement means no Global Hawk for South Korean," Flight Global, 19 July. 2005.

577 Greg Waldron, "South Korea likely to acquire four Global Hawks," Flight Global, 9 September 2011.

578 Defense Industry Daily, "US Will Sell Global Hawks – Will South Korea Buy?," 3 November, 2013.

579 Philip Finnegan, "Export Control Threaten U.S. Edge in Foreign UAV Markets," Teal Group Corporation Press Release, 19 June, 2017.

It was also understood that the primary reason why the U.S. Government did not fully engage into an investigation over controversial technology security cases was because of the high profiled defense acquisition programs announced by the Korean Government. The third round bidding of the F-X program, which considered the F-35A Joint Strike Fighter, second batch bidding of the Aegis Destroyer program, which had in mind of products from Lockheed Martin, Aerial Refueling Tanker, and so forth, provided lucrative opportunities for the U.S defense industries. Therefore, it was argued that the more the U.S. authorities raise tech-security concerns, the lower the possibility of U.S. defense contractors winning these lucrative bidding opportunities.[580]

5.6. Chapter Conclusion

By fully riding on the rapid development experience driven by the historical mindset and institutional construct of the developmental state, the Korean aircraft-manufacturing sector took off with an ambitious objective to enter the global aerospace industry during the industrial reformist period of the mid-1980s. However, the inherent challenges brought up from domestic institutional arrangements, international norms and regulation, and the technological complexities of aircraft-manufacturing in general have discouraged the growth prospects of the industry from becoming an innovative player, at which the industry still lingers as a catch-up sector compared to global standards.

The Aerospace Industry Development Framework Plan of 1999 constitutes the basis of the development drive. However, considering the circumstances from the past twenty-years, declaratory policies of government driven development initiatives restrictively transcended into less competitive strengths for industrial growth. Unlike the country's industrial champion products such as automobiles, ships, and electronics, the government showed apparent limitations in coordinating the country's industrial capacities and S&T foundations into highly complex product system like aircraft manufacturing. The finite domestic demand-pull in commercial aviation, inconsistent decision making in indigenous military aircraft development, limited corporate R&D capacities, and less coordinated efforts in promoting domestic aircraft products in the international market have all constrained the industry from building competitive calibers in the field of aeronautical engineering, jet propulsion, avionics, and so forth. Government efforts to overcome the self-evident shortages of dedicated aerospace R&D budget were conflicted by organizational rivalries between the military and commercial authorities holding a major share in domestic aircraft manufacturing, which resulted in insufficient sharing of knowledge and experiences and poor interagency R&D cooperation[581]

The military initially took the lead in nationalizing the development of critical weapon systems during the 60s and 70s. However, in the 80s, the seemingly complex nature of modern weapon systems, especially in military aircrafts, has hampered the strong drive of the military. It is a rare case to see the

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580 황일도, "한국형 전투기 개발 미국의 몽니," 주간동아, 2011.12.4.
581 신보현, "국방연구개발 추진방향과 연계한 항공산업 육성 발전방향," 항공산업연구, 63 권 2 호, 2002, p. 94.

military to become the anchor tenet of nurturing high technology, because weapon systems were urgently required for rapid deployment within a set time to serve for clear strategic and tactical objectives. Therefore, military R&D becomes reluctant to take risks and explore new projects. It merely focuses on technologies that are relatively easy to reach or already proven from foreign sources. In the meantime, aircraft technologies in the other sectors lack a strong pull as well. MOCIE has other priorities to worry about in reference to the country's competitive business areas, whereas business fields that embody high technological risk such as the aircraft industry is not within the Ministry's nearest interest areas. Although MOCIE continued to serve as the chair for the domestic aerospace industry promotion boards, it did so with low esteem and lesser motivation.

Most of the inconsistencies in government industrial policies towards the aircraft-manufacturing sector occur from these organizational characteristics. Considering the total life cycle management routines, the discrepancies derive from the structural disconnect between the critical components between force requirement generation, R&D, acquisition management, and operations and sustainment. In terms of the joint requirement generation process, the military is the sole government agency that raises the warfighter's force needs in the weapon systems development process. However, most of the planners residing in the military – Joint Chiefs of Staff, military service headquarters – receive almost no professional training nor consider the force requirement generation as a career enhancing profession. Most of the officials assigned to force planning rotate out from the position to another staff duty in less than three years, which precludes the officials from accumulating requisite knowledge and experiences to establish a solid force development plan that meets the strategic interest of the country's national security and economic engine base. Considering the complexities of the aircraft manufacturing and indigenous development, most of the decisions made by the military favored foreign procurement. Thus, the decision to go either indigenous or foreign in the process of introducing a weapon system was often distorted by foreign platforms lobbying for the domestic share of the market.[582] Additionally, the Korean Air Force (ROKAF), which is the principal agent of military aircraft programs, have been constantly marginalized in the decision making process over major defense acquisition programs, which misrepresented some military aircraft programs favorable for foreign influences. The Army-Centric decision metrics of the defense sector gave higher priorities on political benefits than on strategic visions that should have incorporated both military and economic endeavors.[583] In this regard, such policy patterns caused unnecessary discrepancies between foreign platforms and indigenously development systems where the government had to expend double the amount of resources to maintain both systems. Under these circumstances, accumulating sophisticated knowledge and engineering skills in system design and integration were unattainable, at which indigenous development programs had to rely most of the technological expertise to its foreign partners.

[582] 이승주 외, 긴요전력 적기 전력화 추진 개선방안 연구, 한국전략문제연구소, 2014, p. 18.
[583] 김종대, "차기전투기에 대한 유감," 디펜스 21 플러스, 2012.8.24.

Because of these inconsistencies, discontinuities in government development decisions, and risk averse attitude toward technology development, the technological readiness level of the Korean aircraft-manufacturing sector was restricted to license production with low localization rates. The technological capacities in system design and integration fell considerably short from that of other forerunners in the global aerospace industry.

The next chapter describes the regional and sectoral systems of innovation in the aircraft-manufacturing sector, and reviews how the two apparatus functioned and interacted under the established national level innovation systems.

Chapter 6. The Aircraft Manufacturing Sector: Regional and Sectoral Level Innovation Systems

6.1. Building Absorptive Capacities through Industrial Networks: Regional Aircraft Manufacturing Clusters

The government's clustering strategy has tallied with the developmental objectives of the local governments. Based on the clustering game plan outlined in the in the 2010 AIDP, the local governments rushed into developing their own strategy to attract both government incentives and corporate investments based on in its respective regional area of expertise.

6.1.1. Overview of Regional Clusters

The AIDP highlights regional strengths based on manufacturing (wider Gyeongnam area), R&D (wider Daejeon), and Information Technology (wider Seoul metropolitan area). In terms of maintenance, repair, and overhaul (MRO), the traditional Busan/Kimhae complex as well as the central Cheongju area were recognized for its growth potentials. But most of all, the forerunner in this race was Gyeongam Province, which is the home of KAI (Sacheon), Korean Air (Busan/Kimhae), Air Force Education and Training Command and tactical airlift squadrons, and the country's largest industrial complex (Changwon). As of 2016, the industrial output on aircraft manufacturing at Gyeongnam Province, together with the Busan/Kimhae production output, accounts for about 88.4% of the entire country, where the province hosts nearly 70% of the country's aircraft-manufacturing companies. Through the established industrial beltway that connects Sacheon-Changwon-Busan/Kimhae, Gyeongnam Province has aspired to become the lead figure in entering the sectors of highly complex product systems such as aircraft manufacturing and MRO business altogether. Gyeongnam Province is also endowed with the regional industry linkages between aircraft manufacturing (Sacheon/Kimhae), automobile (Busan/Changwon), and shipbuilding (Geojae), as all three industrial clusters reside within the close proximities of each other.[584]

Unit: $ Million

Location	2008	2009	2010	2011	Market Share (%)
Gyeongnam	1,298	1,390	1,704	1,677	72.0
Busan/Kimhae	330	264	388	451	16.4
Gyeongbuk	229	242	193	152	8.2
Choongnam	55	42	40	30	1.7
Daejeon	29	24	26	27	1.1
Incheon	-	3	3	2	0.1
Gyeong-gi	2	2	2	3	0.1
Gwangju	2	2	2	2	0.1
Seoul	-	1	7	5	0.3
Total	1,945	1,970	2,365	2,349	100.0

Table 33. Production Output by Region; Adopted from 2012 항공산업통계 (항공우주산업진흥회)

[584] 경상남도, 2016 년 경남지역 산업진흥계획, 2016, p. 70.

In 2004, the Gyeongnam Provincial Government designated the aircraft-manufacturing sector as a regional strategic industry in order to fully exploit the region's industrial strengths in high tech complex product systems. In the course of doing so, the Provincial Government selected the JINSA (Jinju-Sacheon) Industrial Complex, which is situated nearby KAI's Sacheon headquarters, as the region's aircraft-manufacturing cluster. The presence of the country's sole aircraft-manufacturing system integrator at this location made the industrial structure of the Jinju-Sacheon area absolutely reliant on the aerospace business, where the respective business sector employed nearly 60% of the entire residence in this area.[585] As of April 2017, after three years of deliberations and feedback, the Korean Government, represented by the Ministry of Land, Infrastructure, and Transport, approved the JINSA Complex as a national industrial complex specialized in aircraft manufacturing. The designation as a national industrial complex provides various incentives and support packages in terms of tax breaks, capital investments, policy priorities in sectoral promotion opportunities, and so forth. The JINSA Industrial Complex will be receiving an approximation of KRW 340 billion in both public and private investments for a 4 year period until the infrastructure construction concludes.[586]

Three organizations primarily support the aircraft-manufacturing business within the Gyeongnam Province. In the grand scheme of instigating innovation in each industrial sector, the Ministry of Industry and Energy during the Roh Mu Hyun Administration included the aerospace industry as a mini-cluster within the broader Changwon Mechanical Industry Cluster Project. The project strived to connect university (R&D/education/training)-corporation (manufacturing)-GRI into a coordination network in support of introducing greater innovative opportunities within the manufacturing sector in the region. A small but very meaningful success story from this effort was the commercialization of a molding technology developed by a local firm called Sooseong Airframe inside the mini-cluster. The firm developed the technology but was not able to commercialize it for value added goods. In November 2005, the Mini-Cluster project identified the commercialization needs and arranged the support from various technical and business groups within the cluster, which eventually resulted in a $60 million export opportunity to the Fuji Heavy Industries at Japan, with a sustained supply chain support until 2015.[587]

The Gyeongnam Provincial Government, in 2007, provided a vast part of land about 392,000 m^2 in the southwest banks of Sacheon City to build the JINSA Aerospace Cluster (or Industrial Complex). As part of the Provincial Government's long term aspiration to build the innovative Gyeongnam Techno Park, which links the industrial beltway from Sacheon to Kimhae, the Aerospace Center assists corporate investments into the region over business areas such as work space support, collaborative equipment sharing, overseas marketing and export promotion, workforce

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585 Ibid., p. 75.
586 국토교통부 보도자료, 경남 진주사천에 '항공특화' 국가산업단지 추진, 2017.4.27.
587 한국산업단지공단 보도자료, 창원클러스터 시제품 제작지원사업 성공사례 계속 돼," 2006.5.9.

professionalization projects, cooperative R&D, and coordination networks.[588] Sacheon City revised its municipal ordnances to augment city functions that supports the creation of the industrial complex in terms of cultural exchanges (Aerospace Expo), Southern Coastline Economic Zone (Sun Belt), Sacheon Aerospace Museum, real estate support for industrial land use, and so forth.[589]

Around the period when the Provincial Government decided to sponsor the aircraft-manufacturing business, the overall industrial infrastructure of the JINSA Complex was examined substandard compared to the competitiveness and productivity level of other regional industry clusters. At the time around 2003, the productivity (KRW 3.5 trillion) and economic value added (KRW 1.25 trillion) assessed over the JINSA Complex accounted slightly over 5% of the entire industrial output of Gyeongnam Province, which was comparatively lesser than other competing cities in the same region.[590] Therefore, in order for the JINSA area to emulate as a serious contender in this high-tech business, it was imperative to find ways to build-up the necessary infrastructure in the area. A notable aspect about the JINSA Complex was the high concentration in aircraft manufacturing. Sacheon being the home of the country's sole aircraft system integrating company (KAI), the associated small and medium sized manufacturing firms all concentrated in the close proximity nearby this area in order to seek the best synergetic effects. As of 2016, the Sacheon area accounts for nearly 82.5% of the country's entire production output in aircraft manufacturing, in which hosts about 32% of the country's manufacturing firms registered in the aircraft manufacturing category. The proportion of aircraft manufacturing in the regional areas surrounding Sacheon itself also accounts for about 60%, which signifies the high concentration rate of sector in the wider Sacheon area in general.[591]

JINSA Complex also houses education and training centers focused on aircraft manufacturing. The technical manpower pool educated and trained in nearby universities (Gyeongsang National University) and vocational schools (Korea Polytech, Aviation Technical High School) support the gist of the requisite technical workforce. The portion of capital intensive R&D is supported by local branch laboratories of GRIs. Less than a mile away from the JINSA Complex is the Aviation Research Center under the Defense Agency for Technology and Quality (DTaQ). The Korea Aerospace Research Institute's (KARI) Test and Evaluation Center is within less than an hour distance from JINSA, in addition to the Korean Institute for Machinery and Metals (KIMM) that performs comprehensive research in aircraft related composite materials and components. JINSA is also the headquarters of the major training centers of the Korean Air Force such as the Air Force Education and Training Command, 3rd Training Wing, Air Force Aviation Science High School, and other specialty technical training schools. Thus, the area is abundant with the nutrients to nourish aircraft related business.[592]

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588 Gyeongnam Technopark webpage, accessed on July 17, 2017, http://eng.gntp.or.kr/sub3/sub5.jsp
589 강인범, "항공우주산업 미래, 사천에 물어보라," 조선일보, 2008.4.4.
590 안영수, "경남 항공우주산업 클러스터 구축의 타당성분석과 발전전략," 항공산업연구, p. 14.
591 Ibid., p. 78.
592 Ibid., p. 16.

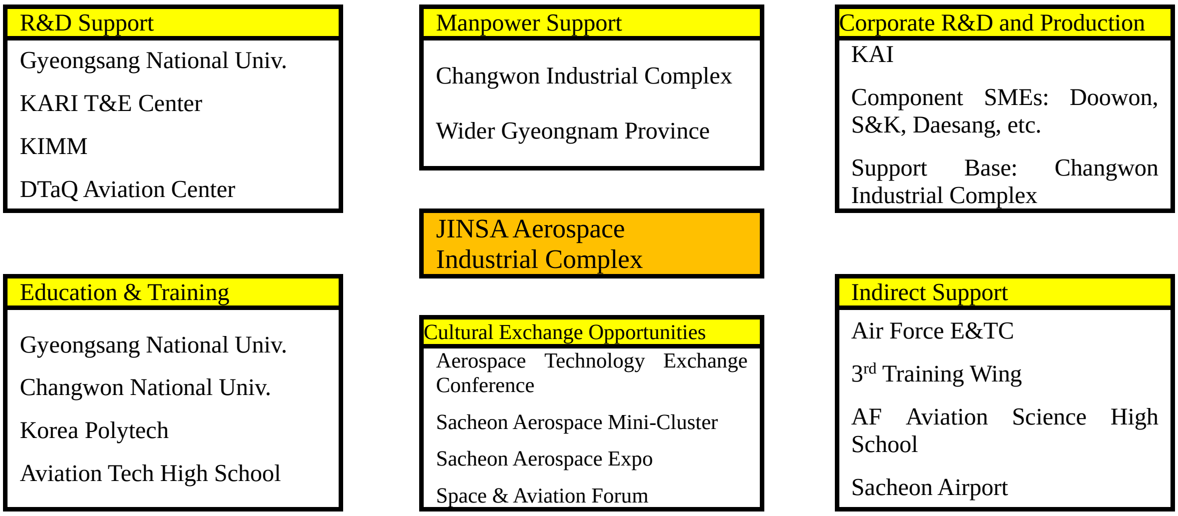

Figure 20. Support Structure of JINSA Aerospace Industrial Complex

However, despite the extensive developmental assets, the inconsistencies and discontinuities in government decision making over aircraft manufacturing restrained bold investment decisions within the broader Gyeongam Provincial area. Attributing to the plain reality of minimal corporate anxieties and low foreign investment interest in the aspect of investing into a provincial aerospace project, most of the capital flows are expected to come from public sources, mainly through government initiated national programs. Clustering requires high degrees of concentration and sustained regional support. Based on the AIDP Framework, however, the government identified multiple regions as potential candidates for regional aircraft-manufacturing clusters. Such decision has instigated unnecessary competition between different provincial governments and metropolitan cities in order to seize the opportunities for increasing local jobs through government support and corporate investments. This is déjà-vu all over again of the intense competition against Chaebol firms over the finite share of the domestic aircraft-manufacturing market during the late 1980s. The conditions are remarkably identical; rosy expectations of the future aircraft-manufacturing market; excessive competition against contending entities; overlapping investments and false promises made to local corporations. The competition spills over to contenders residing in the same region. The Busan/Kimhae MRO complex, Changwon Industrial Complex, and Jinsa Complex are all competing against each other instead of finding ways to build effective cooperative networks.

Based on a survey conducted by the Gyeongnam Development Institute between 2007 and 2009 over the effectiveness of the national and regional level policy support on the aircraft-manufacturing sector, the results from the firms residing within the Changwon Industrial Cluster showed mixed returns in terms of competitiveness sectors measured in price, product quality, and technology. But overall the survey indicated slightly above average performances in each sector examined. According to the survey, the corporations expressed difficulties in securing the right size and skilled manpower (32.6%), sufficient quantities of workloads (30.2%), adequate finances (27.9%), and so forth. The difficulties in manpower was mostly on securing quality technicians (37.2%), but also on shortages in R&D workforce

(20.9%), preference over big business corporations (14%), and scarce numbers in system designers (9.3%).[593]

City	Average	Sectoral Competitive Category		
		Price	Product Quality	Technology
Average	*3.8*	*3.6*	*4.0*	*3.9*
Changwon	3.8	3.4	4.2	3.9
Gimhae	3.7	3.5	3.8	3.9
Sacheon	3.9	3.8	3.9	3.9
Hahman	2.7	3.0	3.0	2.0

Table 34. Aircraft Manufacturer's Competitiveness Survey (Gyeongnam Province) *Measured in Likert Scale (1 to 5)*

In areas of competitive strengths and weaknesses extracted from the same survey, the JINSA Complex, or the overall aircraft-manufacturing sector in general, showed weaknesses in three primary areas. Firstly, in terms of the presence of a pivotal figure capable of adjudicating shortages in competitive resources, the JINSA Complex or the wider Gyeongnam Province showed weaknesses in such functions. The Complex was mostly reliant on corporate capacities in these adjudicating functions, in which corporate capacities fell far short in reaching out to other competitive surveyed areas such as in securing appropriate workforces, capital investments, technological opportunities, etc. Secondly, structure in educating and training the right workforce shows weak linkages with outside training institutions, which degrades further opportunities in attracting talented workers finding jobs in this sector. Structural linkages with local universities and training institutes also show weak connections in terms of building strong curriculums or R&D structures in support of constructing strategic networks. Lastly, weak linkages between the manufacturing base and service providers make it harder for firms to market aircraft products in the international markets. The significance of the aircraft-manufacturing sector requires extensive public and private partnership when promoting the respective end item against the apparent contenders in the international market. The capability shortfalls in these primary areas continue to pose challenges for the JINSA Complex, and the Korean aircraft-manufacturing sector in general, in terms of upgrading the industrial structure into a high performance innovative area.[594]

Components	**Sources of Competitiveness**	
	Strength	**Weakness**
Motivating Force	Nationally designated strategic industry Nationally driven industry promotion Strong development motives by local government	High reliance on government policy directions Insufficient support in attracting skilled workforce Insufficient local start-ups
Environment	Strongest concentration rate in aircraft manufacturing Close proximity of manufacturing firms Firms actively engaged in cooperative relations	Avionic firms located in remote location High reliance on foreign components Limited supply chain and public finances
Resource	Strengthened R&D capacities in related sectors Close linkages with R&D institutions Strong cooperative linkages with global firms	Increases in labor costs Poor corporate management skills Limitations in expanding public R&D capacities
Coordinative Mechanism	Business based network established Strong cooperative network between intermediate inputs	Inadequate venture capital raised Weak linkages between manufacturers and service providers Lack of marketing functions

593 김영표, 경남의 항공산업 육성방안, 경남발전연구원 기본연구 2009-5, p. 49.
594 Ibid., p. 65-68.

Table 35. JINSA Complex Competitiveness Survey

6.1.2. Maintenance, Repair, and Overhaul (MRO) and Component Manufacturing

In conjunction with national and regional level clustering strategies, the associated industrial areas of component manufacturing and various engineering work were equally designated as a parallel business sector with high hopes to bolster the development of the aerospace industry. The MRO business has especially become a highly anticipated business area for aircraft-manufacturing firms considering the growing civil aviation market in both transport and cargo shipments. Almost all regional aerospace clusters associated the MRO field as a primary business sector to support its development strategies. For instance, the number of total civilian aircrafts managed by public authorities and domestic commercial airliners more than doubled from 290 in 2004 to 653 in 2014.[595] The MRO work required to sustain the operation of this fleet of civilian aircrafts has become a self-sustaining business area of its own.

The governing framework for MRO promotion is mandated in three separate legislations; Aerospace Industry Development Promotion Act (administered by MOTIE); Aviation Act (MOLIT); Special Measures for Defense Industry Act (MND/DAPA). The field of component manufacturing is stipulated in the implementing marching orders of these baseline frameworks. Covering for both military aircrafts and commercial aviation, MOTIE's 2010-2019 Aerospace Industry Development Framework Plan selects the MRO business as a strategic industrial sector for future development. In support of building local infrastructures and industrial competencies, the Framework Plan designated primary development regions for local clusters.[596] The Aircraft Policy Framework Plan of 2015-2019 describes the marching orders of MOLIT's Aviation Act regarding the MRO segment. MOLIT is accountable for building industrial competencies in terms of land, transportation infrastructure, and supporting facilities. Therefore, MOLIT's Framework Plan highlights a phased strategy to develop aerial transportation and MRO based on regional economic characteristics and competitiveness. According to the Plan, the MRO functions are clustered and distributed in civilian aviation (Incheon, Kimpo), engine repair (Changwon, Bucheon), and airframe repair (Kimhae).[597]

In addition to the competitive dynamics represented in these MOLIT's Framework Plan, other local governments expressed strong intentions in entering the MRO market. Aggregating its competitive advantage in electronics and precision science, in 2010, the Gyeongbuk Provincial Government mapped out a grandiose plan to aggressively invest public resources to establish a special industrial district highly specialized in avionics, aka the "Youngcheon Aero Techno Valley". The investment scale grossed up to KRW 350 billion within a five-year period that supports a three phased development plan, including the construction of requisite R&D infrastructure for test and evaluation, associated component

[595] Extracted from Aviation Data Portal System, Ministry of Land, Infrastructure, and Transport
[596] 2010-2019 Aerospace Industry Development Framework Plan
[597] 국토교통부 보도참고자료, 항공정비산업(MRO) 육성방안, 2015.1.15.

production, and research and education facilities.[598] Most significant aspect of Gyeongbuk Province's development strategy was the successful investment of Boeing Corporation to build a regional MRO center in support of providing performance based logistics (PBL) services for F-15K Fighters, E-737 Airborne Early Warning and Control Aircrafts, and AH-64E Apache Attack Helicopter Fleet used by the Korean Armed Forces. After a $20 million investment into the region, the Boeing avionics MRO center started business in June 2015 inside the Youngcheon Aero Techno Valley, which constitutes avionics production facilities, test, analysis, and certification centers, and so forth. The creation of Boeing's regional facility has shortened the delivery lead time of critical components for the F-15K fleet from 8 months to 3 weeks. The presence of major Korean defense electronics firms such as LIG Nex1, Samsung Thales, and the Gumi Industrial Complex provides symbiotic business opportunities for the Boeing MRO Center. Also, the close proximity of local military airbases and airports also portrays the significance of the Youngcheon area as well.[599]

In the defense sector, the Act on the Management of Military Supplies stipulates the legal credentials of MRO responsibilities. Traditionally, military depots performed the majority of maintenance and repair works, but the changing trend in system complexities reflects Performance Based Logistics (PBL) as an operating vehicle for military MRO. The essential concept of PBL considers the outsourcing of MRO work through an established contract with a commercial firm that partially or entirely covers the required spectrum of maintenance and repair responsibilities. The military still assumes the majority of maintenance and repair work, while the selection criterion for PBL contracting mostly relates to weapon systems that demonstrate low operational reliability in repair works, critical components with long lead delivery time, complex systems that require professional repair works, and so forth.[600] The Ministry of National Defense first introduced the PBL concept in the 2008 Defense Reform Framework Plan, and designated 13 programs in April 2009 as a demonstration project case.[601] Based on the objective of maintaining a full readiness posture in operational effectiveness, the expectation of this contractual arrangement is to hold the PBL firm accountable in retaining such military goals.

Based on these growing MRO requirements for PBL contracting, the scope and scale has substantially increased in recent years. The defense budget for PBL contracting started with a modest KRW 48.1 billion in 2010, and increased almost tenfold to KRW 390 billion in 2014. Military aircrafts accounts for a major portion of the PBL contracts in this respect.

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598 서대봉, "아태 항공부품 소재산업 허브는 경북," 매일신문, 2010.5.26.
599 하인식, "미국 보잉사 항공전자 MRO 센터 준공," 한국경제, 2015.6.2.
600 이경생 외, 성과기반군수(PBL)지원 계약제도 적용방안 연구, 안보경영연구원 09-021 방위사업청 용역과제, p. 8.
601 The thirteen programs considered UAVs, K-10 Resupply Vehicle, decontamination equipment, torpedoes, KT/A-1, FA-50, T/TA-50; 국방부, 전평시 장비가동률 향상으로 최상의 전투준비태세 유지, 정책브리핑 2009.4.23.

Year	Contract System		Contractor	Scope of PBL	Cost	Contract Duration
2010		KT-1	KAI	835 components	₩35.7B	Ex-post Settlement
			KT-1 Basic Trainer, KA-1 Light Attacker			2010-2015
2011		Corps level UAV	KAI	142 components	₩10.6B	Ex-post Settlement
			aircraft and ground control			2011-2015
2012		F-15K	Boeing	948 components	$303M	Fixed Price Contract
			airframe, avionics			2012-2017
		KF-16 Engine	Pratt & Whitney	4,031 components	$316M	Fixed Price Contract
			F-16 engine systems			2012-2017
		FA-50	KAI Hanwha Techwin	5,409 components	₩70.5B	Ex-post Settlement
			FA-50 airframe, engine system			2012-2016
2013		T-50	KAI Hanwha Techwin	6,011 components	₩68.9B	Ex-post Settlement
			T-50 airframe, engine system			2013-2016

Table 36. PBL Contracts on Aircrafts *Source: 2015 Ministry of National Defense*

The performance outcomes of adopting PBL contracting methods in military MRO works resulted in shortening around 63-321 working days' worth of contract administrative periods. This was a direct result of eliminating the supply chain risk factors by securing components and materials early enough at the time of signing the PBL contract.[602]

*ICS: Internal Countermeasure Set

Aircraft Type	Scope	Before PBL	After PBL	Difference
KT-1/KA-1	Component, Repair	209-220 days	10-145 days	↓ 64-210 days
UAV	Component	260 days	36 days	↓ 224 days
KF-16 Engine	Component	119 days	17 days	↓ 112 days
T-50	Component, Repair	191-248 days	11-65 days	↓ 126-237 days
F-15K	Repairing ICS System	427 days	106-364 days	↓ 63-321 days

Table 37. Shortened Procurement Period *Source: 2015 Ministry of National Defense*

As of 2014, the domestic MRO market is estimated around KRW 3.2~3.4 trillion, accounting for both military aircrafts and civilian aviation. This is a 26-33% increase from the market size of 2003 (KRW 2.4~2.7 trillion). The military sector constitutes about 56.9% in the domestic MRO market (KRW 2 trillion), which is a 15.2% increase from that of 2003. Civilian aviation constitutes about KRW 1.4 trillion, which is subdivided into airliner repair work (KRW 1.1 trillion), and aircraft manufacturing MRO work (KRW 370 billion).[603] The growth potentials of the MRO business into the next five-year projection (2020) show a positive growth rate of 23.5%, which accounts for approximately KRW 4.25 trillion. The growing projection of civil airliner transports (18% increase) and military aircrafts (between 1,400 to 1,500 aircrafts) represents the basis of such growth potentials.[604]

602 우제웅·장기덕, 수리부속 조달 효율화를 위한 발전방향, KIDA 주간국방논단 제 1487 호, p. 8.
603 안영수·민현기·김별아, 국내외 항공 MRO 산업의 최근 이슈, 산업연구원 Issue Paper 2015-387, pp. 15-17.
604 Ibid., p. 68.

Unit: KRW 100 million

	2003	2007	2014
Commercial	9,063	10,576	14,400
Military	15,000~18,000	15,000~18,000	18,000~20,000
Total	24,063~27,063	25,576~28,576	32,400~34,400

Table 38. Domestic MRO Market

The domestic MRO market share is primarily divided into workloads managed by airliners for local maintenance and repair functions, and aircraft manufacturing companies for military aircrafts or MRO contracts outsourced from overseas vendors. In terms of workloads covered by airliners, most of the MRO workshare is performed by domestic airliner companies such as Korean Air (airline sector) and Asiana Airlines. The two airliners run their own repair shop, but the scope of these repair functions exclusively cover the workload of the two respective domestic airliners and not the repair requirements available from other domestic or foreign airliners.[605] Considering MRO workloads shared by aircraft manufacturers, three major companies compete over military contracts as well as foreign contracts. Korean Air operates the largest commercial depot maintenance programs for the Korean Air Force and U.S. Pacific Air Forces. Since the late 1970s, Korean Air conducted Programmed Depot Maintenance (PDM) over U.S. military aircrafts such as F-4, F-15, F-16, C-130, and so forth. Considering rotor wing aircrafts, Korean Air performed Standard Depot Level Maintenance (SDLM) and Preventative Maintenance Inspection (PMI) on CH-53, UH-60, CH-47 refurbishment, and so forth. In total annual sales, Korean Air earns about KRW 230 billion in overall maintenance work.[606] The business portfolio of Hanwha Techwin, formerly Samsung Techwin, mostly consists of military engine repair works. Starting with the repair works in the late 1970s over the J79 gas turbine engines applied on F-4 Phantoms aircrafts, Hanwha Techwin earns a revenue of approximately KRW 100 million a year.[607] KAI primarily engages in Performance Based Logistics (PBL) contracts with the military over the KT-1 Basic Trainer, KF-16 fighter, T-50 Advanced Supersonic Trainer, KUH-Surion Helicopter, and so forth.

[605] Korean Air and Asiana Airlines, which accounts for almost 80% of the market share, dissect the domestic MRO market. However, the rapid growth of Low-Cost Carrier (LCC) airliners as well as the growing need of a regional MRO center for foreign airliners that connects into Incheon International Airport as a regional hub, calls for a strong initiative to promote domestic MRO

[606] Korean Air Tech Center briefing on U.S. Government Program History, Korean Air, December 2010.

[607] 안영수·민현기·김별아, 국내외 항공 MRO 산업의 최근 이슈, 산업연구원 Issue Paper 2015-387, pp. 15-17

Unit: KRW 100 million

Major Players		Market Size	Remarks
Air Liners	Korean Air	7,650-8,100	airframe, engine, internal aircraft repair cycle (90% of workloads)
	Asiana Airlines	2,000-2,200	Internal aircraft repair cycle (40-50% of workloads)
	Low Cost Carriers	400-500	Internal aircraft repair cycle (20-30% of workloads)
Subtotal		10,050-10,800	-
Aircraft Manufacturers	Korean Air	2,300	Repair work outsourced from U.S. aerospace firms (KRW 75 billion annually) P3-L system upgrade and overhaul (KRW 400 billion)
	Hanwha Techwin	1,000	Major military engine repair and maintenance
	KAI	300-350	PBL work on KT-1, T-50, KUH
Subtotal		3,600-3,650	-
Total		13,650-14,450	-

Table 39. MRO Workshare by Major Aircraft Firms (2014 *Source: KIET Annual Report on Domestic Aircraft Firms*

However, a number of structural issues become problematic in improving the competitiveness of the domestic MRO sector. At first, the domestic MRO businesses being locked into wasteful competition against each other becomes a factor that obstructs industrial growth in this sector. Domestic MRO firms can fully capitalize on the growing MRO needs not only generated from the domestic market demand, but also from international airliners connecting into Korean airports. Korean Low Cost Carrier (LCC) airliner services also seek quality MRO work in order to sustain its daily flight operations. But unfortunately, domestic airliners view the MRO sector as an auxiliary support branch that assists the air carriage and transport, and not as a promising business opportunity. The current work breakdown structure shows the two biggest domestic commercial MRO firms, Korean Air and Asiana Airlines, are restrictively constrained on its own airliner repair work, while not taking advantage of the expansive MRO opportunities offered from other international or domestic airliners. Hence, the domestic MRO business does not enjoy any economy of scale in this sector. Such aspect represents the domestic industry’s short sightedness and a dearth of strategic vision to bolster the MRO sector into a larger market.[608]

The second element of wasteful competition is the absence of an effective adjudicating authority over the market. The intense competition among local governments to win government special subsidies in the MRO business shows indications of excessive investment and overlapping program developments. Such phenomenon is déjá vu of the 1990 competition structure of the aircraft-manufacturing sector. The Aircraft Industry Regional and Functional Development Strategies under the Aerospace Industry Development Framework Plan describes the need to prevent overlapping investments among regions and industry sector in order to maximize capacity development. However, each provincial or municipal governments that hold a piece of involvement in the aircraft manufacturing sector have aspired to gain a chunk of government subsidies in the MRO business as an effort to attract external investment and grow local jobs. As of 2015, eight provincial governments – Incheon, Choongbuk, Choongnam, Gyeongbuk, Gyeongnam, Busan, Daegue, and Jeonbuk – were competing for the government’s exclusive designation as a local hub for MRO work. In the midst of such competition,

608 최영재, 항공정비산업 발전방안 정책기획연구, 국토교통부 정책용역과제, 2010.1, p. 58.

the lack of a strong coordinating mechanism that effectively controls and adjudicates overlapping industry interests and regional policy priorities causes another round of inter-industry and inter-regional competition.[609] Especially, the fierce but prolonged competition between Gyeongnam (Sacheon) and Choongbuk (Cheongju) over hosting the MRO national industrial complex is a case where the absence of an adjudicating authority resulted in unnecessary investments and wasteful efforts in the same business field.[610]

Thirdly, high labor costs and poor component localization worsens profitability of MRO firms. The business categories of MRO work consist of airframes, engines, components, and lines. Depending on the business categories, the proportion of labor costs and component purchases differs. For instance, components and material purchases constitute about 91% for engine repair work, whereas component and material purchases for line repair work constitutes about 23%. Therefore, considering the MRO business as a service intensive area for repairing and maintaining aircrafts, labor costs constitute a major factor in gaining comparative advantage against other firms.[611] As of 2013, the average MRO wage scale on labor rate parities for Asian firms was $47 and growing, whereas U.S. firms was nearly $70. The business areas of Asian MRO firms were mostly concentrated in low tech/cost areas, whereas U.S. firms were mostly engaged in high tech/cost areas. On the other hand, the wage scale for Korean firms marked around $70~80 in 2013, which degrades the country’s competitive advantage in price in this field.[612] Profit margins per aircraft MRO units are low because of the high reliance on foreign components and technology. Due to the high reliance on foreign technology and components, about half of the net sales, approximately KRW 760 billion, from domestic MRO works is spent on purchasing foreign components and technology, which eventually shrinks the overall profit margins.[613]

Fourthly, the division in responsibilities between different government agencies resulted in desynchronizing government policies. Instead, the uncoordinated implementation of agency-specific policy initiatives precluded each respective government entity from mobilizing public resources towards an agreed objective. Each government agencies, MND, MOLIT, and MOTIE initiated their own respective initiatives on MRO with different objectives and intentions, but resulted in overlapping programs and resources. Such agency differences in the absence of a strong coordinating mechanism subsequently resulted in overlapping business sectors. Especially, overlapping policy initiatives between MOTIE and MOLIT resulted in similar policy lines regarding concepts between industrial clusters (MOTIE) and industrial complex (MOLIT) in the aerospace sector. The MRO sphere comprises a key business sector within these agglomerated concepts.

609 안영수 외, “항공전자산업 연계형 거점부품단지 조성 기본계획 수립 및 타당성 조사 연구용역,” 산업연구원, 2014, p. 72.
610 최우영, “경남 vs. 충북 MRO 단지 유치전에 답보 상태,” 머니투데이, 2015.3.27.
611 TeamSAI Consulting Services, Global MRO Market Economic Assessment, Aeronautical Repair Station Association, January 2014, p. 19.
612 TeamSAI Consulting Services, A Time for Renewal: The Global **MRO Forecast 2013–2023,** 2013 MRO Americas Conference, p. 14.
613 강윤경, “손 놓은 항공정비 시장…외국에 다 뺏길라,” 월간 마이더스, 2016 년 8 월호.

Government Policy	Highlights	Responsible Agency	Remarks
Aerospace Industry development Framework Plan (2010-2015)	Designates primary and supporting regions in cluster and MRO policy	Ministry of Trade, Industry, and Energy (MOTIE)	Part of the 13 original strategic industry development agendas
Aviation Policy Framework Plan (2014)	Technologically upgrade the sector into high tech through MRO	Ministry of Land, Infrastructure, and Transportation (MOLIT)	Requires KRW 60 billion in national budget between 2015-2019
Directives on Performance Based Logistics Support	Open defense R&D functions to commercial entities (MRO functions)	Ministry of National Defense (MND)	In order to enhance military readiness posture

Table 40. Overlaps in MRO Related Regional Development Policies

Because of such insufficient coordination structure, the MOTIE initiated component localization efforts concluded with a disappointing scorecard. The original intent of aspiring to become a world class aerospace manufacturer by developing competitive technical capacities in components and composite materials, supported by enormous government subsidies proportionate to the proposed program scale. Government subsidies provided with no collateral, noninterest incurring matching funds was to sponsor the development of new technology, acquirement of core technology, and commercialization of those findings. Nevertheless, the complex and difficult application-review structure managed by the MOTIE-Korea Institute of Economy and Trade-Aerospace Technology Research Association, discouraged small and medium firms from seeking government assistance in this respect. Thus, after less than three years of its initiation, the program application rate plummeted substantially, rendering the review board meaningless, and the subsequent reduction of the sponsoring resources.[614]

Year	2010	2011	2012
Competition Rate	1.6:1	1.3:1	1:1
Public Funding	KRW 850 million	KRW 1.12 billion	KRW 646 million

Table 41. Competition for Government Subsidies on Component Localization

The uncoordinated structure also caused overlaps in distributing public resources in terms of maintaining government owned aircrafts. The number of helicopters operated by government entities other than the military such as the National Police Agency, Forest Service, medical institutions, and a variety of other local governments account for about 180 units. As of 2010, the Forest Service outsources 100% of its heavy maintenance needs to foreign companies. Other agencies contract their own MRO services with mostly foreign entities as well. Neither of these organizations show combined efforts in the sense of streamlining the overlaps or making use of existing domestic resources regarding routine depot maintenance and repair work. The Korean military runs six (6) maintenance depots specialized in aircraft MRO. None of these depots accommodates the public maintenance and repair services generated from the government side at all. Thus, despite the government's declaratory slogans over the efforts to bolster the MRO sector, the amount of public resources, as well as future business opportunities, become wasted in the seeming numbers of overlapping contracts with foreign services

[614] 지식경제부, 2013 년도 지식경제 기술혁신사업 안내, 2013.1, p. 55.

without fully utilizing its current capacities due to the lack of non-existent coordination authorities claiming responsibility over these technical needs.[615]

Lastly, in the military sector as of 2017, PBL contracting still remains in its nascent implementation stage within the Korean Armed Forces, in which the concept needs further scrutiny in order to revamp this method as a new business platform to bolster the aircraft-manufacturing sector. The current PBL practice mostly remains in a low point where most of the awarded contracts primarily focus on promptly delivering component support to shorten the delivery lead-time and reduce procurement costs of critical spare parts to the customer. The scope of PBL contracts do not adequately reach out to system upgrades or overhaul work that requires substantial systems engineering designing capabilities and accumulated technical experiences. Thus, most of the PBL firms currently serve simply as component suppliers, but not system providers.[616] Thus, PBL concepts contributes marginally in promoting domestic firms to localize components and secure a long lead time for accumulating critical technological experiences in concept design.

The military's emphasis on deploying military aircrafts instead of acquiring the requisite knowledge and technology experience has placed the status of the component manufacturing sector low in priority. In this regard, the localization rate of military aircrafts marks less than 55%, which makes the aircraft-manufacturing sector highly reliant under foreign components and materials, intellectual property rights, and furthermore under stringent technology security measures. Such aspect holds the domestic deployment of these aircrafts under restrictive foreign export control regulations in terms of technology development and MRO work related opportunities.[617] The low rates in technology localization has consequently resulted in poor collaboration between local clusters and the defense sector. Overseas outsourcing of a number component support and services brought about high reliance on costly foreign resources whereas low utilization of locally available industrial capacities.[618] Such aspects pose significant challenges in building up a robust MRO sector in support of a robust regional industrial cluster.

6.2. Sectoral Level Innovation Systems: State Business Relations: Industrial Settings and Competition Structure

Not only does the small and constrained scale of the Korean aircraft-manufacturing sector obstruct further growth opportunities, but the structure itself continues to preclude the industry to evolve into global standards. The industry is dominated by one or two big business conglomerates associated with subcontractors arranged in a production life cycle intertwined in research and development, manufacturing, and licensing, where the major customer base is overly reliant on military programs that

615 정소현, "중앙 119, 외국산 소방헬기 입찰 즉각 중단해야 커지는 목소리," 시사위크, 2017.6.30.
616 국가재정운용계획 국방분과위원회, 2014-2018 국가재정운용계획 국방분야 보고서, 2014, p. 226.
617 국회의원 강창일의원실 세미나, 대한민국 항공산업, 미래를 위해 도약하라!, 2011, pp. 22-35.
618 안영수 외, 항공전자산업 연계형 거점부품단지 조성 기본계획 수립 및 타당성 조사 연구용역, 산업연구원, 2014, p. 155.

are tightly under international technology security restrictions. Thus, the overarching landscape is an inflexibly inverted pyramid structure, where a volatile supply chain presents unstable business conditions for subcontractors and component suppliers. In this regard, the industry is in dire needs to diversify into international markets and production lineups into more commercial categories to expand marketing opportunities.

6.2.1. Competitive Dynamics of Aircraft manufacturing before the 1997 Asian Financial Crisis

In the late 1980s, with the growing market demand generated by lucrative military aircraft projects, the aircraft manufacturing business emerged as the next gold mine for big business conglomerates and was publicized by the government with high anticipations to upgrade Korea's industrial and technological competitiveness to a more advanced playing ground. The primary motivation was the perception that the Korean industry can no longer maintain its competitive edge in labor-intensive manufacturing sectors with the continued increase of labor costs and apparent limitations in productivity. As such, the aircraft-manufacturing sector captured the attention of industry strategists as a window to transition the domestic industry structure into capital intensive advanced technological fields. In this aspect, the government and major conglomerates strived in every part of its dimension to promote an overly promising business forecast in order to lure domestic and foreign investments into the sector.

A very typical industry forecast publicized by the government and major conglomerates illustrated that the demand pull of the commercial aviation sector until year 2000 will likely be worth of 5,311 aircrafts ($278.3 billion), while the military aircraft sector until year 1995 will likely be 21,752 aircrafts ($350 billion).[619] The major defense projects dubbed, 'Eight Major Aircraft Development Program', which included heavy helicopters, fighter aircrafts, advanced trainers, and so forth, along with de-regulation policies that lowered entry barriers into the market, created a strong demand pull that motivated both public and private investments into a growing industrial field. The government initiated a number of incentives to lift the ban of the restrictive aircraft-manufacturing sector for local businesses by providing tax breaks, financial support, and enacting deregulation measures. Earlier, the support structure of the Promotion Act of 1978 was to classify aircraft business permits into three categories (designated, licensed, registered). In relations to the Special Measures Act of the Defense Industry, the aircraft sector was subject to Specialization and Systemization. Within the designated category, the competitive structure was shared between Korean Air (Total Airframe Manufacturer) and Samsung Precision (Engine Manufacturer), where Daewoo Heavy Industries slid into the niche market as a component manufacturer.

On 9 May 1986, the Ministry of Commerce and Industry announced a mid-term development

619 매일경제, "재계, 항공우주산업 참여확대," 1988.4.29.

plan with lowered entry barriers that included government subsidies for companies to acquire special tools and appliances, reduced customs for raw material imports, and additional tax breaks on corporate investments in the aircraft-manufacturing sector. Thus, the underlying intent was to overcome the split competition structure of the industry between Korean Air and Samsung Aerospace by removing the restrictive barriers and encouraging new entrants for improved competition.[620] The intent was further reflected in the AIDPA of 1987, where the clauses for permits in the previous Promotion Act was streamlined to only require a simple registration process to enter the aircraft industry. The registration process was later eliminated in the revised AIDPA of 1999, which allowed full competition within the domestic industry.[621]

Business Rivalries: Cutthroat Competition over Eight Major Aircraft Development Programs

During the early incubation period of aircraft manufacturing in the late 1970s, state-led strong industrial directives and government authorities shaped the initial construct of the sector. However, as the economy entered into the 1980s, state driven initiatives and control over the sector turned weak and were replaced by market forces, in which the competitive dynamics between established firms in the sector, notably the big family led conglomerates, chaebols, became more evident.

The continued entry of new firms into the domestic market during the mid-1980s has created a dog-eat-dog situation where multiple firms were excessively making overinvestments in competition over the same defense program. New business entries into the market was prompted by government instigation to attract more private investments over a definite share of business opportunities, while providing no regulative buffers to safeguard corporate resources and commitments. Intense competition over a finite amount of business opportunities was deteriorating technological competitiveness of the domestic industry. The opportunities announced by the government were the 'Eight Major Aircraft Development Project', that included the Korea Fighter Program (KFP: F-16 Fighting Falcon), Heavy Helicopter Experiment (HX: UH-60 Black Hawk), Korea Light Helicopter (KLH: Bo-105), and so forth. Approximately 40 domestic companies responded to these promotional forecasts and swiftly organized corporate strategies to enter the domestic aircraft market.

Big businesses such as Korean Air, Samsung Aerospace, and Daewoo Heavy Industries predominated the domestic market, but late entrants such as Sammi, Hyundai, Daewoo, etc., attempted to penetrate the entry barriers by strategically aligning with global aircraft firms such as Sikorsky, Augusta, Bell, and so forth.[622] In order to streamline the competition structure, the Ministry of Commerce and Industry, on 20 July 1990, designated three primary companies within the sector – Samsung Aerospace, Korean Air, Daeweoo Heavy Industries – as specialized firms for aircraft manufacturing, and expressed intentions to concentrate public resources to nurture these firms into

620 매일경제, "항공산업 신규 참여 개방," 1986. 5. 6.
621 항공우주산업 개발촉진법 1999 개정
622 주호석, "조 단위 사업을 잡아라, 재계 판도 바꿀 열전 돌입 – KFP/HX," 매일경제, 1991.10.25.

global standards. Other firms that were not blessed with this specialized designation was forced to leave the industry.[623] Henceforth, both government and industry heralded aircraft manufacturing as a new gold rush to secure better business deals within the fledgling sector.

Aircraft Type	Program Name	Contract Awarded
Fixed Wing	F-16 Production (KFP)	Samsung Aerospace (SSA)
	T-50 Development (KTX-2)	Samsung Aerospace (SSA)
	KT-1 Development (KTX-1)	Daewoo Heavy Industries (DHI)
	F-4 / F-5 Upgrade – program downsized	Korean Air
	Mid-sized Commercial Airliner – program canceled	Samsung Aerospace
Rotor Wing	UH-60 Production (HX-Heavy)	Korean Air
	Bo-105 Production (KLH) – program downsized	Daewoo Heavy Industries (DHI)
	UH-1H Upgrade (HX-Light) – program canceled	DHI / SSA

Table 42. Eight Major Aircraft Development Programs raised in the late 1980s

The other side of the story, however, portrays a very contradictory anecdote. The government designation of the three chaebols as specialized aircraft-manufacturing firms created an onset of unnecessary competition over a limited share of a small market. Most other countries vying to promote the domestic aircraft-manufacturing base select a national champion that become beneficiaries to a bundle of state-led industrial stimulation policies, spanning from R&D support, financial assistance, international marketing efforts, and so forth. The selection of three chaebol firms, who mostly performed in overlapping business sectors with similar technological competencies, resulted in creating a vicious rivalry composition against each other. As a matter of fact, business earnings in aircraft manufacturing remained low in proportion. For instance, in 1991, Samsung Aerospace earned 28.4% from aircraft manufacturing, whereas Daewoo Heavy Industries and Korean Air each earned about 3.4% and 5.9%. Reviewing the business performances of aircraft manufacturing firms, the entire industry suffered from constant deficits where the overall balance sheet was marked KRW 30 billion in red ink, which represents 14% of business losses from the industry's sales statement.[624] This implies that aircraft manufacturing stayed low in priority within the businesses and was not considered a major business area for Chaebol conglomerates despite all the auspicious statements made by government and top management about the highly anticipated outlook of the industry.

The government stance against such excessive competition was considered almost incompetent. Various declaratory policy lines to support and nurture the industry were dubious and received large skepticism from the industry. Basically, the public authorities such as the Ministry of Commerce and Industry, Ministry of National Defense, Ministry of Science and Technology, and so forth seem to have almost no control over the ferocious competition among the major aircraft firms.[625] While government mitigation roles were in question, aircraft manufacturing firms seriously perceived the redundancy and superfluous competitive industrial structure. On February 1988, under the adjudication of the Federation

623 한겨레, "삼성항공 대우중공업 대한항공 항공산업 전문업체 지정," 1990.7.20.
624 홍재학, "우리나라 항공우주산업 현황과 KFP 산업," 국방과 기술, 1992 년 7 월호, p. 34.
625 권대우, "이대원 항공우주산업진흥협회장 대담: 2000 년 초 세계 10 위 항공선진국 부상," 매일경제 1996. 11. 8.

of Korean Industries, thirteen aircraft manufacturers agreed to establish a coordinating mechanism within the industry that can mitigate excessive competition and redundant investments within the industry. The Korea Aerospace Industries Association (KAIA) was created under this expectation. The corporate objective of KAIA was to promote cooperative research and share marketing knowledge of Korean manufactured aircraft products – while alleviating unnecessary rivalries and avoiding cutthroat competitions.[626] However, industry cooperation never took place in the domestic market. Government mitigation efforts were inconsistent and ineffective, major conglomerates refused to cooperate, and industry R&D activities ceded to international aerospace giants and never efficaciously came into fruition. The delayed establishment of KAIA exemplifies the tardy movement of this cooperative mechanism. Despite the general consensus to create a government-industry coordination mechanism, the opening ceremony of KAIA had to wait until September 1992, after nearly four years since its inaugural announcement. Between the incubation periods, the major conglomerates continued to fiercely compete against each other over the chairmanship of the association. The conglomerates viewed the chairmanship as a position to exert preferential influence over contractor selection in the proposed Eight Major Aircraft Development Projects. In this regard, Samsung Aerospace, Korean Air, and Daewoo Heavy Industries furiously battled each other to take over the KAIA chairmanship position throughout the years.[627]

Low performance margins and the unpredictable domestic market during the early to mid-1990s also brought uncertainty into industry integrity. Market mechanisms did not properly function because of inadequate government intervention into the market. Instead of interacting as a catalyst to strengthen the technological foundations and business qualities, government support packages were manipulative and distortive towards the market. Under the guise of providing protection against external competition, the government's industrial sponsorship was not necessarily shaped to build firm competence or bolstering a healthy technical base. Government policies were more likely implemented towards simply sustaining the production base by constantly pumping in revenues to prolong the scanty existence of domestic aircraft firms. Despite the big business conglomerates, such as Samsung, Daewoo, Hyundai, and Korean Air, constituted the major players of the industry, most of the workload of these companies were not on manufacturing major end items but merely on subcontracted workloads from global defense firms such as Boeing or Airbus. Technology development efforts were primarily dependent through technology transfer mediums from U.S. and Western European firms, while the domestic basis for firm level R&D stayed under insignificant standards. Government deregulation policies forced corporations to seek international alliances instead of building internal technological capabilities, because companies were compelled to acquire requisite technical components in a compressed timeline in order to comply with major milestones of a defense acquisition program. Major defense programs such as the UH-60

626 매일경제, "항공우주산업 협회 관련 13사 창립키로," 1988.2.12.
627 매일경제, "한국 항공우주산업 협회 발족 난항," 1988.6.2.

and F-16 coproduction was about to end in 1998 without a solid commitment to pursue follow-up programs. Samsung Aerospace allied with Bell Helicopters to enter the international and domestic rotor wing market by license producing the commercial B-407 Light Helicopter. Daewoo Heavy Industries attempted to acquire a Polish helicopter firm while sought strategic alliance opportunities with European firms such as Augusta and Eurocopter. Hyundai and Korean Air aligned with McDonnell Douglas and Sikorsky to broaden the spectrum of international markets and technical partnership.[628] In this regard, domestic firms became unduly reliant on international partners as subcontractors, whereas building technical competence in system design and integration capacities became far more restrictive.

6.2.2. Asian Financial Crisis and the Consolidation of the Aircraft-manufacturing sector

The predominance of the developmental state theorem was seriously disrupted by the Asian Financial Crisis of 1997. As the structural deficiencies of the Korean economy amassed in the 1990s, a series of deteriorating economic performances such as sluggish growth rates, reduced international trade, and the resulting heavy pressure on the thin margins of firms have consequently weakened Korea's durability against external shock. As a result, a chain reaction of corporate insolvency and bankruptcy over large family run business conglomerates, Chaebol, started to bring down the entire economy, which eventually placed the country into financial default that urged for an immediate bailout by international financial institutions such as the International Monetary Fund.[629]

There are a number of studies that reviewed the causal effects of the Asian Financial Crisis based on international and domestic motives. One of the main explanations focuses on the domestic reasons where moral hazards in state-business relations manipulated the government's role of supervising high-risk firm investments. As such, instead of the Chaebol firms taking full responsibility of their mismanaged investment portfolios, the highly privatized corporate risks were effectively socialized and deferred to public.[630] Other arguments relevant to the line of debate considers the reduced capacities of the government in disciplining businesses in the process of the diminishing influence of authoritarian rule after the country's transition into a democratic society.[631] In addition to these factors, the constant trending of market liberalization initiatives implemented through deregulation efforts lifted entry barriers for corporations entering traditional stronghold sectors where a handful of domestic firms used to enjoy monopoly privileges.[632] In this aspect, unregulated market disorders disproportionately grew out of government control, where public authorities were unable to supervise and adjudicate corporate

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628 신현만, "항공업계 불황탈출 몸부림," 한겨레, 1996. 4. 23.
629 Moon-Soo Kang, "The Causes and Consequences of Korean Economic Crisis," Korea Development Institute Seminar Paper Collection: The Economic Crisis and Restructuring in Korea, January 2003, p. 61.
630 Paul Krugman, "What Happened to Asia?," at http://web.mit.edu/krugman/www/DISINTER.html
631 Jongryn Mo and Chung-in Moon, Democracy and the Korean Economic Crisis," Policy Forum 98-03: Democracy and the Korean Economic Crisis, Nautilus Institute, 1998, http://nautilus.org/napsnet/napsnet-policy-forum/napsnet-forum-15-democracy-and-the-korean-economic-crisis/
632 Yoon Je Cho, "The Financial Crisis in Korea: Causes and Challenges," Rising to the Challenge in Asia: A Study of Financial Markets, Vol. 7, Asia Development Bank, 1999, p. 13.

behaviors. The investment boom, especially in the heavy and chemical manufacturing sector, between 1994 and 1996 demonstrates such unregulated firm investment behavior in the period of diminishing government control over the market. During the three-year period, investment in facility tools and equipment increased by 38.5% per year. Especially between 1994 and 1995, investment grew at rates each year by 56.2% and 43.5%. These investments were heavily capitalized by short-term overseas borrowings, in which the proportion borrowed from foreign financial sources accounted for nearly 21% of the entire capital investments.[633]

After the country's debts were put on hold by international financial authorities, a series of structural reform processes over the public and private sector ensued. Corporate reform process was predicated over the assertion that the Chaebol centric industrial structure engendered exorbitant investments and superfluous diversification, where public authorities can no longer effectively regulate and control due to the lack of appropriate restraining instruments to administer despotic business decisions made by the founding family of the Chaebol firms. Hence, a new institution that gives weighted value on checks and balances over Chaebol firms, financial establishments, and shareholder interests was introduced after the Asian Financial Crisis. At first, the government announced the 'Big Deal' program with the objective to swap overlapping business sectors among Chaebol firms, and the 'Workout' program with the objective to rehabilitate financial difficulties. Fair trading regulations and financial supervision were strengthened to restrict overinvestments of Chaebols into high risk areas and prevent redundant program transactions. Lastly, market regulations to protect minority shareholder rights were implemented to hinder despotic decision-makings of majority shareholders, who were predominantly the Chaebol owner families.[634]

Industrial Sector	Big Deal Arrangement	Post Big Deal Status
Automobiles/ Electronics	Divestment of Samsung Motors, Daewoo Motors, and Daewoo Electronics	Samsung Motors acquired by Renault Daewoo Motors acquired by General Motors Daewoo Electronics primarily acquired by Dongbu Group
Semiconductors	Merger between Hyundai Electronics and LG Semiconductors	Hynix formed and subsequently acquired by SK
Oil Refining	Divestment of Hanwha Engergy's oil refining sector to Hyundai Oilbank	Hyundai Oilbank
Petrochemical	Merger between Hyundai Petrochemical and Samsung General Chemicals	Canceled due to disagreement with Japanese creditor (Mitsui)
Electricity Generation	Divest the electricity generation business of Samsung and Hyundai Heavy Industries to Korea Heavy Industries	Korea Heavy Industries (state owned) privatized and sold to Doosan Heavy Industries
Marine and Boat Engine	Divest Samsung's marine engine sector to Korea Heavy Industries	
Railway Vehicles	Joint establishment between Hyundai, Daewoo, and Hanjin	Korea Railway Vehicle Co. in 1997 sold to Hyundai Rotem
Aerospace	***Merger of aircraft-manufacturing sector of Samsung Aerospace, Daewoo Heavy Industries, and Hyundai Space & Aerospace***	***Establishment of Korea Aerospace Industries in October 1999***

Table 43. Big Deal Business Arrangements, reproduced from October 1997 FKI News Release and News Archives

633 Stephan Haggard and Jongryn Mo, "The Political Economy of the Korean Financial Crisis," Review of International Political Economy, Vol. 7, No. 2, 2000, p. 200.

634 Jang-Sup Shin and Ha-Joon Chang, *Restructuring Korea Inc.*, Routledge Curzon, 2003, p. 84.

Restructuring Process: Preconditions of Industry Consolidation before the Asian Financial Crisis

During the mid-1990s, the aircraft-manufacturing sector already went through intense debates over the possibility of consolidating the industry structure into a unified government sponsored corporation. After observing the trend of mega mergers and acquisitions in the global aerospace and defense industry, the Korean government undertook a slim attempt in early 1995 to restructure the domestic aircraft-manufacturing sector by consolidating the three major Chaebol firms – Korean Air, Daewoo Heavy Industry, and Samsung Aerospace.[635]

Considering the long gestation period, only large firms that can withstand the volatile market demands, which is directly reactive to economic and political challenges, are suitable to survive in the global value chain of aircrafts. This sectoral characteristic of the aircraft industry triggered the massive consolidation activities between firms, which eventually concluded in the duopolistic structure of the global aircraft industry, predominated by Boeing and Airbus in the commercial sector, and Lockheed Martin and EADS in the military sector. Putting into account of the global trend of mega mergers and the need to create a scaled economy for the domestic industry, the Ministry of National Defense initiated a directive to streamline the disseminated R&D and production capacities in order to effectively manage the Eight Major Aircraft Development Programs. The Consolidation Strategy for Military Aircraft Development Programs, which was directed by the Ministry on March 21, 1996, intended to manage the industry under restrictive government control by an interagency effort called the Aircraft Industry Planning Group, create an industry consortium for cooperative marketing and R&D, and designate aircraft manufacturing firms as Specialized and Systematized firms under support of defense industrial subsidies.[636] However, because of the sharp disagreement between the Chaebols and the incapacity of the government, the consolidation effort never materialized into a real plan.[637]

As a precursor of the industry Big-Deal project, government authorities and aircraft manufacturers engaged in a series of discussions in June 1997 before the shock wave of the financial crisis impacted on the Korean entire economy. The industry forecast showed gloomy prospects of business opportunities because there would be no new orders after the F-16 license production ceded in 1998. Government authorities showed extreme reluctance and hesitance in making program decisions on the Eight Major Aircraft Development Programs because of stark differences over budget availability and technical challenges even before the financial crisis became real.[638] In the technological sense, despite the twenty years of running the aircraft manufacturing business, the industry failed to effectively accumulate critical knowledge and technology that would successfully upgrade the sector into the domains of high value-added opportunities. With a short term narrow vision to win military aircraft programs, the major firms committed most of its resources primarily into component production and

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635 김성걸, "항공산업 통합 추진," 한겨레, 1995.3.16.
636 동아일보, "군용기 개발사업 통합추진," 1995.3.23.
637 김성걸, "방위산업 업체별 나눠먹기," 한겨레, 1996.10.9.
638 홍성범, 민군겸용 패러다임과 기술개발전략, 과학기술정책관리연구소 정책보고 94-01, p. 82.

subcontracted assembly work instead of exerting efforts to accumulate experiences in the realm of system design and integration. The government also preferred direct purchases through foreign sourcing instead of indigenous development, in which compelled domestic firms to concentrate on subparts and components instead of complete aircraft forms. Because of these aspects, the overall technological readiness level in system integration, which included system design, manufacturing, program management, and marketing capacities, was comparatively marked less than 30% against other advanced aircraft manufacturing countries.[639]

The collapse of the ROK-China Regional Airliner Program provided the catalyst for the consolidation movement. On 18 June 1996, after three rounds of negotiations, the Aircraft Subcommittee of the ROK-China Industrial Cooperation Committee broke down and concluded to not pursue the cooperative development of the regional airliner program. The objective of the co-development program was to expand the aircraft manufacturing portfolio into the commercial sector in order to secure a sound amount of new orders. As a result of two Presidential meetings, the two countries agreed to initiate a cooperative development program to manufacture midsized regional jet planes that can absorb the growing East Asian market. Initially, the two countries agreed in principle to split the 70-80% share of development costs, while introduce a third partner that can invest 20-30% into the program. After fierce competition over the joint development program, Samsung Aerospace was awarded the contract among the three aircraft manufacturing companies to manage the Korean portion of the overall development and assembly work of the main airframe. But in order to maintain the production capabilities of the domestic industry, the arrangement was adjusted by MOCI to equally distribute the remaining share of the development and manufacturing work with the other two competitors, Daewoo Heavy Industries and Korean Air.[640] On the other hand, the Chinese counterparts withdrew from this proposal and insisted the Korean investment be limited to 12%. Also, the Chinese suggested to establish the final assembly line at Shanghai. The Korean position was acceptable with the Shanghai assembly line, but the 12% share of the program was not acceptable. Korea intended to at least take part in the special coating and interior work of the aircraft by introducing engineering techniques adopted from Airbus, but the Chinese did not accept this counter proposal.[641] At this point, after witnessing the trilateral agreement between the European Union, China, and Singapore to establish a joint venture for developing a regional airliner, the Chinese did not seem to have much enthusiasm in pursuing a joint aircraft development program with the Koreans in the first place.[642] Hence, securing additional workloads by structural right sizing of the industry turned into a more desperate undertaking for domestic firms.

In this respect, a consensus was built among the four major aircraft manufacturers regarding

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639 Reference material provided to the National Assembly by the Ministry of Knowledge Economy, 4 February, 2014

640 서정희, “중형항공기 삼성주관,” 매일경제, 1994.8.19.

641 한겨레, “한-중 항공기 합작 백지화,” 1996. 6. 19.

642 U.S. International Trade Commission, The Changing Structure of the Global Large Civil Aircraft Industry and Market: Implications for the Competitiveness of the U.S. Industry, Publication 3143, November 1998, p. 5-13.

the idea to divest the aircraft sector into a single entity, with high expectations that the government provide the requisite finances to sustain the industry until new defense projects materialized. However, the Ministry of Commerce and Industry refused to participate in the new venture after a few months of deliberation. The government policy at that time was to commercialize existing public enterprises, whereas the industry's request to transform the aircraft-manufacturing sector into a state-owned company would defy all the established rules and principles in terms of reducing the role of government control over the market.[643]

What exacerbated the situation was the Asian Financial Crisis itself when the entire economy fell into the bottomless pit of short-term overseas debts. The net sales of the four major aircraft manufacturers – Samsung, Daewoo, Korean Air, and Hyundai – earned lesser than not only the companies of major G7 countries, but also lesser than peer competitors of the same tier group such as Israel and Taiwan. Despite the dire situation to build a scaled economy and foundational skills with associated infrastructures to compete in the global market, domestic firms were primarily engaged in a ruthless battle against each other over a slice of the finite domestic market share. On the contrary, foreign firms that strategically aligned with domestic firms gained a critical foothold to enter the domestic market. The public finances subjugated under the financial stewardship of the International Monetary Fund forced the government to exercise fiscal austerity, which compelled the cancellation or postponement of major defense programs. The Korea Multiple Helicopter (KMH) development program, a multibillion-dollar deal to build a multi-purpose platform for utility and attack functions was cancelled in 1997. Companies like Korean Air and Daewoo Heavy Industries that invested billions of dollars in equipment and production facilities in preparation for the KMH contract award had to consider the possibility of converting the capital investments into other business opportunities. Samsung Aerospace, who was awarded the Korea Trainer Experience-II (KTX-2: T-50 Development) in October 1997, had to weather-out the production gap between the end of F-16 production and the KTX-2 full rate production phase.[644] As mentioned above, the near cancellation of the Korea Light Helicopter (KLH: Bo-105) cost Daewoo Heavy Industries millions of dollars in business losses, which completely destroyed the financial solvency of the company's defense sector.[645]

Industry Restructuring Process and the Establishment of the Korean Aerospace Industries (KAI)

The overall restructuring process was conducted under the auspices of the Corporate Restructuring Committee under the Financial Supervisory Commission, which was then again under strong control of the Presidential Office. Although the creditor group supervised the restructuring process, the Financial Supervisory Commission, represented by the Corporate Restructuring Committee,

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643 The requisite finances demanded by the aircraft companies was approximately KRW 90 billion. 서울신문, "정부 항공정책 난항/항공기 제작 단일법인 지분참여 포기," 1997.6.24.

644 이승리, "IMF 사태와 항공우주산업," 항공우주학회지 제 26 권 1 호, 1998, p. 174.

645 김당, "이양호 대우 커넥션, 검찰 비켜갔다," 시사저널, 1996.11.7.

took the actual lead in the overarching components of industrial restructuration. The implementing principles of the restructuring process followed five components; 1) business consolidation into core competence areas; 2) capital structure improvement; 3) elimination of cross-debt guarantee; 4) enhancement of management transparency; 5) improvement of management accountability.[646] Only after complying with these principles shall the government exert efforts to salvage ailing companies with relief funds and public support. These principles were strictly applied to the restructuring process of the aircraft-manufacturing sector.

As previously stated, aircraft manufacturing firms – Samsung Aerospace, Daewoo Heavy Industries, Hyundai Space and Aviation, Korean Air – were constantly discussing the terms for consolidation even before the financial crisis as the industrial sector dived into overcapacity through excess investments. The financial crisis expedited the consolidation process, in which the four major firms agreed to establish the Consolidated Aircraft Corporation in the interim of continued restructuration efforts. However, Korean Air withdrew from the consolidation discussion, complaining that Samsung Aerospace was manipulating the consolidation process in favor of its own corporate survival. Thus, the remaining three companies became subject to the restructuration process. In September 1998, the three companies signed a memorandum of understanding to consolidate the aircraft-manufacturing sector of the three companies. Later that year, the three companies agreed to reduce 30% of its assets as an effort to reduce corporate debts, with a desire to receive government rescue packages in the process of saving its failing businesses. As part of the restructuring process, there was a need to substantially reduce the corporate debts of all three aircraft manufacturing companies combined in the outbreak of the financial crisis was about KRW 1.42 trillion. After disposing of approximately KRW 731 billion worth of corporate assets, including the entire estate and manufacturing assets of Hyundai Space and Aircraft located at the Seosan Manufacturing Line, the corporate debt ratio fell below 246%, with a remaining corporate debt of KRW 550 billion.[647]

Despite these efforts, the Corporate Restructuring Committee assessed these efforts as insufficient and refused to inject immediate financial salvage funds to rescue the aircraft-manufacturing sector. The main reason for the refusal were; 1) unpredictable business opportunities caused by strong reliance on military programs; 2) high necessity to attract foreign capital investments. The first reason primarily refers to the fact of being too reliant on military projects, which have constantly presented foggy aspects of business development caused by government indecisiveness and inconsistencies. Therefore, there was a need to diversify the business portfolio of the newly consolidated aircraft corporation. If the new corporation does not overcome this aspect, then the future prognosis of the company would remain gloomy. The second element refers to the international creditor’s view of the Korean aircraft-manufacturing sector. Business investments into the consolidated Korean aircraft sector

[646] Jang-Sup Shin and Ha-Joon Chang, p. 91.
[647] Report to the Creditor’s Group, Corporate Updates of the Korean Aerospace Industries, Korean Aerospace Industries Inc., October 1998.

by international creditor groups would indicate positive credentials for a bright future prospect of the industry. In that sense, the Corporate Restructuring Committee demanded to develop solid business opportunities in commercial aircraft manufacturing as well as to attract international investments in order for the new corporation to receive the financial support in need.[648]

The solution provided to mitigate the concerns of the Committee was to have all three companies invest into the new corporation with equal share in stakes, provided that the board of trustees appoint a professional business manager as the Chief Executive Officer with demonstrated proficiency in corporate management practices and intact from external influence. Moreover, the three companies agreed to distribute 33% of the share to foreign investments.[649] To attain this end, the consolidated corporate headquarters of the three aircraft firms proactively sought for foreign investments from each of their respective foreign partners such as BAe, Lockheed Martin, Boeing, Aerospatiale, and so forth. Each of these international partners had a vested interest in the potential business opportunities of the Korean domestic market, primarily focused on the military sector. Thus, the companies were negotiating the terms over investing approximately $200 million in initial shares over this newly established Korean aircraft manufacturing firm.[650] Only after showing the sincere efforts for restructuring the consolidation process did the government started delivering the support packages to rescue the aircraft sector.

In April 1999, the government approved the restructuration process through the Aerospace Industry Development Policy Council. In reference to the Aerospace Industry Development Promotion Act and Special Measures on the Defense Industrial Base, the new corporation was designated as a specialized entity in aircraft manufacturing, which awarded government priority assurances in defense contracts. Later that year, in October 1999, under the auspices of the Corporate Restructuring Committee, Samsung Aerospace, Daewoo Heavy Industries, and Hyundai Space and Aviation divested each of their aircraft manufacturing divisions, and consequently established the Korea Aerospace Industries Limited (KAI). Bundles of preferential treatment were provided to KAI as it was awarded exclusive privileges as a specialized aircraft manufacturing firm under the Specialization and Systemization Act in support of the general defense industrial base.[651]

However, despite these restructuration efforts, corporate management and business performance of the newly created KAI during the first five years did not sufficiently meet public expectations. The consolidation itself was incomplete where Samsung Aerospace did not divest its engine sector and Korean Air refused to participate and decided to go separate ways. Aircraft engine development requires highly accurate precision technology, which can spillover to other industrial fields of manufacturing. The international trend in aircraft manufacturing typically separates airframe manufacturing and aircraft engine development because the two areas require distinctively different

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648 장광익, "항공기 단일법인 내년 출범 난항," 매일경제, 1998.12.12.
649 The Defense Industry Promotion Act restrained foreign entities from owning more than 33% of corporate shares of Korean defense firms. 오성철, "빅딜 참여기업 경영 배제," 매일경제, 1998.9.9.
650 김동원, "통합항공법인 2억불 외자유치, 매일경제, 1999.02.01.
651 Material provided to the National Assembly by the Ministry of Knowledge Economy, 4 February, 2014

engineering skill sets, where aircrafts have high demands in integrative design and systems engineering technology, whereas aircraft engines concentrates in precision instrumentation. Samsung's specialization in engine development allowed the sector to diversify into centrifugal air compressors, semi-conductor chip mounting, optoelectronics, and other high valued business areas that presented lucrative growth opportunities in the market.[652] Also, the consolidation process had little incentive for Samsung considering its established partnership with major international engine companies such as Pratt & Whitney and General Electric. Samsung invested more in anti-corrosion technology and turbine blades in order to broaden its business areas as part of maintaining this partnership.[653]

On the other hand, Korean Air was not in a position to participate voluntarily in the restructuring process. Korean Air claimed that the proposed terms for consolidation raised by the Council worked in contrary to the company's demand for maintaining a preferential monopoly status within the aircraft-manufacturing sector. However, there is another layer to this story that relates to the dark history of state-business collusion in Korea.

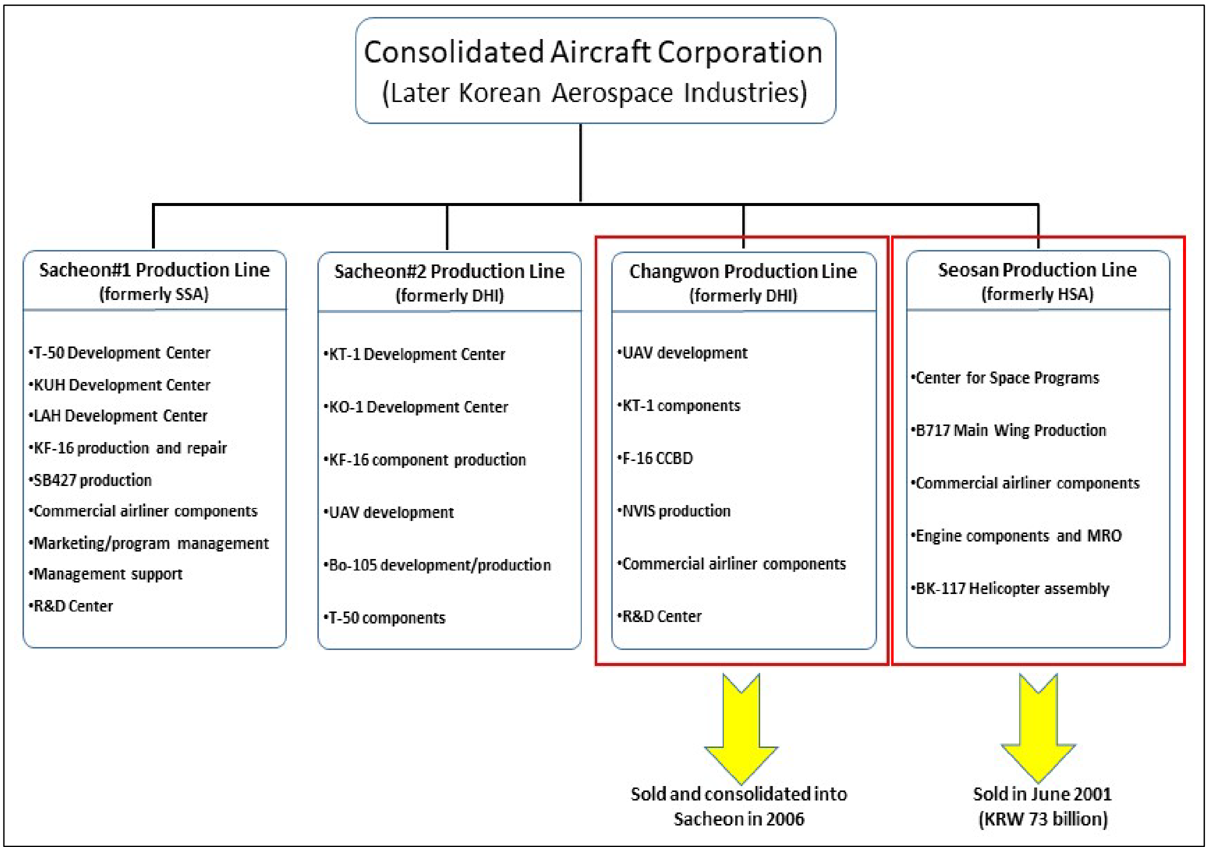

Figure 21. Consolidated Aircraft Corporation Organizational Structure

Since the mid-1990s, the company was under intense public criticism for the number of plane crashes occurred in the years preceding the Asian Financial Crisis. Presenting favoritism to Korean Air

652 연합뉴스, "삼성항공, 회사명 변경작업 착수," 1999.10.14.
653 연합뉴스, "삼성항공, 엔진부문 민수사업 비중 확대," 1999.9.9.

in such deteriorating circumstances could risk political votes to the incumbent Kim Dae Jung Administration at the time. Moreover, Korean Air's absence in the government led consolidation effort represented a case that symbolizes the malicious convention of crony capitalism between the state and family-run Chaebol firms in Korea. A direct accusation raised by Korean Air executives considered the marginalization of Korean Air in its own business sector against its rivals was strongly influenced by political forces at the time. During the early years of the Kim Dae Jung Presidency (1998 – 2003), Korean Air was penalized by tax authorities for tax evasion and money laundering. Also, Korean Air lost a number of opportunities to its archrival Asiana Airlines in inaugurating new international flight routes, as well as its prestige as the nationally chartered airliner for the President.[654] In November 1999, in addition to the previous accusations, the company was charged for providing political slush funds to former President Roh Tae Woo, and was imposed a penalty tax of about KRW 542 billion.[655] Additional rumors about the worst-fated relationship between the Korean Air founder, Chairman Cho Joong Hoon, and President Kim Dae Jung, which traces its origins back to 1973 in reference to the attempted assassination scheme against then opposition leader Kim and the possible involvement of Korean Air within that plot, has resulted in such politically biased reaction against the company amid the restructuring process.[656]

Business performances fell far below public expectations. With a starting capital of KRW 290 billion in 1999, KAI went through continued hardships in its business performances. The net loss during the year 2000 alone was KRW 111 billion, and the following year marked KRW 60 billion. At the time, market analysts assessed that KAI barely managed to stay alive through the efforts of capital increases made from shareholders and the rescue aids provided from the creditors group. As the business losses grew bigger during the first two years of the company, the three holding companies provided approximately KRW 100 billion in capital increases, and the creditor group converted KRW 73 billion debts into equity under the circumstances that KAI take efforts to reduce overhead costs and attract foreign investments. Additionally, just before falling into default, the company's debts nearing KRW 369 billion in payable obligations were relaxed to a four-year installment with a five-year grace period. Despite these propelling self-efforts for debt relief, however, about KRW 170 billion was encroached in corporate capital during 2001, whereas corporate debt ratio increased from 246% to 326% in 2001. The business earnings during this period was KRW 47 billion but the interest costs incurred from these debt payments in 2001 alone was KRW 54 billion.[657] The manpower of all three aircraft-manufacturing firms before the consolidation accounted for 3,544 in total. The transition in 1999 and 2000 resulted in laying off about 344 workers. Business earnings during this period slightly experienced a 2% increase, but the 9.7% reduction in manpower represented the large-scale corporate restructuring process. In

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654 이형삼, "대한항공 국민의 정부에 대반격," 월간 신동아, 2002 년 4 월호.
655 장영희, "족벌경영 날개 꺾이다: 조중훈 회장 3 부자 기소," 시사저널, 1999.11.25.
656 김당, "조중훈은 왜 DJ 납치사건의 막후 해결사가 되었나," 오마이뉴스, 2007.10.28.
657 공희정, "추락하는 것에는 날개가 없다." 오마이뉴스, 2002.9.16.

parallel to these transformational undertaking, the consolidated corporation enjoyed an exclusive position in government contracts as demonstrated in continual programs awards in the T-50 Advanced Trainer, Korea Helicopter Program, and so forth.[658]

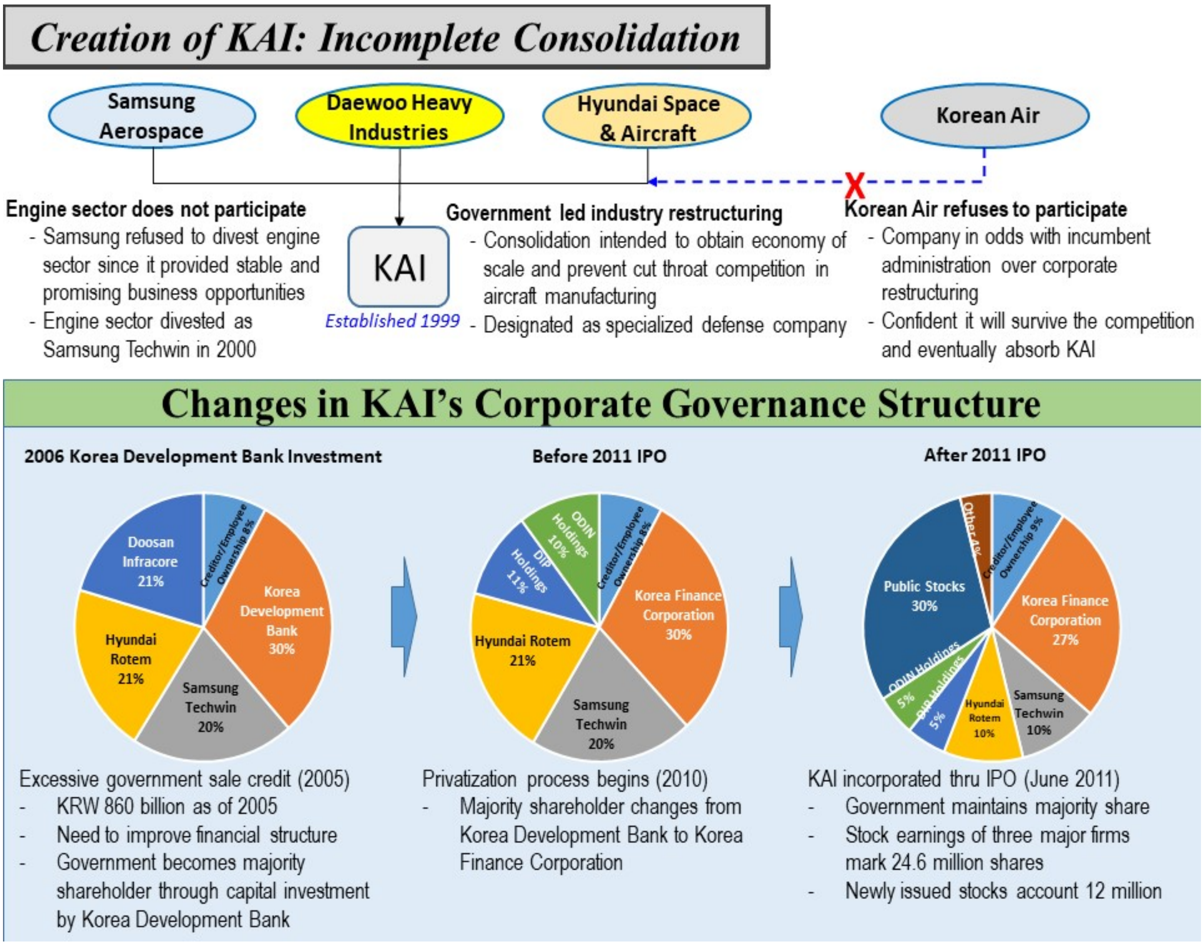
Before Consolidation (1998)			After Consolidation (2000)	
Company Name	Business Earnings	Manpower	Business Earnings	Manpower
Samsung Aerospace	₩405.9 billion	1,802	₩557.9 billion	3,200
Daewoo Heavy Industries	₩111.7 billion	1,042		
Hyundai Space and Aviation	₩30 billion	700		
Total	₩547.6 billion	3,544		

Table 44. Business Earnings and Manpower During Restructuring Process
Source: 산업연구원, 국내외 항공기산업의 환경변화와 대응방안, 1999.

The company was swayed by political influences in corporate operations, in which the incumbent administrations literally managed the company as a state-owned enterprise without presenting many opportunities to innovate as a corporate entity. Government bureaucracy spread out in corporate management sectors where the chief executive officer, who had neither knowledge nor prior experience in running a business that manufactures highly complex product systems, ruined a number of critical negotiation deals with international partners.[659] The collaborated process to attract foreign investments and diversify business portfolios was not easily attainable. Business deals to attract foreign capital from Boeing and BAE for improving the corporate financial structure were unsuccessful. Additionally, individual efforts to attract foreign investments initiated by executive members of KAI were frustrated by the government and public officials with very unaccountable reasons to comprehend. Corporate executives of KAI attempted to attract investments from Middle Eastern investment firms, which offered even much favorable terms for corporate operations compared to the Boeing-BAE Consortium. The investment deal proposed by Adnan Khashoggi, a Saudi-Arabian businessperson, in May 2002 was to provide $200 million in capital investments, assign three board members with Korean citizenship, and not interfere with daily corporate management. Khashoggi also offered an extensive opportunity to utilize his marketing networks where KAI can promote its products in the international market. On the contrary, the investment picture proposed by the Boeing-BAE Consortium was far too restrictive, with an investment package of only $37 million and exclusive rights to veto management decisions.[660] Additionally, defense offset arrangements generated from combat aircraft procurement programs were not strictly enforced to diversify KAI's business area into the commercial sector. According to the initial contract between the Korean Government and Boeing Corporation over the F-15K offset trade, Boeing was to award approximately $346 million worth of manufacturing work in F-15K components and $732 million worth of manufacturing work in commercial airliner components to Korean firms. Most of the F-15K related manufacturing work was agreed and implemented, but the

658 안영수, 국내외 항공기산업의 환경변화와 대응방안, 1999, p. 22.
659 Retired military officers or public officials, who had no business experience whatsoever, were appointed as CEOs or placed in corporate advisory roles. 정남구, "날개 스스로 꺾는 한국항공," 한겨레 21 제 417 호, 2002.7.10.
660 공희정, "보잉사는 무시, 카쇼기는 외면, 비틀거리는 한국항공의 양날개," 오마이뉴스, 2002.9.19.

commercial element was not fully executed. Especially, the workload to manufacture approximately $255 million worth of components of the Boeing 747 Section 11 was terminated, and transferred over to an Australian firm instead of KAI. The stated reason by the Korean defense authorities regarding the cancellation of the Section 11 workload was due to the diminishing market demand of the Boeing 747 and incomplete contractual terms between KAI and Boeing over the offset arrangement. But considering the remaining offset arrangements provided by Boeing were mostly in low-tech engineering parts, it was highly possible that Boeing called off the deal to constrain the future development prospects of a potential business competitor in the global aerospace market.[661]



6.2.3. State-owned or Privately Managed? Attempts to Privatize KAI

Stable business performance of KAI

Starting in 2005, after going through turbulent seasons of structural reform and overhaul, KAI's management structure became stabilized and the business performances started to improve, where the company grew in business sales with an average rate nearly 20% annually. Securing a stable amount of workloads from defense contracts such as the T-50 Supersonic Trainer, KUH Surion

661 공희정, "보잉 F-X 절충교역 약속 불이행 파문확산, 약속했던 주요물량 지난해 호주로 넘겨," 오마이뉴스, 2002.9.9.

Helicopter, and various MRO contracts, KAI has experienced a stable growth rate since 2008. Notably, business earnings accrued from the export of the T-50 trainer to Iraq and the Philippines took a share over 25% (KRW 178 billion) in 2015 alone. Contracts awarded from international aerospace giants such as Boeing and Airbus over subcomponent manufacturing and airframe structure also constituted a significant amount of business earnings as well (KRW 265 billion in 2015). The improvement of business performances in recent years after the creation of the company was a result of reorganization through downsizing and cost cutting.[662]

In this aspect, the company value of KAI continued to grow since the firm went public in 2011. The value per share of KAI at the point of initial public offering in July 2011 was KRW 18,500. The highest performance per share reached KRW 106,500 in August 2015, growing nearly six times in scale compared between the years. Because of such high valued growth in company value, the anticipated price range for acquiring KAI vertically climbed from KRW 1 trillion to more than KRW 3 trillion. Putting into account the premium for company control rights, the price range would grow even higher.[663]

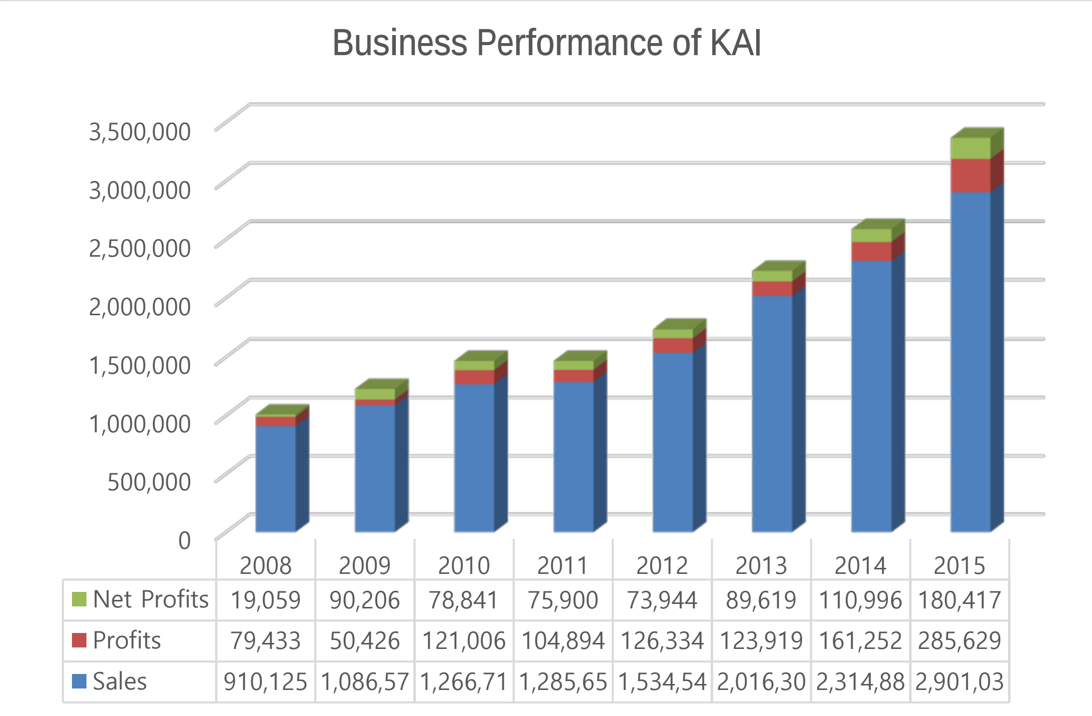


Figure 22. KAI's Business Performance, Unit: KRW 1 million

Politically Driven Privatization Policies over KAI

In August 2010, the government decided to sell state-owned shares and parts of the stocks owned by the other three major shareholders, totaling about 40% of the entire shares of KAI. The privatization process was to be a block deal of selling out 41.75% of the KAI share owned by the state-owned Korea Financial Corporation, Samsung, Doosan, and Hyundai, to a single private firm that had

662 연합뉴스, "KAI 매출 영업이익 사상 최대 실적," 2015.10.28.
663 정재웅, "실적은 참 좋은데, KAI 민영화 공중에 뜬 이유," Business Watch, 2016.1.13.

the resources and willingness to inherit KAI and grow the country's sole aircraft manufacturing firm into a world-class aerospace firm. However, since KAI became designated as a specialized defense firm, the local law prohibited foreign takeover of corporate ownership, in which the inheritor must be a domestic firm.[664]

Privatizing state-owned enterprises, or corporations where the state is a major shareholder such as in the KAI case, was a major campaign commitment made by the Lee Myong Bak Administration. State owned enterprises were falling behind and performing poorly in business operations caused by negligent and reckless management practices. Additionally, quasi-state run enterprises where the government holds a major share of the firm, of which the acquired shares originated from providing financial salvation packages to failing private businesses during the 1997 Asian Financial Crisis, were considered for sellouts in the market. As of 2008, the number of state-owned or state-run enterprises marked 305 with a commitment of an astronomical national budget of KRW 338.3 trillion annually. The objectives for privatizing these state-owned or state-shared enterprises were to scale down the government's involvement and financial burdens in managing these institutions. The driving principles for privatization were; 1) deregulate restrictive government control over industry; 2) improve public sector performances; 3) proactively engage public services into open competition. In 2008, the government announced the privatization of 305 state-owned or state-run enterprises, which included KAI.[665] Especially, considering the privatization of KAI, the strong justification was the fact that the state-owned structure discouraged the growth of critical international marketing capabilities of the company in comparison to its standing technological readiness levels, which degraded the company's competitiveness in the international aerospace industry.[666]

The potential candidates with the highest possibility that would've inherited KAI were Korean Air or one of KAI's three major stakeholders – Hyundai Motors, Samsung Techwin, Doosan Corporation. Considering the foundations of KAI mostly being built up from formerly Samsung Aerospace, Samsung Techwin was the most likely firm that had strong justifications for the takeover scheme. Samsung was also the company that won the loyalty of the labor union regarding the privatization process. However, Samsung declared that it had no intentions to enter the aircraft manufacturing market through acquiring the majority shares of KAI.[667] Furthermore, Samsung sold off its entire defense business branches such as Samsung Techwin and Samsung Thales to Hanwha Corporation and completely exited the defense market in the fall of 2014.[668]

Hyundai Motor Group was also a strong candidate for acquiring the aerospace and defense firm. Considering the experiences of KAI in engineering design and system integration work over complex

664 윤선희, "정책금융공공, 한국항공우주산업 상장 후 매각 추진," 연합뉴스, 2010.8.30.
665 Since its establishment in 2000, the government injected about KRW 8.7 trillion of public funds in the course of normalizing KAI; 조성봉, "이명박 정부 공기업 선진화 정책의 평가와 향후 과제," 규제연구 제 20 권 제 2 호, 2011 년 12 월.
666 Interview with a KAI executive, 22 September, 2015.
667 서영지, "김순택 삼성 부회장 KAI 인수 생각 전혀 없다," 이데일리, 2012.4.25.
668 최명용, "한화그룹, 삼성테크윈 인수로 KAI·종합화학까지 거머쥐다," News1 뉴스, 2014.11.26.

product systems, there were many synergetic areas where Hyundai Motors could have benefited over the merger. Nevertheless, Hyundai was reluctant to move into a high-risk business field through investing an astronomical amount of capital to acquire a company that mostly finds its business opportunities in defense contracts. Henceforth, Hyundai Motors sold off its entire share of KAI (4.85%) in 2016 and decided to concentrate more on its main automotive sector.[669] On the other hand, Hyundai Motor's sister company, Hyundai Heavy Industries (HHI), had a keen interest in entering into the aircraft manufacturing business by acquiring major shares of KAI. A shipbuilding company with global standards, HHI was determined to diversify into a high-tech field, although there were concerns over the synergetic effects between a shipbuilding firm and aircraft manufacturing firm. At the time of the public bidding, HHI had sufficient resources with a business cash flow over KRW 9.5 trillion prepared to acquire KAI.[670] In December 2012, HHI entered as the sole bidding company in the privatization process, but the bidding was miscarried because the Korean law restrictively allowed only a competitive bidding of at least two tendering parties for cases like selling out government shares of state-owned or state shared companies. The Presidential Election of 2012 was perhaps the strongest contributing factor that frustrated the public sellout of KAI's state-owned shares of December 2012. The two major Presidential candidates each expressed reluctance with privatizing the state-owned shares of KAI with reasons that the state had larger roles to grow the industry into higher competence levels.[671]

Korean Air was the company that expressed the strongest interest in undertaking KAI through the exertion of consistent efforts in the years after the 1999 Big Deal, with high aspirations of taking over the domestic aircraft-manufacturing sector. During a business conference in March 2009, the Chairman of the company announced that Korean Air had all the intentions and interest to assimilate the corporate competencies of KAI. Korean Air mainly targeted the shares held by Doosan Corporation, which was always finding ways to exit the defense market, including aircraft manufacturing, in order to gain financial ammunition to focus on energy plants or other strategic business areas.[672] Acquiring the country's single largest aircraft manufacturer would provide synergistic benefits to Korean Air in areas of combining its MRO businesses with KAI's competitive technological capacities as a system integrating firm. Additionally, the corporate identity of Korean Air had great pride in itself as Korea's first pioneering company that advanced into aircraft manufacturing in the early 1970s. Thus, acquiring KAI had very symbolic implications for building up Korean Air's corporate brand value.[673] There were several attempts in the pass by Korean Air to acquire the majority shares of KAI. During three consecutive events in 2003, 2006, and 2009, Korean Air exerted efforts to acquire the shares, which were then owned by Daewoo Heavy Industries & Machinery, the successor company of Daewoo Heavy Industries and the predecessor company of Doosan Infracore. All three merger attempts failed because

[669] 서일범, "재계 내년 방패경영: 내실 다지기로 퍼펙트스톰 대비," 서울경제, 2016.12.26.
[670] 이상배 외, "대한항공 KAI 입찰포기…TV 토론 후폭풍?," 머니투데이, 2012.12.17.
[671] 이정훈, 최현준, "KAI 매각 또 무산, 민영화 백지화 되나," 한겨레, 2012.12.17.
[672] 박종욱, "두산 보유 KAI 지분, 대한항공이 인수하나," 매일경제, 2009.3.13.
[673] 교통신문, "대한항공, 항공기 제조산업 본격 진출," 2003.8.30.

of the financial shortages of Korean Air. Learning the lessons from the past over the failed attempts to takeover KAI, Korean Air made efforts to join forces with foreign partners such as EADS or Boeing to form an international consortium of investors.[674] However, with Korean Air's ailing financial status, it became extremely challenging to gather enough financial credits to acquire KAI. In order to acquire the shares of KAI as of 2012, Korean Air needed more than KRW 1.8 trillion to obtain the status as a majority shareholder. But because of the global financial crisis and high oil prices during the period, the company's debt ratio as of the third quarter of 2012 marked over 1050%, the worst of all the major stakeholders. To make matters worse, the Korea Development Bank, which was the largest shareholder of KAI and the main creditor bank of Korean Air, expressed negative opinions over Korean Air's intention to takeover KAI, considering Korean Air's unhealthy financial status and the ramifications to the future management prospects of KAI.[675] In this regard, even if Korean Air takes over KAI as a majority shareholder, it was highly possible that Korean Air may divest some of the primary business branches of KAI in order to save itself from financially falling into default.

There were strong suspicions of state-business collusion between the incumbent Lee Myong Bak Administration and Korean Air during the attempt to privatize KAI. The chairperson of Korean Air, Mr. Cho Yang-Ho, had meetings almost monthly with the Korean President before the government announced the privatization program.[676] In January 2009, President Lee Myong Bak directed a financial overview by the Ministry of Knowledge Economy to assess the possibility of Korean Air taking over KAI. The initial assessment concluded negative against Korean Air's takeover, judging that Korean Air's debt ratio of 829% makes it less appealing to acquire a company with a lower debt ratio of 107%. But the Presidential Office insisted to selloff KAI after a meeting convened by the Policy Chief of the Blue House in 7 September, 2012, which also opened the possibility of a sole source direct sell-over with high considerations over Korean Air as the purchasing firm.[677] The major political figures responsible for privatizing KAI were direct associates of the President. The primary authority that took the lead over KAI's privatization process was the Korean Development Bank (KDB). The President of KDB, Mr. Kang Man-Soo, who formerly served as the Minister of Strategy and Finance, was a top lieutenant in economic policy making President Lee Myong Bak. The implementing agency for selling off the government shares of KAI was the Korea Finance Corporation. The chairperson of this organization, Mr. Jin Young-Wook, was the right-hand man of Kang since his service days in the Ministry of Finance. Mr. Kim Hong Gyeong, a retired deputy minister from the Ministry of Finance, and who contributed a major role in the Presidential campaign, was ironically the government appointed CEO of KAI. Interestingly, the financial institution assigned for advisory services over the selloff was Credit Swiss, which handled the financing of major overseas projects initiated by the Lee

674 김현일, "공기업 KAI 민영화 시끄러운 내막," 사건-In, 2012.05.14.
675 김재한, "KAI 매각, 국내 항공산업 위기인가?," 월간항공, 2012 년 11 호.
676 김종대, "청와대와 대한항공의 특수관계: 조양호 회장의 MB 코드 맞추기," D&D Focus, 2009 년 4 월호
677 김종대, "방산업 어차려에 자주국방 비명," 주간동아, 2012.11.26.

Administration, and also believed to have connections with the President's older brother.[678] Another key figure in this connection was Dr. Kim Tae Hyo, the President's senior staff in national security affairs. Dr. Kim also happened to be the son-in-law of the founding family of Korean Air. Although the position was not directly involved with the privatization process, Dr. Kim's capacity in national security affairs had substantial influence over formulating defense industrial policies.[679]

As of 2016, the privatization process of KAI has turned out even more difficult. In September 2015, the state controlled Financial Services Commission directed the divestment of all non-financial institutions held by the Korea Development Bank in order to bolster policy-lending programs in support of industrial finances.[680] At the same time, the corporate governance structure of KAI was going through substantial changes. Despite the stable business performances of the firm and the promising government defense contracts that would be exclusively awarded to KAI, the major stakeholders of the company, such as Samsung, Doosan, and Hanwha, were selling entirely or partially their shares in the stock market after the initial public offering of 2011. In 2015, Samsung agreed to sell Samsung Techwin, which held about 10% share of KAI, to Hanwha Corporation. Hanwha landed on a block deal of re-selling its 6%share over KAI in the stock market. Doosan sold its entire share of KAI to institutional investors such as the National Pension Service the same year. From these block deals, within a week period the stock price of KAI plummeted from KRW 77,100 to KRW 65,400 as of January 2016. Because of the devaluation of KAI's stock, it became challenging for Korea Development Bank to actively progress with divesting the remaining 26.5% share of the aircraft manufacturing firm. Especially, because KAI was designated as a defense firm, according to Korean law, the divestment of state-owned shares of KAI had to go through an intensive interagency review that involved the Ministry of National Defense, Ministry of Trade, Industry, and Energy, the National Science and Technology Committee, and so forth.[681]

Public Objections against Privatization

The government's attempt to privatize the company ran into a number of roadblocks and public criticism amid the stable business performances of KAI based on the exclusive contract awards on major military aircraft development programs. Especially with the continued valuation of KAI's public shares in the stock market, selling out the majority share in a block deal to a single bidder became more unaffordable for potential buyers like Korean Air or Hyundai Heavy Industries.[682]

In the perspectives of the KAI labor union and civil activist groups, the attempted move of Korean Air to takeover an outperforming company, under closely colluding with government officials, was simply nonsense. Up onto this point, the KAI labor union endured harsh reorganization processes

678 박종훈, "KAI 민영화 추진에 노조 반발, 추진배경도 의심," 참여와 혁신, 2012.6.16.
679 감명국, "카이 인수 뒤에 밀약 있었나: 대한항공의 한국항공우주산업 인수설 확산," 시사저널, 2009.4.21.
680 이보람,"금융위, 산은 비금융 자회사 매각 추진," 뉴시스, 2015.9.8.
681 신관식, "KAI 민영화? 속타는 산업은행…인수 후보들 줄줄이 뒷걸음," 일요경제, 2016.01.13.
682 강봉진, "KAI 저주? 인수후보 창사이래 최대위기," 2014.12.19.

since the consolidation of the former aircraft-manufacturing sectors of the three Chaebol companies. In order to resurrect the insolvency inherited from previous business operations, KAI went through a series of corporate asset disposals, manpower reductions, wage freezes, bonus returns, and so forth, in order to normalize its business operations.[683] Accounting for only the aircraft-manufacturing sector of Korean Air, the business performances of the two companies at the time when the first privatization process was announced shows contrasting outlooks. Net sales of KAI were almost threefold compared to that of Korean Air. KAI had more than ten times the number of researchers than Korean Air, where each individual employee showed higher performance rates (net sales per capita. The dissent from the KAI labor union mostly spotlighted on job security and suspicions over the true investment intentions of interested parties. There was fear that KAI will fall under prey to vulture capitalists through various schemes of hostile takeover, where the country's only aircraft manufacturing firm will eventually become dismantled by these speculative investments. Particularly considering the fact of Korean Air, which had the worst debt ratio marking over 1000%, revealing the highest potentials to inherit KAI, there were grave concerns of these debts spilling over to KAI.[684]

Performance Category	KAI	Korean Air (Aircraft-manufacturing sector)
Business Sales	KRW 9,101	KRW 3,776
Business Profits	KRW 784 (8.7% of business sales)	N/A
Ordinary Profit	KRW 191 (2.1% of business sales)	N/A
Assets & Liabilities	KRW 1.055 trillion	KRW 0.6278 trillion
Workforce	2,852	1,651
R&D Workforce	902	80
Debt Ratio	132%	462%
Sales per Capita	KRW 320 million	KRW 230 million

Table 45. 2008 Business Performance of KAI and Korean Air (Source: 2008 KAI document)

Another element that discouraged the privatization process was the intense objection from the local industrial community and subcontractor groups. The Municipal City of Sacheon, where the KAI business headquarters was located, severely objected privatization, fearing it will divert future investment opportunities to other locations. Starting from 2006, Sacheon City invested heavily into building industrial districts specialized in aerospace under the premises that the government will continue to support KAI as a public entity. Under this belief, approximately 70 small and medium sized firms invested nearly KRW 100 billion into the newly constructed Sacheon Aerospace Cluster. The basis of these local concerns originated from the assumption of a potential takeover of KAI conducted by Korean Air. At that moment, Sacheon City was in fierce competition against Daegu and Busan City over hosting a larger portion of government investments in the aerospace sector. Busan was the foothold for Korean Air's aircraft manufacturing base. Under the law of physics, it was highly unlikely that Korean Air would sustain the manufacturing capacities of KAI's Sacheon facility while maintaining its Busan/Kimhae production line. Having this in mind, the National Assembly also rejected the on-going

683 장명호, "KAI 흑자 돌아서자 민영화…MB 뒷거래 의혹," 경남도민일보, 2012.6.13.
684 바른지역언론연대, "KAI 민영화 무조건 반대하지 않는다-류재선 KAI 노조위원장," 오마이뉴스, 2017.1.24.

privatization process of KAI, and strongly insisted the government to recalibrate its original intentions towards building the country's only aircraft manufacturing firm into a more competitive world class player.[685]

6.2.4. Public to Private Sector Technology Spillovers

Based on the governing ordinances of the Technology Transfer Promotion Act and supporting institutions, the technological products of government funded public research shall be transferred to the industrial sector in pursuance of stimulating commercialization and innovation. The Korea Technology Transfer Center, through its regional centers and Technology Liaison Offices (TLO), administers the conditions to build assurances in complying with the transaction of intellectual property rights, promotion of selective technology development, and the construction of industrial infrastructures conducive for technology transfer. Successful technology spillover cases derived from this transfer process in the aircraft-manufacturing sector include products such as industrial gas turbines, turbo-chargers, new composite materials, bullet-proof materials, and so forth.[686]

In the defense sector, the transfer process is administered by the Dual-Use Technology Promotion Center under the purview of the Agency of Defense Development through the initiatives stated in the Civil-Military Technology Partnership (CMTP). As briefly commented in previous chapters, the performance of technology transfer through spinoff is unimpressive as the program has been tamed with decreasing interests from other public and private entities. In order to address these inherent challenges, the government revised the CMTP Promotion Act in 2014 to expand the participation of central government agencies into this initiative. The revised legislation established the Special Committee in Civil Military Cooperation under the National Science and Technology Council, and empowered the Ministry of Trade, Industry, and Energy to serve as the control tower that administers the CMTP by coordinating and adjusting inter-agency R&D efforts with 11 government agencies.[687] The change reflected in the revised legislation was a direct consequence of the sluggish and dull performance of ADD in the overall technology transfer process. Since the start of the CMTP in 1997, the initiative supported 24 technology transfer projects as of 2011. About 96% of the transfer initiatives were conducted by corporate efforts. Not a single technology was transferred from ADD to the private sector. Although ADD claims that the agency exerts its own efforts self-regulate defense spinoffs, the initiative is not executed under the guidance of the CMTP.[688]

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685 김영표, "㈜ KAI 민영화 추진반응과 정책시사점," 경남발전연구원, Issue Paper 2009-20, pp. 10-22.
686 항공우주산업진흥협회, 항공우주기술 타산업 활용 및 연계방안 연구, 산업자원부 정책연구보고서, 2006, p. 7.
687 민군기술협력센터, 민군기술적용연구사업 절차 및 사례, 민군협력진흥원, 2015.7.16.
688 안영수 외, 창조경제 시대의 민군기술융합 촉진을 위한 제도개선 방안, 산업연구원, 2013, p. 102

Unit: *KRW 100 million*

Supervising Institution	Number of Transfers	Government Funding		Private Investments		Total	
		Value Amount	Percentage	Value Amount	Percentage	Value Amount	Percentage
ADD	0	0	0	0	0	0	0.0
Other GRI	1	7	77.8	2	22.2	9	100.0
Business Firms	23	96	69.1	43	30.9	139	100.0
Total	24	103	69.3	46	30.7	148	100.0

Table 46. Public to Private Technology Transfers (1997 - 2011)
Source: 산업연구원, 민군기술협력 기본계획 수립을 위한 용역, 2012.

Defense contracts awarded to private companies functioned as major instruments of technology transfers in aircraft manufacturing, of which private entities took part in an undertaking of a larger defense acquisition program. According to a 2005 survey on the spillover effects of technology transfers in aircraft manufacturing, three primary technical categories developed under government sponsorship were identified as technologies that had critical diffusion effects into other industrial products. The three were propulsion devices, composite materials, and avionics. At first, propulsion technologies derived from the development and manufacturing of small gas turbine engines, which subsequently diffused into various engines and power units. Samsung Techwin acquired the requisite technologies for localizing small gas turbine engines by partaking in various military jet engine projects. Based on the experience accumulated from these programs, the company's Power Systems engineering Laboratory successfully developed the 100kW Auxiliary Power Unit that further progressed into 12 new engineering products, from ultra-micro compressors to artificial joints.[689] As the country's only manufacturer of gas turbines, Samsung Techwin accumulated extensive experiences in system design, aerodynamics, structure, and testing from developing and manufacturing nearly 4,000 turbine units that mostly came from military jet engine contracts. From 1991 to 2006, the Ministry of Commerce, Industry, and Energy launched the first indigenous gas turbine development project, dubbed the TG1200 Turboshaft Engine, which generated a 1.2MW electric output with a design life of 30,000 hours. Samsung Techwin was the prime contractor to build the engine under a co-development arrangement with the Kore Aerospace Research Institute, Korea Institute of Machinery and Materials, Seoul National University, and so forth.[690] The successes in TG1200 and ensuing exploits in other variants were all possible based on the foundations built up from the thirty year experiences in defense contracts.

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689 항공우주산업진흥협회, 항공우주기술 타산업 활용 및 연계방안 연구, p. 40.
690 전승배, "삼성테크윈의 가스터빈 개발 및 생산기술," 기계저널 제 46 권 제 10 호, 2006, p. 57.

Military Service	Program	Product Developed	Cooperative Partner	Program Type	Component Localization
Air Force	KF-5E/F	J85-GE-21B	General Electric	License Manufacturing	-
	KF-16 (KFP)	F100-STW-229	Pratt & Whitney	License Manufacturing	41.2% (110 items)
	KT-1	PT6A-62	Pratt & Whitney	License Manufacturing	27%
	F-15K	F110-STW-129A	General Electric	License Manufacturing	29% (26 items)
	T/A-50	F404-STW-102	General Electric	License Manufacturing	26%
Army	UH-60P	T700-SSA-701C	General Electric	License Manufacturing	35% (29 items)
	Surion KUH	T700-SSA-701K *(Evolved from 701C)*	General Electric	License Manufacturing	48%
Navy	KDX-II/III	LM2500	General Electric	License Manufacturing	45%
Under Development	A380 (Airbus) - Commercial	Trent 900	Rolls Royce	Co-production Partner	In Progress
	KF-X	F414-GE-400	General Electric	License Manufacturing	In Progress

Table 47. Samsung Techwin's Jet Engine Experience
Source: Sohn Young Chang, "Engine Development Program for Army Light Attack Helicopters," 2014 ROK Air Force Air Power Seminar

Secondly, the application of composite materials used from building aircraft structures into other industrial sectors spun off some meaningful outcomes. The technology for light weighted aluminum materials developed by Korean Air contributed to significant weight reduction performances in railway vehicles. Such achievements were possible based on Korean Air's long experience in developing light weighted composite materials for aircraft structural design with the assistance of advanced design analysis equipment using CATIA and NASTRAN modeling solutions. It was a case where structural design/analysis/test/production technology used for aircraft manufacturing directly applied into railway vehicle development. The transfer process was administered by MOCIE, supported by participating private entities such as Korean Air, Hanjin Heavy Industries, Hyundai Precision Engineering, Dongyang Steel, and so forth. Although immediate transfer efforts did not result into commercialization of the respective technology, the process contributed to improving the technological competitiveness of the domestic locomotive manufacturing firms.[691] A similar bi-product of weight reduction efforts through material science processes is also found in bulletproof engineering on cockpits for utility and attack helicopters. The S-Glass bulletproof materials were further applied into armor personnel carriers (K-21 IFV) and naval vessels (KDX-III destroyers and PK-X fast crafts), as well as Landing Craft Air Cushions (LCF-II 631).[692]

Thirdly, avionics in Korea is a sector that falls far behind the global standards. There are approximately forty some firms involved in the avionics business, but most of them contribute less than 10% of its business portfolio into avionics, thus the sector falls far short of creating a scaled economy. Most of the avionics businesses are headed by big firms such as KAI, LIG Nex1, Hanwha Systems, Ucon Systems, with the support of its affiliated small-middle sized subsidiaries. Most of the workshare are concentrated in hardware production for small components whereas software development related with building integrated system architectures lingers in the second-rated field. Some of the technology

[691] Korea Aerospace Research Institute, Studies on Technology Spin-Off Effect and Cooperation Roadmap Among Industry, University, and Research Institute in the Aerospace Sector, *Korea Research Council of Public Science & Technology*, 2005, p. 52.
[692] Ibid., p. 54.

originating from control technology spun-off into flight control systems for unmanned air vehicles.[693] Despite the country's competitiveness in the overall IT sector, avionics in Korea remain in mediocre performances due to the lack of system integration technology and requisite workload available in the sector. Nonetheless, with the backing of a strong electronics industrial infrastructure, the avionics sector enjoys some competitive advantages in technical fields such as in Electro-Optic/Infra-Red (EO/IR). The integration of Synthetic Aperture Radars into aircrafts requires highly advanced precision technology on EO/IR, which resonates into other radar capabilities in ground, air, and sea. The high resolution required for multiple image processing and time precision creates a ripple effect in both the upstream (mechanics, materials, IT, etc.) and downstream (weather forecasting, satellite, GPS, etc.) industries.[694]

6.3. Structural Constraints within the Aircraft-Manufacturing Sector

6.3.1. Risk Averse Mentality in Research and Development

As covered in previous chapters, a critical factor that obstructs a conducive atmosphere to build talent for a vibrant research and development architecture is the prevailing risk averse mentality surrounding the overarching R&D defense industrial sector. According to an update brief to the President by the Ministry of National Defense regarding the current competitiveness status of the defense S&T and industrial outputs, the risk averse mentality in weapon system development was raised as a factor that hinders sustained advances in defense technology. Major defense firms involved in the weapon system development business share the same mentality in this aspect. However, the essential reason behind such passive attitude lies the harsh penalty fees imposed by government authorities over defense firms in case of a development failure.[695] The government's imposing of penalty fees to defense firms are justified by the fact that a glitch in weapon system development and manufacturing process leads to warfighter capability gaps. Therefore, penalty fees are believed to serve as an assurance against potential program mismanagement. On the other hand, the challenge here is that such penalty fees are imposed discriminatively, which discourage entrepreneurship and risk taking.

In 2013 alone, major defense firms were penalized with substantial amounts of penalty fee. KAI was fined with a KRW 13.3 billion penalty, Hanwha hit by 6.7 billion, and S&T Motiv KRW 6.6 billion.[696] Domestic defense firms are not only forced to absorb heavy penalty fees but also have to deal with discriminative regulations compared to foreign firms. In the case of KAI, the penalty fee imposed in 2013 originated mainly from the delayed delivery of the P-3CK Maritime Surveillance Aircraft Upgrade Program. The main reason for the delayed delivery was caused by KAI's U.S. subcontractor called L-3 Communications, which provided assistance in system and technology

693 김소영, 미래 항공기의 핵심기술 항공정자 경쟁환경 및 연구개발 동향분석, 한국과학기술정보연구원, 2013, p. 22.
694 중소기업청, 중소·중견기업 기술로드맵 2017-2019: 항공우주, 2016, p. 248.
695 임진수, "리스크 없는 것만…도전하지 않는 국산 무기개발 사업," 노컷뉴스, 2014.2.14.
696 김호준, "방위사업 지체상금 제도 국내업체 역차별," 연합뉴스, 2013.9.22.

transfers for the upgrade program. In this sense, L-3 Communication failed to comply with the original timeline on the part of providing technology transfers, technical assistance, and aircraft refurbishment services within the given contractual dates. L-3 Communication delivered the aircrafts two years later than the original contract date. However, despite the fact that KAI was imposed with substantial penalties, Korean government authorities exempted most of the penalty fees against L-3 Communication, in which L-3 eventually ended paying no penalties at all.[697] In consideration of this case as a classic example of discriminative government policies, defense firms became more focused on ways to avoid paying penalty fees instead of developing or learning requisite technology and improving production processes.

The penalties imposed on test failures over weapon systems development programs also restrains sectoral efforts to bolster R&D productivities. In July 2017, the Defense Acquisition Program Administration (DAPA) filed a case against a team of five ADD researchers for damages charged over KRW 6.7 billion on a crashed unmanned aerial vehicle prototype that was undergoing test flight trials. The air vehicle was being tested for the Army's corps level tactical surveillance program with a total program budget of KRW 118 billion. Failure to reverse a simple sensor circuit installed in the aircraft was identified as the cause of the crash. There was every means to avoid the incident from occurring, where there were trails of procedural negligence committed by the program researchers. However, charging a large penalty worth a life time fortune to individual scientist and engineers apparently discouraged innovative thinking and bold actions in the laboratory.[698] In reference to U.S. standards or program guidance in military aircraft development, the first priority for consideration is to find an optimized economic solution based on trade-offs in costs between R&D, procurement, and maintenance. In this aspect, provisions on durability or precision allows deficiencies to a level that does not obstruct performances. Therefore, the criterion over the development process is amenable to certain failures and does not imply zero defects. For instance, if a lubricant leak from a component but does not impact on the overarching system performance, and the leakage can be controlled under routine inspections with low cost-bearings, then the defect is rated acceptable.[699]

Referring to U.S. standards, critics against such harsh decisions argue the penalty criterion regulated by DAPA is overly too restrictive that restrains innovative development. A similar case is found in the K-2 Black Panther Main Battle Tank Program. The tank development was stalled for nearly ten months from 2016 to 2017 because of a durability test failure on the power pack transmission system. The indigenously developed power pack system gears the track vehicle to survive tactical maneuvers in harsh terrain. However, the excessively high technical standards and durability criterion established by DAPA constantly disqualified the transmission system. The ripple effect was a production suspension on the entire supply chain of the MBT program, which involved 119 companies and estimated business

[697] 김동욱, "지체상금 제도의 문제점과 개선방안," 한국방위산업학회 발표자료, 2014.8.14.
[698] 이민정, "무인기 추락 손실액 67억원 연구원이 배상하라 징계논란," 중앙일보, 2007.10.13.
[699] Department of Defense, Joint Service Specification Guide: Air System, 21 September, 2004, p. 24.

damages of KRW 100 billion.[700] A number of veterans in the defense industry business commonly raise the point of the lack of coordinative authorities and bad leadership practices under the auspices of the Agency of Defense Development (ADD) that discourages advances in technological development by corporate entities. To date, ADD has ruled over the defense industry with its monopoly power in defense technology development. The Agency dissuaded corporate R&D efforts under the guise of state-led technology development or national security assurances.[701] These restrictions constrain the efforts of diffusing core technology to the commercial sector. But it turns out ADD has been simply copying sensitive technologies imported from foreign sources without adding much additional efforts for evolutionary development.

In the grand scheme of considering risk averse mentalities, policy indecisiveness in determining aircraft development programs observed through the indigenously developed KF-X program encapsulates these abusive practices. The KF-X program, which intends to indigenously build a fourth generation fighter capability to replace the aging F-4 and F-5E/F fighter fleet, is conceived with the ambitions to achieve a commanding air superiority as well as to bolster the domestic aerospace industry. However, the program went through six iterations of feasibility studies before moving into the actual decision making for launching a full scale development program. Out of the six feasibility studies, only one study conducted by a local university engineering lab assessed the program as feasible, whereas the other five studies recommended either a negative or a more cautious approach. Interestingly, four feasibility studies were awarded to the Korea Institute of Defense Analysis under the Ministry of National Defense, which constantly expressed strong skepticism over the KF-X. Even within those four studies, the same researchers who have strongly opposed indigenous development continued to become part of the review board, which harbors strong suspicion over the credibility of the study results.[702]

Review Period	Review Agency	Assessment
March-December 2003	KIDA	Necessary to bolster aerospace industry
Dec 2005 – Jul 2006	KIDA	Economically and technologically not feasible. Recommend international co-development, program estimate KRW 6 trillion
Dec 2006 – Feb 2008	KDIA, KDI, ADD	Economically not feasible, development estimate KRW 10 trillion
Apr – Oct 2009	Konkuk University	Economically feasible, development estimate KRW 5 trillion
Jan – Oct 2012	KIDA	Economically not feasible, development estimate KRW 10 trillion
Nov 2013	KISTEP	Economically not feasible, high uncertainty in development aspects

Table 48. KF-X Feasibility Studies

The risk factors associated with weapon systems development and emerging complexities of coordinating different organizational and technical components for systems-of-systems development are insufficiently addressed in senior corporate leadership appointments, which became marred in differing political interests driven by parochial factionalism. The absence of professional appointments to key leadership posts in defense acquisition systems and corporate management also causes serious

700 손종호·이소현, “국산 K2 전차 내년 납품도 스톱…방산업계 피해 눈덩이,” 아주경제, 2017.8.28.
701 Interview with a defense industry official in 8 October, 2014
702 김영태, “한국형전투기사업의 이상한 타당성 검토,” 노컷뉴스, 2013. 9. 11.

predicaments in sustaining capacity buildups in the aircraft management sector. A common theme observed when surveying executive level appointments at major defense and aerospace related institutions, such as the Korea Aerospace Industries (KAI) and Defense Acquisition Program Administration (DAPA), it becomes quite rare to find a person who hails from a program management or defense acquisition background. The majority of the appointments either come from retired military or financial technocrats who were nominated based on political connections and interests, not by specialized competencies. Putting aside the bona fide argument of credentialing 'core' verses 'specialized' competencies, the decision making behavior from these senior appointments mostly lacks the genuine understanding of the complexities affiliated with international norms and regulations meshed into weapon system developments, which results in risk averse behaviors or decisions that restrain circumstances that promote sustained learning and innovation.

Agency	Title	Name	Term	Background	R&D/PM Experience
		Kim, Jung Il	Jan 2006 – Jul 2006	Military	O
		Lee, Seon Hee	Jul 2006 – Mar 2008	Military	O
		Yang, Chi Kyu	Mar 2008 – Jan 2009	Military	O
		Byeon, Mu Geun	Jan 2009 – Aug 2010	Military	X
DAPA	Minister	Jang, Su Man	Aug 2010 – Feb 2011	Public Service (Finance)	X
		Roh, Dae Rae	Mar 2011 – Mar 2013	Public Service (Finance)	X
		Lee, Yong Geol	Mar 2013 – Nov 2014	Public Service (Finance)	X
		Jang, Myeong Jin	Nov 2014 – Jul 2017	R&D	O
		Jeon, Jei Kuk	Aug 2017 –	Public Service (Policy)	X
		Lim, In Taek	Nov 1998 – Sep 2001	Public Service (Development)	X
		Gil, Hyeong Bo	Oct 2001 – Sep 2004	Military	X
KAI	CEO	Jeong, Hae Joo	Oct 2004 – Jul 2008	Public Service (Trade/ Industry)	X
		Kim, Hong Gyung	Aug 2008 – Apr 2013	Public Service (Trade/ Industry)	X
		Ha, Seong Yong	May 2013 – Oct 2017	Internal KAI promotion	O
		Kim, Jo Won	Oct 2017 –	Public Service (Audit)	X

Table 49. Senior Leadership Appointments at DAPA and KAI

Corporate leadership appointments at KAI are even more marred with political interests. Although incorporated as a business entity, KAI is notionally considered a state-run corporation since the government holds the majority share of the company as a product of bailing out financially delinquent domestic aircraft manufacturing firms from the 1997 Asian Financial Crisis. Contrary to the common notion of appointing a Chief Executive Officer (CEO) who should be well versed in the language of corporate management and complex product systems, the appointment of KAI CEOs normally came from political judgments, mostly to those who either contributed in major political events or those considered close aids to the President.[703] All of the CEO appointments were directed by the Presidential Office, or when reviewed in retrospect, all CEOs had some sort of contributions in the Presidential Elections but had no background experience in the corporate or defense acquisition program management. The appointment of the only CEO with a track record of having management experience in defense aerospace was later revealed to have been attributed to his family relationship

[703] 남희현, "항공우주산업 새대표 김조원을 보는 시각은 기대반 우려반," Business Post, 2007.10.11.

with the President.[704]

6.3.2. Disruptive Components: Political Disturbances in Knowledge Accumulation

Defense business has been considered to the general public as a politically high risk area, not in a sense of complexities in technology, but more in a sense of illicit activities prone towards corruption and irregularities. The notion originates from the revealing of the Yulgok Force Build-up Scandal, which resulted in the arrestment of the top brass military leadership, including two Ministers of National Defense, and three four star generals. Since then, the defense industry has become discredited by the public as a source of irrationality and fraud. Under this notion, political authorities have frequently targeted defense acquisition programs as a means of exploitation to distract public attention over politically controversial subjects.

During the period of 2008 and 2017, the Prosecutor-General's Office conducted three large scale investigations over domestic defense firms. Each investigation was triggered by political motivations instead of constituting a real case against an actual charge. The Lee Myong Bak Administration launched a large investigation force that targeted the defense acquisition programs contracted during the previous Roh Mu Hyun Administration. The motivations behind the investigations are known to be targeted against the political popularity of the former Roh Administration. In March of 2008, during the first several months in office, the Lee Administration experienced serious setbacks from the public over its unilateral decision to sign a Free Trade Agreement with the United States, which had serious repercussions in terms of agricultural and livestock products. Especially with the decision to open the livestock market to U.S. beef, the approval ratings plummeted to an all-time lowest rate around the 20 percentile level. Thus, with the upcoming general of 2008 and the ensuing municipal elections, the Lee Administration was desperately finding an exit strategy to win back public approval ratings.[705] The Lee Administration considered the loyalist group of the former Roh Administration was behind most of the public rallies and political disapproval against the new administration. Therefore, the political leadership perceived the need to suppress the rising criticism in a justifiable way, in which the defense contracts signed by the previous administration became a primary target for scrutiny. In this regard, under the directives by the President himself, the Chief Prosecutor initiated the full scale investigation over various defense contracts and defense firms throughout the Presidency of the Lee Myong Bak Administration.[706]

Also, in order to carry out the enormous government projects pledged by the President during the election, the Administration had to find ways to cut the corners of the overall national budget to fulfill the campaign commitments. The defense sector in this aspect is always a good opportunity to carve out substantial amounts of tax payer's money and reallocate the funds into other priority programs.

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704 김동현, "KAI 사장 사임 하성용, 박근혜 정부 때 임명된 항공전문가," 연합뉴스, 2017.7.20.
705 이준한, "이명박 지지율은 올라갈 수 없다," 한겨레 21, 제 714 호, 2008.
706 김종대, "지난 정권 비자금 추적부터 실세들 뛰어든 개혁 논쟁까지," 신동아, 제 603 호, 2009.

In support of rebalancing the national budget, the President justified the reduction of the defense budget by claiming the country can benefit from cutting nearly 20% of the rebate money paid as commission fees to defense brokers, which becomes a source of widespread corruption practices in defense contracts.[707] The unilateral reduction of 20% in certain defense acquisition programs during the Lee Administration restricted the program managers to procure substandard components and equipment, which prompted the forgery of official documents, irregular quality assurances, and discouraged technology development efforts.[708]

In November of 2014, under the guise of *'eradicating corruption and improving the defense industrial base'*, the Park Geun Hye Administration inaugurated the *Joint Investigation Department Against Defense Program Irregularities* (JID) under the Prosecutor's Office. The Department gathered officials from the military, tax service, law enforcement, and so forth, and created the largest investigation in the history of the prosecution office. To take advantage of this opportunity, the Bureau of Audit and Investigation also established its own investigative organization called the Joint Auditing Group to join forces with the Prosecutor Office against illicit activities in defense acquisition programs.[709] However, the actual motivation of the investigation was triggered by two political scandals at the moment. The first case considered the criticism against the Administration's competency over managing defense acquisition programs. The Park Administration was under severe criticism over the decision with the third Fighter Experiment Program (FX-III), in which the authorities rescinded its earlier decision of selecting the Boeing F-15 Silent Eagle, and chose the Lockheed Martin F-35A Lightning-II.[710] Public scrutiny over the legitimacy of rescinding a legal decision that properly went through all phases of the defense acquisition management system constantly burdened the political leadership in the Blue House. The FX-III decision had direct impact on the Korea Fighter Experiment (KF-X) development program, in which the development authorities were severely denounced by the public for not securing enough technology from the FX-III defense offset trade arrangements.[711] After the issue was raised in the 2015 National Assembly Audit, the Blue House started scapegoating DAPA officials and the defense industry as a maneuver to disentangle its negligence in the FX-III and KF-X predicament.[712]

What exacerbated the approval ratings of the Administration was the Sinking of the Sewol Ferry in April 2014, which caused the lives of nearly three hundred passengers. The government's incompetence shown in the course of the rescue operation was severely criticized, subsequently

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[707] 김범현, "이대통령 커미션 줄이면 무기구입비 20% 줄 것," 연합뉴스, 2009.9.21.
[708] 조성식, "위기의 방위산업, 박정희는 그렇게 하지 않았다," 동아일보, 2016.5.24.
[709] 김요한, "방위사업 비리 전방위 조준 합동수사단 출범," SBS News, 2014.11.21.
[710] To have a better understanding of the reverse decision, refer to Jung Hyuk Choi, "Challenges of Institutional Coordination in Complex Defence Acquisition Programs: The Case of the Republic of Korea's F-X Program," *Defence Studies*, Vol. 16, No.1, 2016.
[711] The U.S. State Department refused to authorize the transfer of four core technologies (EOTGP, AESA, IRST, RF Jammer) under the premise of national security concerns. Donald Kirk, "U.S. Tech Rebuff Slams Korea's KFX Fighter," Forbes Asia, 16 October, 2015.
[712] 최혜정 손원제 이제훈, "KFX '기술이전 불가' 보고받고도 강행…주철기·김관진 책임론," 한겨레, 2015.10.7.

plummeting its approval ratings. The media at this point started to highlight the Navy's attempted deployment of a salvage/rescue ship named the ATS-31 Tongyeong to the disaster scene of the Sewol Ferry. Eventually, the Navy had to cancel the deployment because the vessel was grounded because of a number of performance deficiencies identified in the development and introductory phase. The media portrayed the substandard performance of the Hull Mounted Sonar (HMS) and Remotely Operated Underwater Vehicle (ROV) caused the sudden cancelation of the ATS-31 Tongyeong's dispatch mission.[713] Government actions came in pursuit of the media coverage and arrested the top defense acquisition officials responsible for the sonar and vehicle procurement of the Tongyeong. The incumbent Chief of Naval Operations, Admiral Hwang Ki Cheol, was arrested for professional malpractice and government document forgery the following year as he was held accountable for signing the HMS contract while serving as the Director General of Navy Ship Programs at DAPA. Eventually, most of these allegations charged against defense acquisition officials and defense firms during the past decade turned out to be inordinate investigations, in which most of the accused suspects were acquitted in court against the indictment raised by the prosecutors. The representative case was the court decision over Admiral Hwang Ki Cheol on the ATS-31 Tongyeong case, which ruled the former Chief of Naval Operations innocent from all charges pressed on him. Other cases that filed similar accusations against weapons brokers or defense firms were also ruled not guilty, and discharged from all prosecutions.[714] The allegations filed against the program managers of the AW-159 Wildcat Maritime Operation Helicopter Program (MOH) were also ruled innocent and acquitted from all charges by the court. The indictment of the MOH program was in fact considered the biggest achievement case for the district attorneys and was celebrated with high recognition, but the acquittal ruling afterwards casted the prosecutors in the Joint Investigation Department into public shame.[715] The majority of these indictments and investigations over defense contracts and defense firms contained false allegations, but were fully executed anyway by the authorities, augmented with media publicity, in order to attract public attention and achieve higher approval ratings for the incumbent administration. As a representative case over these false indictments, the court ruled 'not guilty' in October 2017 over the BAI audit reports that claimed KAI gathered undue profits of KRW 54.7 billion throughout the Surion Korea Utility Helicopter Program. The judgement ruled the BAI audit did not reflect the accurate clauses of the program contract awarded to KAI, which complied with the terms highlighted in the indemnification of development costs.[716] Most of the cases against domestic defense firms, if not all, did not have a particular intent to overhaul and improve the defense industry or the comprehensive defense acquisition process, thus lacked a clear policy objective leaving aside a coherent reform agenda. The investigations

[713] ATS-31 Tongyeong later proved to have qualified all phases of Test & Evaluation, however, was not the suited vessel that could've salvaged the sinking Sewol Ferry at the point. 유영식, "통영함이 세월호를 구조하지 못한 진짜 이유," 월간조선, 2015 년 1 월.

[714] 송원형, "검찰 내 모범생 방위사업비리 합수단, 요즘 체면이 말이 아니라는데," 조선일보, 2015.11.18.

[715] 문상현, "방산비리 합수단 성과 뻥튀기 후 논공행상 벌였다," 일요신문 제 1287 호, 2017.1.8.

[716] 안상희, "법원 2015 년 KAI 547 억원 부당이득 감사원 감사결과 잘못돼," 조선일보, 2017.10.23.

in fact had a specific destination towards excavating potential slush funds secretly delivered to political opponents in the process of concluding defense contracts.[717]

However, there is no doubt that these investigations had grave impacts on the domestic defense industry. The political pressure squeezing in from all directions towards the defense industry, associated with restrictively diminishing defense expenses for domestic development programs, resulted in reduced productions and financial difficulties of local defense firms.[718] Because of the repressive investigations by the prosecuting authorities, multiple suicidal incidents arose from domestic defense firms, including the CEO of LIG Nex1 who took his life after returning from investigation, and the Senior Executive Vice President of KAI over a similar motivation.[719] Such results proved the accusations built around domestic defense firms were groundless, but the sheer size and magnitude of the state-led investigations also show another ill-fated dimension of political intents that are conducted with a mere purpose of saving face for popular votes, while not necessarily arranged for effectively implementing reform agendas or streamlining the defense business.

6.4. Chapter Conclusion

In regards to the multitude of aircraft development opportunities that emerged throughout the three decades, the government's aspiration to upgrade the country's technological competitiveness level and the industry's desire to diversify into high tech business sectors created a strong consensus to promote the aircraft manufacturing business as a key area to expand the industrial boundaries of the country. Various high profiled institutions and regulations were created by the government in support of building a competitive aircraft manufacturing sector. Unfortunately, these strong motivations did not sufficiently translate into success stories.

The decision to lower entry barriers of the aircraft manufacturing sector with the purpose of introducing competition for enhancing competencies over a finite domestic market share resulted in a cutthroat competitive situation amongst major domestic players, but with infrequent government mitigation efforts. Unlike previous cases where the government effectively managed and coordinated the prospects of industrial development, the aircraft manufacturing sector was far more complex that involved substantial challenges in technology, program management, global competition structure, proprietary rights, international security, and so forth.

Insufficient government oversight and control over industrial competition policies consequently deteriorated sectoral competitiveness in both technological and financial capacities. Government control in defense R&D, without constructing an effective technology transfer and diffusion mechanism into the commercial market, has marginalized sectoral technology refinement and

[717] Prosecutions mostly strived to solicit evidence of defense firms attempting to bribe politicians from the opposition parties. 김종대, "정권에 등 돌리는 방위산업체, 중소 협력업체들의 들끓는 분노," D&D Focus, 2010 년 8 월호.
[718] 김종대, "비리 수사 폭격 맞은 방산업계," 시사저널, 2010.8.10.
[719] Suicidal incidents also included defense contractors conducting research in the process of developing indigenous systems, 박지윤, "검찰수사 받던 방산업체 전 사장 자살," 매일경제, 2010.6.10.

engineering competencies in the commercial subdivisions of the aircraft manufacturing sector. In order to comply with key program milestones of government awarded weapon system contracts, the companies had to rely heavily on foreign technological resources, which had contributed limitedly on building domestic technological capacities. Indecisiveness and frequent changes on the planning and programming of major defense acquisition programs in aircraft development placed higher risks and uncertainties in the defense industrial sectors of aircraft manufacturing. In this regard, the sectoral players had limited opportunities to accumulate critical knowledge and experiences, which is indispensable in building program management capacities for complex product systems. The disconnect between the technology development hierarchies of the public sector and commercial manufacturing apparatus of the private sector has obstructed the fluent evolution of the aircraft manufacturing business into becoming a robust technological field of the economy.

Whatsoever, the government continues to launch prospective opportunities for the aircraft-manufacturing sector with hopefuls of inducing sectoral development and innovation. The following two chapters are case studies in this regard that represents recent events of the Korean Government and industry to build an indigenous R&D and production capability in the domains of fixed-wing and rotor-wing.

Chapter 7. Case Studies: The T-50 Supersonic Advanced Trainer Program

7.1. Sources of Capacity Building in the Fixed Wing Sector – From Tiger II to Fighting Falcon

Under the banner of self-reliant defense of the country, the strong push to indigenously manufacture combat fighters originated in 1974 after the declaration of the Nixon Doctrine, ensued by the simmering possibility of U.S. military retrenchment from the Korean Peninsula in 1977. As of 2018, despite the launching of the KF-5E/F Tiger II local assembly program in 1979, the country still does not own a combat aircraft of its own design even after forty years of commitment into the aircraft-manufacturing business. This chapter reviews the fluctuations of combat aircraft development, the sources of knowledge accumulation and technology diffusion, and the systems of innovation within the development efforts of combat aircrafts. It reviews three major military aircraft programs, with a focus on the development process of the T-50 Golden Eagle Supersonic Trainer.

Introduction of military aircraft programs experienced a number of opportunities and challenges for both military and commercial entities in the recent history of force build-up efforts. The fixed wing sector went through the traditional phased evolution of aircraft-manufacturing; following depot maintenance – license manufacturing (KF-16 Fighting Falcon) – co-development (T-50 Advanced Supersonic Trainer) – indigenous development (KF-X in progress). Although a turboprop aircraft and not a jet fighter, the KT-1 Woongbi is also a platform developed and deployed under indigenous efforts. This chapter surveys the progress and achievements made in the fixed-wing sector, with a priority focus on the T-50 Golden Eagle Program.

Period	Program	Lead Agency	Program Type	Proprietary Rights	Modification Rights
1981-1986	KF-5E/F	Korean Air (Corporate)	License Manufacturing (Northrop)	None (constrained under export control regime)	Partial authorizations to overhaul
1988-1999	KT-1	ADD (Government)	Indigenous (Daewoo Heavy Industries)	Obtained	Capable of overhaul and modification
1984-2006	KF-16	Samsung Aerospace (Corporate)	License Manufacturing (General Dynamics /Lockheed Martin)	None (constrained under export control regime)	Partial authorizations to overhaul
1989-2005	T-50	KAI (Corporate)	Cooperative Development (Lockheed Martin)	Limited (constrained under export control regime)	Requires approval by foreign entity (USG/Lockheed Martin)

Table 50. Major Aircraft Development Programs (Fixed Wing)

7.1.1. KF-5E/F Tiger II Jegong-ho Program

The need to build industrial infrastructures for an aircraft manufacturing base emerged in the mid-1970s in consideration of the country's impending national security concerns and economic development needs. The end of the Vietnam War, the cessation of U.S. military aid programs, and the materializing risks of a possible U.S. military withdrawal from the Korean Peninsula alerted the urgency to build a military readiness posture sufficient for self-reliant defense of the country. The surrounding circumstances instigated the need to indigenously develop military aircrafts until the early 1980s.

The first plan to introduce an indigenously manufactured fighter capability derived from a September 1979 Government Committee that identified the development requirements and industrial support to locally assembly a high-tech combat aircraft, which designated the Northrop F-5E/F as the potential program model. The F-5E/F model was already deployed for operations in the Air Force. The government was considering to introduce further more variants with a local assembly license to build domestic industrial capacities and infrastructure. In support of the KF-5E/F local assembly, the government legislated the Aircraft Industry Promotion Act to institutionally establish the technological support system in R&D, manufacturing, and project financing, and also transferred the development authorities from the Ministry of Transportation to the Ministry of Commerce and Industry in order to address the strong willingness to bolster the domestic aircraft industry. On October of 1979, during the 12th Annual Security Consultative Meeting between the defense ministers of Korea and United States, both parties agreed to proceed with joint efforts to co-assemble F-5E and F-5F jet fighters.[720] This agreement made possible the local assembly of 68 F-5 jet fighters by Korean Air with a net value worth of USD 140 million under full US government technology assistance provided through a hybrid business package composed of commercial purchases and Foreign Military Sales offerings.[721] At the time being, the Korean Government demanded the localization of the highly advanced F-16 Fighter, but the U.S. Government refused in concern of maintaining its decisive military edge as well as its technological competitiveness over other countries.[722] Korean Air was handpicked by the government as the prime contractor of the KF-5E/F program, and entered into negotiations with Northrop over the terms and conditions of the local assembly work. After the Korean and U.S. Governments signed the Memorandum of Understanding for the local assembly of the aircraft in October 1980, Korean Air finalized the contract with Northrop for license manufacturing of the aircraft the following month. The engine contract was awarded to Samsung Precision Industries (later Samsung Aerospace) under a manufacturing license with General Electric for the local production of the J85-GE-21A turbojet engine system. The local assembly of the KF-5E/F culminated with a component localization rate of 23% throughout the production of the aircraft between 1981 and 1986.[723]

Because at the time the domestic industry lacked the industrial foundations required for airframe production and precision equipment, the government invested about 56% in financial support for building the initial infrastructure, whereas the remaining 44% finances came from Korean Air and its subcontractors. The government commitment to the program was shared by cabinet industrial agencies (17% by the Ministry of Commerce and Industry) and the military (39% by the Air Force),

[720] Joint Communique of the Twelfth Annual US-ROK Security Consultative Meeting, Seoul, 19 October 1979.
[721] The joint venture with Northrop included co-assembly of 36 airframes for F-5E and 32 airframes in addition to jet engines for F-5F fighters, 조중훈, “항공운송사업의 역할과 발전,” 군사논단 제9호, 1997, p. 281
[722] Jane E. Nolan, Military Industry in Taiwan and South Korea, Macmillan Press, 1986, p. 72.
[723] 공군본부, 항공산업 육성방안 연구, 1984, p. 52.

with a total infrastructure investment of USD 35.65 million. The local industry's proportion into building the infrastructure accounted for about USD 28.7 million shared between Korean Air and Samsung Precision Industries. The entire program budget of the KF-5E/F reached nearly USD 684 million, with about USD 584.4 million spent to overseas sources. The program cost for domestic development was comparably 20% higher than a direct purchase option from Northrop. But the annual direct employment of 800 jobs in high tech engineering, the acquisition of advanced technologies by manufacturing airframes and engines, automated ignition devices, broach machines, and the opportunity to collaborate with global aerospace contenders such as Northrop and GE, indefinitely presented the local industry with precious experience as starter in this high tech sector.[724]

In the nascent stages of aircraft manufacturing, the KF-5E/F was a conduit of technical education for the domestic industry. Throughout the phases in license production of the airframe and turbojet engine, the domestic aircraft-manufacturing sector acquired essential knowledge and technical experience in production/quality/material management, and obtained the opportunity to go through a focused overseas training program for 66 engineers in specialized areas of system assembly, flight performance test, chemical milling, honey comb production, to name a few. The learning and production experiences enhanced the interpretation of design, technical data, engineering procedures, and the production of precision machine tools. Especially for Samsung Aerospace, possessing basic knowledge and skills for producing precision machine tools enabled further production of more sophisticated aircraft engine components, which ruminates as an indispensable instrument to expand the manufacturing capability in this sector. Based on these experiences, Korean Air and Samsung Aerospace were able to win follow-up contracts as a regional maintenance and repair firm with the U.S. military for its F-16 Fighters and with Saudi Arabia for its C-130 Transporters.[725] Thus, the KF-5E/F local assembly upgraded the technical standing of the local aircraft-manufacturing sector, from a maintenance and repair level to a system assembly standard.

However, the decision to co-assemble the F-5E/F aircraft under license did not further translate into building larger capacities for the domestic aircraft-manufacturing sector because of discontinuities into subsequent development programs. Korean Air was not awarded further contracts from the government in manufacturing fixed-wing products, at which the contract awards for succeeding programs were given to other competing firms such as Daewoo Heavy Industries or Samsung Aerospace. Opposed to the initial idea of following up with a subsequent aircraft manufacturing program, the next aircraft program did not materialize until 1991 when the military decided to introduce the F-16 fighter under license production. Samsung Aerospace, a late comer in the sector, won the contract, in which Korean Air and Daewoo participated as component manufacturers in the program.[726] As a result, Korean Air was forced to absorb substantial business losses from the KF-5E/F, and was compelled to

724 Ibid., pp. 56-57.
725 대한항공, 대한항공 20 년사, 1989, p. 278.
726 조황희, 항공기 산업의 기술혁신 패턴과 전개방향, 정책연구 99-38, 과학기술정책연구원, 2000, p.

shut down the production line shortly after the conclusion of the program.[727]

7.1.2. KT-1 Basic Trainer Program

Although a different variant from combat jet fighters, the Agency of Defense Development (ADD) at the time has been vying to launch an aircraft program of its own initiative by attempting to build a basic trainer aircraft. Since 1977, ADD has been developing an experimental unmanned aerial vehicle (UAV), project name 'Solgae' (*Kite*), which completed its first test, flight in 1981. Under technology assistance from Cranfield University's aeronautical engineering department, ADD engineers acquired the knowledge for baseline design and development processes to build the initial configuration of the UAV. In order to fully test the aerodynamics of the airframe, in May 1979, ADD started building instruments capable of examining supersonic wind tunnels and trisonic wind tunnel effects. The airframe and guidance devices were built by ADD whereas the propulsion system was co-developed by ADD and British aeronautical engineers from Cranfield University. However, the project did not materialize into a formal program because the military canceled the Solgae project as an official warfighter requirement.[728] Whatsoever, the Solgae UAV development experience directly assimilated into subsequent aircraft programs within ADD.

Starting from 1983, after the establishment of the Air Domain Laboratory as a result of some organizational reshuffling efforts, ADD researchers surveyed the needs to indigenously develop a basic trainer level turboprop aircraft, on the grounds of building foundational skills and maturing technological readiness levels to develop more advanced combat aircrafts in preparation of ensuing engineering stages. Labeled with a project name 'Korea Trainer Experience (KTX-1)', ADD initiated the conceptual refinement process in 1986 for a tandem-seat trainer aircraft powered by a 550 shp engine. The KTX was also given a nickname 'Yeomyeong' meaning 'daybreak' that indicated a new start for the domestic aircraft-manufacturing sector. ADD developed 6 prototypes with this design. However, the Air Force preferred to own a basic trainer that can perform extended missions as a light attacker and forward air controller, and therefore rejected the initial KTX-1 Yeomyeong configuration offered by ADD.[729] The Air Force was operating the T-41B and T-37C as its basic and advance trainer aircraft, which was reaching its shelf life, thus considered for replacement. In fact, the Air Force at the time being had in mind the Swiss-made Pilatus PC-9 trainer that can simultaneously conduct trainer and attack/observation functions. In order for the KTX to perform at this level, the aircraft had to go through substantial modifications in its aerodynamics design because it required a more powerful engine that can uphold additional armaments and mission equipment to fulfill the extended mission statements. Modifying the engine propulsion from the previous 550 shaft horsepower (shp) to a performance level 950 shp, and accommodating additional equipment on board implied an entirely new

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727 조중훈, 내가 걸어온 길, 나남, 2006
728 https://blog.naver.com/neobio/220561350037
729 김대영, "수출 1 호 국산 항공기 KT-1 웅비," 유용원의 군사세계, available online at http://bemil.chosun.com/site/data/html_dir/2011/11/02/2011110202111.html.

design for an aircraft. A special task force, resembling that of the Lockheed Martin 'Skunk Works', was organized under ADD to accommodate the engineering alterations to the aircraft. In this regard, the KTX-1 Yeomyeong significantly overhauled its original design, and was reborn in 1988 under a new project name 'KTX-1 Woongbi', with Woongbi meaning 'Great Leap'.[730]

The initial program management structure of the KTX-1, after entering the technology development and maturation phase in 1988, started with a bizarre arrangement between the system developer and component manufacturers. ADD assumed overall responsibility in design and system integration, with Samsung Aerospace producing the forward fuselage and engine, Korean Air (KA) the main body and rear airframe, and Daewoo Heavy Industries (DHI) the main wing and tail wing of the aircraft, thus without designating a prime contractor that would manage the overall development and manufacturing phases of the program.[731] Among the three firms, DHI showed the strongest commitment and enthusiasm in the trainer development project. In January 1989, DHI collaborated with ADD and built a miniaturized wind tunnel that allowed the testing of aerodynamics simulated for measuring the effects of air movement around and through the aircraft.[732] Putting into account of DHI's corporate commitment into aircraft development, ADD teamed up with Daewoo in 1990, and awarded the contract for prototype development and overall responsibility for full scale manufacturing of the aircraft.

At the time of starting the project, the circumstances of aeronautical engineering at Korea were under the worst of all conditions. There existed almost no home grown research base capable of developing an aircraft, nor any infrastructure established to perform adequate test and evaluation on prototypes. In order to mind the gaps in technology standards, the KTX-1 development department from ADD signed a three-year technology advisory contract with Pilatus Aircraft of Switzerland. Based on this arrangement, ADD dispatched a team of researchers to the Pilatus facility at Swiss to learn the conceptual design technology for a basic trainer. It was in fact Pilatus who reached out first to ADD after learning the agency's ambition to develop a trainer aircraft. But the intent of the Swiss aircraft manufacturer was not merely on assisting a local trainer development project, but to expand new business opportunities in Korea. In this regard, Pilatus exhibited a restrictive attitude with disclosing cutting edge technology to ADD researchers. In some instances, Pilatus prohibited ADD researchers from bringing rulers in the design chamber to prevent potential disclosures of detailed measurements. ADD researchers had to improvise by using cigar boxes to make rough measurements throughout this duration.[733] With no surprise, the PC-7 and PC-9 trainers of Pilatus Aircraft later became a top competitor against the KTX-1 in the international market for basic trainer aircrafts.[734] The KTX project

730 신인호, "국산 무기개발 비화 KT-1," 국방일보, 2002.1.3.
731 매일경제, "훈련기 국산화 착수," 1988.12.02.
732 매일경제, "대우중 항공기 생산설계 필수기술 풍동 시험용 훈련기 모델 개발," 1989.1.12.
733 조한대, "당신의 역사: 박정희 지시로 쥐도 새도 가족도 몰랐던 미사일 개발," 중앙일보, 2015.1.28.
734 Dylan Malyasov, "Pilatus Aircraft completes delivery of 75 trainers to Indian Air Force," Defense Blog, 13 November, 2015.

was formally named the First Korean Trainer (KT-1) as the program milestones neared the end of the engineering and manufacturing development phase, and qualified all performance standards defined by the Air Force in November 1998.

The KT-1 has become a Korean bestselling aircraft as the trainer vehicle was offered to multiple foreign customers around the world. The significance of the KT-1 comes from the fact that it became the first aircraft designed and engineered through indigenous efforts. Despite the glorious national pride glittering over the first indigenously designed aircraft, KT-1 still had to consider international export control restrictions for its export models as some of the major components fell under U.S. technology security constraints. The first export case of the KT-1 occurred in 2003 when Indonesia decided to purchase 7 trainers from KAI. This case turned out to be a complex process that involved both diplomatic maneuvers as well as business promotional deals to resolve the restrictive limits of international technology security and control measures. The challenge with the Indonesian export was the fact that some of the major components fell under the U.S. arms embargo list against Muslim countries, in accordance with the Global War on Terrorism. The components subject to U.S. export license approval were precision devices such as air conditioners, brakes, and some avionics related parts. However, the United States also exerted efforts to build an international network of partnerships to effectively cope against rising terrorist cells in Southeast Asia. In this regard, cooperation with Indonesia was imperative. At the moment, Korean diplomats successfully negotiated with both Jakarta and Washington D.C. to include the export approval of the constrained items under license review as a Presidential Summit Meeting agenda.[735] Although the issue was miraculously solved, further innovation opportunities could not afford to rely on sheer luck factors any longer.

Purchaser	Type	Aircrafts	Program Value	Year	Remarks
Korea	KT-1	85	USD 400 million	1988 – 1999	Airworthiness Certified
	KA-1	20	USD 11 million	1999 – 2007	
Turkey	KT-1T	40	USD 350 million	2007 – 2013	Type Certified
		15	In progress	N/A	N/A
Indonesia	KT-1B	7	USD 32.9 million	2003	No Certification
		5	USD 23 million	2007	
		5	USD 35.5 million	2008	
Peru	KT-1P	10	USD 200 million	2012 – 2016	Type Certified
	KA-1P	10			
Senegal	In progress	4	In progress	N/A	N/A

Table 51. KT-1 Woongbi Manufacturing and Export Records as of 2018

Following the successful development of the KT-1 Woongbi, the aircraft further evolved into a light-attack and forward air control variant with a project name XKO-1. In April 1999, the XKO-1 project was formally initiated as a support aircraft that complements fighter jets in air-to-ground attack missions. The airframe remained identical to the KT-1, but the armaments and avionics have substantially transformed the internal design and system connectivity from the original design. The subtle change in the exterior showed two pylon ejectors attached underneath both sides of the wings

735 이재명, “KTX-1 연구개발,” 항공우주, 제 4 권 2 호, 2010, p. 25.

that loaded additional composite fuel tanks, and the installation of a launcher and gun pod to mount additional armaments. However, the avionics that supported the additional armaments and GPS guided inertial systems with advanced communication antennas, and pilot-assisting Night Vision Imaging Systems (NVIS) all represented substantial changes from the original baseline design. Additionally, the Head-up Displays built in as an advanced control panel, and Multifunctional Displays introduced for accurate navigation also improved aircraft performance as a light-attacker.[736] Referring to the serious system design and manufacturing gaps that frequently occurred throughout the KT-1 development phases, the earlier engineering interferences were mostly resolved during the XKO-1 program. This was attributed to the program experiences accumulated from the previous development efforts, which directly channeled into the XKO-1 program.[737]

A representative component localization effort of the XKO-1 development considered the power package of the aircraft's hydraulic system. Initially, because of the domestic technological standards fell short of fully localizing the power package, the KT-1 project adopted the component from a British hydraulic system. However, because of the technological sensitivities, the British firm refused to further hand down the core technology required for localizing the component. The localization of the unit involved precision manufacturing and advanced test and evaluation processes, which necessitated collaboration with a forerunner in this field. In face against the impending limitations, the system developer ADD and prototype manufacturer Hanwha Corporation conducted a thorough analysis of the power package applied into one of the KT-1 aircrafts, reviewed the improvement processes of the unit that occurred during the operational periods, and derived the technical standards expected for localization. After overcoming component integration efforts reflected in the preliminary and critical design phases, the inexperience in test and evaluation phases regarding durability testing and high/low temperature fatigue testing presented extra challenges to the project. It was only after the resolution of these aspects, as a result of the tenacious collaboration between the development entities, where the power package became fully localized for domestic manufacturing.[738] In October 2005, after the successful completion of all development milestones, the Joint Chiefs of Staff formally assessed the aircraft's performance acceptable for combat missions, and presented an official name to the project the 'KA-1' light-attack and forward air control aircraft.

Despite the successful development of the KT-1 trainer, the program demonstrated a sense of frustration in state led program management. The process of contractor selection showed redundancy and overlap with other government initiated S&T programs, which caused unnecessary competition among the three major aircraft-manufacturing firms. Around the late 1980s and early 1990s, Korean Air already initiated the development of a four-seat single-engine light monoplane named Chang-Gong

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736 "Directory: military aircraft," *Flight Global*, 25 May, 2004.

737 신인호, "철모에서 미사일까지: 공군 저속통제기 KO-1," 국방일보, 2004.11.2.

738 박종철 외, "AMESim 을 이용한 KT-1 유압시스템의 동력패키지 시스템 선택밸브 동특성에 관한 연구," 한국항공우주학회 추계학술대회, 2011, p. 993.

91, which was awarded under a government led development project programmed by the Ministry of Science and Technology. Three prototypes were developed where the monoplanes successfully conducted its maiden flight in November 1991.[739] Chang-Gong 91 went through a one year technical inspection and 80-hours of test flight, and became the first indigenously developed aircraft to have received an airworthiness certification by the Ministry of Land and Transportation in September 1993. The prospects of international sales also marked meaningful possibilities after some Southeast Asian and Latin American countries expressed interest in purchasing the aircraft. Unfortunately, the export opportunities did not materialize into commercial sales after the Chang-Gong 91 project failed to obtain a bilateral airworthiness certification from the U.S. Federal Aviation Administration.[740] Although Chang-Gong 91 was a commercial commuter project launched by the national S&T authorities, a more intimate cross talk between the commercial and military authorities could've avoided any redundancy in resources and overlaps in development efforts. Korea Air had accumulated experiences from the KF-5E/F license assembly as well as helicopter manufacturing. Nonetheless, government policies dismissed the idea of building concentrated capacities over a firm with an established record of aircraft development, and instead awarded a new contract to a relatively new comer in the sector, Daewoo Heavy Industries. As the Chang-Gong 91 did not materialize into a formal commercial commodity, Korean Air exited the fixed wing development efforts for good, and the accumulated technology and experience of the firm's twenty year efforts did not further evolve into higher standards.

7.1.3. Korea Fighter Program (KFP): The KF-16 Fighting Falcon Multirole Fighter

In the late 1970s, the Korean Armed Forces confronted growing challenges in the conventional military balance between Seoul and Pyeongyang. Especially, the new introduction of MiG-29 Fighters in the North Korean People's Air Force, and the aging of the early F-4 and F-5 variants generated the need to introduce advanced multi-role fighters that perform air superiority missions. In a parallel domain, the industrial authorities developed strong motivations of constructing a self-reliant defense posture supported by a sound defense industrial base. Hence, driven by these two initiatives, the defense and industrial authorities were instigated to pursue a concurrent strategy of building military capabilities and industrial capacities simultaneously. In this regard, the defense authorities intended to introduce F-16 fighters, which was considered the most advanced fighter aircraft at the time being.

The total purchase of 180 F-16 fighters took place in three different stages. The first stage was a direct purchase from the U.S. Government through Foreign Military Sales, at which the Korean Government introduced forty F-16C/D Block-32 fighters from General Dynamics, dubbed Peace Bridge I, under a direct purchase contract in 1981. The second stage was a mix of direct purchase and in-country manufacturing in a slightly upgraded version (Block-52), at which twelve aircrafts were directly purchased from General Dynamics, with an additional 36 aircrafts introduced through licensed

[739] Michael J.H. Taylor, Brassey's World Aircraft & Systems Directory, Brassey's (London), 1996, p. 408.
[740] 매일경제 "국산 경비행기 창공 91 호 형식승인," 1993.9.3.

assembly work under a manufacturing partnership established between Samsung Aerospace and General Dynamics in 1991. The remaining 72 aircrafts were produced under license by Samsung Aerospace, which later merged into the Korea Aerospace Industries (KAI) in 1999, with the final aircraft delivered to the Korean Air Force in 2000. The third phase was an extended license production of an additional twenty aircrafts for the purpose of sustaining the production lines of the aircraft-manufacturing sector, and was concluded in July 2003.[741]

<table>
<tr><th>Program</th><th>Model</th><th>Block</th><th>Direct Purchase</th><th>Assembly</th><th>Co-Production</th><th>Quantity</th><th>Delivered</th></tr>
<tr><td rowspan="2">Peace Bridge I</td><td>F-16C</td><td>Block 32</td><td rowspan="2">40</td><td>-</td><td>-</td><td>30</td><td rowspan="2">1986-1992</td></tr>
<tr><td>F-16D</td><td>Block 32</td><td>-</td><td>-</td><td>10</td></tr>
<tr><td rowspan="2">Peace Bridge II
(KFP-I)</td><td>F-16C</td><td>Block 52</td><td rowspan="2">12</td><td rowspan="2">36</td><td rowspan="2">72</td><td rowspan="2">80
40</td><td rowspan="2">1994-2000</td></tr>
<tr><td>F-16D</td><td>Block 52</td></tr>
<tr><td rowspan="2">Peace Bridge III
(KFP-II)</td><td>F-16C</td><td>Block 52</td><td>-</td><td>-</td><td rowspan="2">20</td><td rowspan="2">15
5</td><td rowspan="2">2002-2004</td></tr>
<tr><td>F-16D</td><td>Block 52</td><td>-</td><td>-</td></tr>
</table>

Table 52. F-16 Fighter Programs by Deployment Phases

Since the designation of the aircraft-manufacturing sector as a strategically focused high priority industry in the early 1980s, defense offsets were considered as the principle conduit for technology transfers in the process of nurturing domestic industrial capacities. Defense offsets from the F-16 program were arranged in two phases. The first arrangement was offered from the Peace Bridge I program after signing the contract under Foreign Military Sales with the U.S. Government in 1983. In March the following year, the prime contractor of the Peace Bridge I Program, General Dynamics, responded with a defense offset package worth USD 8 million in business value that included the local production of the forward and center fuselage, inverted stabilizer, and related manufacturing technology. The offset package was handled by the Ministry of Commerce and Industry, which solicited applications from four domestic firms willing to enter the aircraft-manufacturing business – Daewoo Heavy Industries, Korean Air, Korea Heavy Industries, and Daedong Heavy Industries. The local firms had to invest in building the essential manufacturing infrastructure in order to accept the offers from the defense offsets. However, the investment cost associated with building the essential infrastructure such as in constructing facilities, purchasing production lines, recruiting and training engineers, etc., grossed approximately USD 30 million, all for a mere amount of USD 8 million worth of offsets. The applicants asked for government support in the form of subsidies, but the authorities denied the request for reasons of imposing a fiscal austerity policy at the time being due to the ailing economic situation. In early 1984, three companies eventually turned down their application, but Daewoo Heavy Industries remained in the competition and received the final offer for the offset deal.[742]

Further aggravating to this situation, however, General Dynamics demanded an additional cost of USD 6 million under the title of 'In Country Support Fees' that covers travel and logistic support in providing technology assistance and training for Daewoo engineers and program managers participating

741 한국경제 2001. 10. 15, 서울에어쇼 2001: 주요 참가업체 – 록히드 마틴…20 개국 수출
742 김종하, "방위력 개선사업과 무기획득정책 평가," 군사논단 제 12 호, 1997, pp. 103-105.

in the offset deal. The defense acquisition authorities managed to mitigate the cost down to USD 4.4 million, but Daewoo still had to share USD 1.9 million.[743] At the time being, Daewoo had a strong motivation to enter the aircraft-manufacturing sector as part of its corporate diversification strategy of expanding into other business opportunities. Daewoo has already showed sincere commitment in the sector by preparing new investments for building technological infrastructure in aeronautics required for the KTX-1 basic trainer program at the time. The top management at Daewoo had high expectations in the aerospace and defense sector as a new business area, especially foresaw the emerging opportunities in the upcoming F-16 program that would add a new strategic business branch into its aircraft-manufacturing portfolio once the company successfully lands on an exclusive contract deal with the government. In this regard, Daewoo Heavy Industries decided to take the inherent risks of the F-16 offset deal with General Dynamics, and therefore committed substantial corporate resources with a long-term objective of being selected by the government as a prime contractor for the second phase Peace Bridge II co-production program. General Dynamics also reduced the high demands in cost sharing, in anticipation of winning subsequent defense contracts from the Korean Government that would follow the Peace Bridge I Program.[744]

In order to forge an enhanced airpower structure that counters the mediocrities of Korea's conventional military balance against North Korea, the Air Force generated new force requirements mindful of an advance fighter capability, reflected in a 1985 report to the President by the Air Force Chief of Staff titled "Developing Domestic Aircraft Industrial Capacities through KFP (Korea Fighter Program: Second Phase Peace Bridge) Co-Production". The report highlighted the need to upgrade technological foundations and manufacturing competencies in order to reach a true self-reliant level of defending the nation and promoting industrial competitiveness.[745] The ad-hoc Aircraft Industry Promotion Committee was established in 1985 as an interagency coordination forum between the military and industrial authorities within the cabinet to plan and discuss the detailed strategy for building both military capabilities and industrial capacities in the aircraft manufacturing domain. Despite the comparatively expensive price tag associated with license production against a direct-of-the-shelf purchase, the Committee set the acquisition strategy of the program as a commercial license production program with limited elements of Foreign Military Sales in order to reap out the most optimal benefits from the program.[746] The second phase Peace Bridge was a competition between the General Dynamics F-16 and McDonnell Douglas F/A-18, at which the Air Force and Aircraft Industry Promotion Committee's initial F/A-18 selection in 1989 was rejected in 1991 over the F-16 by the Presidential

743 Ibid., p. 107.

744 The second phase Peace Bridge II (KFP) accounted for the production of more than 120 F-16C/D fighters; Francois Texier, *Industrial Diversification and Innovation: An International Study of the Aerospace Industry*, Edward Elgar, 2000, pp. 140-143.

745 류화선, "한국 군수항공산업 각축의 내막," 신동아, 1989 년 5 월호.

746 Cost embedded under license production arrangements include proprietary rights and royalty, building additional infrastructure, technical assistance, license purchases, lower economies of scale, and so forth.

Office.[747] In this regard, after a turbulent type selection process between the Air Force and primary defense authorities from the Presidential Office, the license production of the F-16C/D was finally selected for the second phase Peace Bridge program in March 1991, at which the program officially changed its title to the Korea Fighter Program (KFP).[748]

As though a prelude to the surprise selection of the F-16 over the F/A-18, to the dismay of all aircraft-manufacturing firms, especially for Daewoo Heavy Industries, the defense acquisition authorities selected Samsung Aerospace as the prime contractor of the Korea Fighter Program (KFP) in October 1986. The selection of Samsung over Daewoo raised a series of public criticism almost equal to the debate over aircraft type selection. As mentioned in previous sections of this chapter, Daewoo Heavy Industries has shown a strong commitment in entering the aircraft-manufacturing sector by risking substantial upfront costs in infrastructure investments in order to build initial manufacturing capacities during the Peace Bridge I defense offset arrangements. The firm also further invested into building foundational skills and knowledge by participating in the KT-1 Woongbi Basic Trainer program at the same time of working itself to win the KFP contract. A comparison of the three contemporary major aircraft-manufacturing firms shows that Korean Air tops the three while Daewoo lags behind in all aspects of the company's performance; short history, investments, employees, experience, and so forth. Whatsoever, the rapid capacity building efforts within a relatively shorter period than its peers encapsulated the company's strong commitment into this sector, support by its corporate strength demonstrated in other business sectors such as finance, machinery and tools, electronics, and so forth. In this respect, in September 1986, the working group's survey of the Aircraft Industry Promotion Committee recommended Daewoo Heavy Industries as the prime contractor for the KFP. However, the Presidential Office rejected the recommendation and directed to reexamine the survey process. Putting into account the fluctuating political variables altogether, the Committee immediately turned around its initial assessment, disqualified Daewoo Heavy Industries, and selected Samsung Aerospace as the prime contractor over the KFP program the following month.[749]

The collusion between state and business has taken place at this juncture over contract awards. Formally established institutions and regulatory procedures were overrun by political manipulation. Although Daewoo was assessed with the highest grades by the Committee, its lead was merely within a small margin against it competitors. Reportedly, a week before the announcement of the final contract to Daewoo, the Chairman of Samsung Group had a secret gathering with senior officials at the Presidential Office, most likely the President himself. The general knowledge tells that it was through this intersection how the decision for the KFP contractor selection was overturned in favor to Samsung.

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747 배영일, 한국전투기사업의 정책결정, 한국학술정보㈜, 2012, pp. 141-144.

748 There's been much criticism over the sudden turnaround of the KFP initial decision by the Presidential Office that relates to illicit collusion and a possible corruption scandal involving political slush funds for the incumbent administration. 김종대, "대한민국 차세대 전투기 사업 잔혹사: 한반도 안정 위협하는 죽음의 상인들," 민족 21, 제 106 호, 2010, pp. 102-105.

749 배영일, pp. 110-117.

At the time, Mr. Lee, Byeong Cheol, the Chairman of Samsung Group, had his eyes on the developments of Japan's aerospace industry, revealed by the FSX Program in collaboration with the United States. Through this effort, Samsung has abandoned the earlier reluctance to commit itself into the defense business, and started actively investing into the newly emerging aircraft-manufacturing sector.[750]

Leaving behind the stormy type selection and contractor award process, the KFP returned to its initial track, which was to serve in building both military capacities and technology competitiveness. In order to achieve this goal, the program authorities had to exert efforts to obtain technology transfers and reach certain localization rates in component production as much as possible.

Section	Primary Contractors and Subcontractors	Localization (%)
Engine	Samsung Aerospace	44
Avionics	Goldstar Precision, Goldstar Electric, Daewoo Electronics, Samsung Semiconductors and Communications, Ewha Electric, Jeil Precision, Hyundai Electronics, Daeyoung Electronics, AFCOA Korea, Litton Korea	34
Fuselage/ Machinery	KIA Machine & Engineering, Daewoo Heavy Industries, Korean Air, Dongmyeong Heavy Industries, Rocket Electric, Tongil Heavy Industries, Korea Fiber, Hyosung Heavy Industries	Fuselage: 61 Machinery: 52
Material	Samseon Engineering, Oriental, Korea Fiber	-

Table 53. KFP Contractors and Component Localization Rates
Source: Samsung Aerospace 20 Years, 1997, p. 402.

U.S. Technology Provision and Restrictions over the KFP

The KFP was subject for public scrutiny in the U.S. Congress, not only because the program fell under Section 36 of the Arms Export Control Act, but because of the growing concerns of providing assistance to a potential contender in a time of diminishing U.S. economic dominance. Aerospace was one of the very few remaining industrial fields where the U.S. continued to maintain competitive advantage against other competing entities worldwide. The concerns of eroding such leverage in the business sector were raising skepticism within the political constituencies over the effectiveness of U.S. security cooperation and conventional arms transfer policies. Most of the concern over the KFP within the U.S. Congress placed tremendous weight on the possibility of nurturing the technological capacities of an emerging aerospace contender at the expense of deteriorating the competitiveness of its own industry. The U.S. Congress rigorously scrutinized the program and identified the number of deficiencies resulting from poor interagency coordination between the Department of Defense and Department of Commerce for not factoring in the impact of technology transfers with the effects to the local American economy. Government oversight on export control measures regarding technology transfers and component manufacturing workshare was inadequate in the course of crafting the KFP contract between Korean defense acquisition authorities and General Dynamics. With the full acknowledgement of Korea's ambitions to enter the global aerospace market, U.S. Congress was baffled over the idea that the crucial elements of capacity building derived from American sources. Thus, Congress was urging the need to consider a direct off-the-shelf program instead of a co-production deal

[750] Francoise Texier, Industrial Diversification and Innovation: An International Study of the Aerospace Industry, Edward Elgar, 2000, pp. 145-147.

for the KFP.[751]

At the time being, the most controversial military co-development program in the aspects of technology security was taking place between the U.S. and Japan regarding the Fighter Support Experience (FS-X) in consideration to Japan's ambitious drive to develop an indigenous but expanded variant based on the F-16 baseline configuration. Although different in scope and substantially lower in developmental magnitudes, the KFP was being scrutinized in parallel with the FS-X program within the U.S. legislative authorities. The challenges presented in the viewpoint of U.S. conventional arms transfer policies was that the KFP and FS-X attracted higher attention on the commercial benefits to Korea and Japan than actual military contributions for American regional alliance politics. The general perspective accepted within the U.S. was that Japan has gained significant technological capacities through the sizable volume of American military and economic assistance, which has become a major threat to the U.S. economy throughout the 80s and 90s. The same logic was being applied to the KFP case where the country has also benefited from large packages of U.S. military assistance in various dimensions of the country's scheme to build-up its force structure and defense industrial base.[752] Nonetheless, the fundamental difference between the KFP and the FS-X lies on the fact that the FS-X involved substantial degrees of transferring system design and development technology, whereas the KFP involved the transfer of production information and know-how in assembly work, which was considered lesser in sophistication compared to the FS-X. Compounding to the situation was the huge lay off of workers by one of the major U.S. aerospace giants, McDonnell Douglas, the year prior to the export decision. McDonnell Douglas announced a plan to cut at least $700 million from its operating budget, which forced over 10,000 employees leaving the company. In a time of shrinking defense budgets, development cost overruns, and struggling commercial aviation products, the company became financially stressed off from the once dominant figure as an aerospace giant from the sector.[753] The substantial business losses, followed by the layoff plans, have raised grave concerns within the U.S. Government and Congress over the country's competitive edge in aerospace.

Consequently, the U.S. Government inhibited the availability of certain technologies for license production and limited the proposed industrial benefits from the initially expected spinoff effects. The KFP originally attempted to purchase three (3) F-16 aircrafts directly off the shelf, twenty (20) aircrafts in kit form as local assembly work, and the remaining ninety-seven (97) aircrafts under domestic license production. In the course of executing this arrangement, the defense authorities insisted General Dynamics to buy back locally manufactured components, not only for the KFP but also for other U.S. government programs as well. The special offset guidelines imposed upfront in soliciting the Request for Proposals for the KFP competition highlighted a minimum of 60% in a preferable form

[751] Joint Hearing before the Subcommittees on Arms Control, International Security and Science, and Asian and Pacific Affairs of the Committee on Foreign Affairs House of Representatives, 102nd Congress, August 1, 1991.
[752] Jack Nunn, Arms Cooperation in the Pacific Basin, in Ethan B. Kapstein ed., Global Arms Production: Policy Dilemmas for the 1990s, University Press of America, 1992, pp. 138-146.
[753] Richard W. Stevenson, "McDonnell Douglas Plans Wide Layoffs and Cost Cuts," The New York Times, June 21, 1990.

to support domestic aerospace industrial development projects. Opposed to the original program requirements drafted by the Korean Government, the U.S. Government viewed license production as a form of defense offsets in itself, which would've exceeded the actual offset value over the given 60% guideline. After the U.S. Department of Defense and Department of Commerce intervened in offset negotiations, the production arrangement and offset thresholds were substantially revised. In the process of examining the KFP arrangements, the U.S. Department of Defense had more coordinative sessions with its counterparts at the Department of Commerce in comparison to Japan's FS-X program. This alludes to the fact of how much scrutiny was given to KFP alone by the U.S. authorities. The U.S. Government returned with an offer to increase the numbers of direct purchase to forty-eight (48) and commercial license production to seventy-two (72). The direct purchase numbers were adjusted to twelve (12) purchases off the shelf and thirty-six (36) local assembly in kit form. Under the direct intervention of the U.S. Secretary of Defense, the offset threshold was adjusted to 30%, while without accounting for license production as defense offsets. The intervention of the highest U.S. defense authority – Secretary of Defense – in a commercial arrangement between a foreign ally nation and a U.S. defense firm was unprecedented, which indicate the level of interest the KFP was under at that point.[754]

Subchapter Conclusion

The domestic efforts of capacity building in military aircrafts experienced a number of successful cases while also confronted multiple stumbling blocks. Often times, political collusions circumvented legitimate decisions made through proper deliberation processes. In that matter, sectoral efforts of capacity building were undermined and in some cases entirely abandoned, which precluded continued efforts for knowledge accumulation and subsequent potentials for innovation. Most of the capacity building processes concentrated on building manufacturing infrastructure and workshop level technicians, while little efforts were committed to R&D and enhancing the sector's technology readiness levels. In this respect, local development programs showed high reliance on foreign parts and technology, especially dependent on American sources. Through the defense offset package, however, the inclusion of providing technology assistance to build an advanced trainer aircraft for the Korean Air Force has set the conditions to improve the prospects of sectoral competitiveness. Further details will be described in the following sections.

7.2. Korea Trainer Experience Second Batch (KTX-2): T-50 Golden Eagle Supersonic Advanced Trainer

The T-50 Advanced Trainer Program is a one of a few supersonic trainer aircrafts in the world that evolved into multiple roles, spanning from advanced trainer (T-50A), aerobatics (T-50B), trainer and

[754] Statement of Joseph E. Kelley, Director of Security and International Relations Issues, General Accounting Office, Before the Subcommittee on Investigations Committee on Armed Services, House of Representatives, April 4, 1990.

light attacker (TA-50), and multirole fighter (FA-50). With a development budget of KRW 2.11 trillion programmed under an eight-year period for development and production, the aircraft was the first indigenously developed fighter, supported through an international strategic alliance arrangement with Lockheed Martin for co-development, and has been extensively marketed to global customers.

The program was one of the very first indigenous aircraft development efforts that went through modern engineering and manufacturing processes, including computer aided design/engineering/manufacturing, integrated systems engineering, test & evaluation, and product life cycle management. For a country like Korea that lacked the experience in designing and building its own aircraft, technology assistance from advanced foreign partners was imperative. The success potentials of this strategic partnership relied on how effectively and efficiently the program authorities, ranging from the program management office to the prime contractor, can acquire the requisite knowledge and skill base for the development program. Absorptive capacity depends on whether the firm obtains prior knowledge and experience on the subject matter program. T-50 was an example of this capacity since it evolved from the KT-1 development and KFP license production experience the country has accumulated from Daewoo Heavy Industries and Samsung Aerospace. The program was a result of these prior efforts, on-top of the multiple technology transfers from British and U.S. sources, and subsequently a co-development effort between KAI and Lockheed Martin. This section will review the motivations, program milestones, and sources of innovation that occurred throughout the development of the T-50 program.

7.2.1. Development Motivations and Objectives

The development motivations were generated from three objectives. 1) Build an advanced trainer aircraft that can perform multirole missions in an evolutionary prospect. 2) Provide opportunities to upgrade the domestic aircraft-manufacturing sector. 3) Strive to build a self-reliant defense capability. The requirement generation process of the T-50 followed an evolutionary sequence that started from an advanced pilot trainer and concluded over a multirole fighter aircraft. Normally, an advanced jet trainer has the potentials to become a tactical light attacker after some additional overhaul works made in avionics and armaments. The force requirement for an advanced trainer originally started in 1989. At the time being, two major aircraft programs were in progress – the KFP F-16 license production and the KT-1 Basic Trainer. In parallel to these development programs, the Air Force raised additional requirements for an advanced trainer that can cover high performance training functions before formally becoming a certified fighter pilot. Thus, a bond of sympathy developed within the senior echelons of the Air Force to introduce such capability, which evolved into project name Korea Trainer Experience 2 (KTX-2). The looming specters of the Iran-Iraq War during the mid-1980s also raised the attention of acquiring indigenous development capacities for an aircraft capability as well. After the pullout of U.S. military assistance to Iran, the F-14 fighter, which constituted the major air capability of the Iranian Air

Force, was completely grounded for no use in the air campaign against the Iraqi forces. The situation showcased the real threat perception of lacking a self-reliant military support structure, caused from excessively relying on foreign sources without building domestic capacities, which may virtually result in neutralizing its own readiness posture. The Iranian case triggered the need to nurture industrial competencies within some senior level officials in the Air Force and ADD.[755]

At the time of specifying the development needs, Korea was far behind global technological standards in building an indigenous aircraft, thus the country was in dire needs of technology assistance from international forerunners of the sector. The majority of the technology originated from the KFP offset deal under a collaborative provision with General Dynamics. As noted in the previous section, General Dynamics owed a 30% offset package to Samsung Aerospace under the KFP contract. The dollar value of the offset approximated nearly USD 14 million, but was considered insufficient as a manufacturing deal to further expand into a concrete business opportunity. A direct offset arrangement in subject areas such as concluding on a counter-trade contract between the two firms would result in simply expending the offset value in producing low end aircraft components without much meaningful spinoff effects into the industry. At this point, aerospace was frequently cited as a buzz word for new business opportunities and industrial upgrade in the late 1980s where major Chaebol firms were hastily rushing into the sector without being properly equipped with requisite R&D capacities and manufacturing infrastructure. Senior engineers in the Air Force, ADD, and Samsung Aerospace all aspired to take full advantage of this state driven demand pull, with their eyes on the follow-up development potentials after the KFP license production. In regards to an evolutionary development sequence, the authorities had in mind of developing an advanced trainer aircraft as a subsequent project after the KFP. The Air Force took the lead in this discussion after undergoing multiple rounds of deliberations within the force requirement departments. After the Air Force fully approved the exploratory phase of an advanced trainer program in 1989, the development authorities at ADD had to further specify the operational requirements in parallel with the country's technology readiness level. As a result of these multiple review sessions, the authorities concluded an indirect offset package that involves substantial amount of technology transfers would be the best option to fully capitalize from the KFP offset trade arrangements.[756]

The program confronted resistance internally and externally before becoming a formal program of record. Regarding external factors, an advanced trainer emerged as an urgent requirement for the Air Force during the early 1990s in order to properly train its pilots in preparation of the imminent F-16 flight missions before 1996. At the time being, the Air Force was flying the obsolete T-33 and the TF-5B as its advanced trainer, which were shortly considered for replacement. Hence, it was physically unfeasible to complete the indigenous development effort within the given timeline.

755 이정훈, "골칫덩이 KFX, T-50 기술로 우회해야," 주간동아 1016 호, 2015, p. 22.
756 이정훈, T-50, 이렇게 만들었다, 지식산업사, 2006, pp. 167-174.

However, the replacing the development program to a foreign procurement would result in entirely undermining the opportunity to build an indigenous industrial capability. In order to fulfill the trainer needs while supporting the indigenous development efforts, the Air Force was compelled to introduce an interim solution before the conclusion of the KTX-2 development. At first, the Air Force selected the Italian Aermacchi MB-339 jet trainer, but abruptly reversed the decision to purchasing twenty (20) Hawk Advanced Trainers from the British Aerospace (BAe). The catalyst of the sudden change derived from the triple layered offset package proposed by the Executive Vice President of BAe himself, which included the training of test pilots, technology assistance in developing a trainer simulator, and the transfer of system design technology for a subsonic advanced trainer, under a price tag of USD 8.5 million per aircraft. The offset package provided the opportunity for a team of ADD researchers to study critical design skills and manufacturing processes at the BAe research lab over a 14-month period.[757]

BAe, however, had aspirations to sell more trainers to the Korean Air Force with additional light attack performance features. In early 1992, the Air Force generated the need for additional advanced trainers, but the newly identified force requirement did not agree with the development milestones of the KTX-2. Under collaborating with some retired top brass Korean Air Force officials, BAe staged a secondary lobbying scheme to sell twenty more aircrafts. The additional purchase would take away a significant portion from the KTX-2 program budget and eventually increase the unit cost of the aircraft to unaffordable limits, which may potentially cancel the entire development efforts. This would provide extra opportunities for BAe to monopolize the entire trainer program of the Korean Air Force. In a desperate move to save the KTX-2 from an off-the-shelf purchase, the parties supportive of an indigenous capability strongly insisted to lease a U.S. trainer as an alternative option until the KTX-2 development efforts conclude. In this regard, the defense authorities decided to lease thirty (30) T-38 Talons for its advanced trainer under a USD 86 million contract as a bridging capability until the KTX-2 becomes fully operational in 2005.[758]

Regarding internal factors, an advanced trainer capability had to compete against other force requirement priorities within ADD as well as with the three military services. After the country's foremost defense R&D lab approved the exploratory phases of developing an advanced trainer, the program had to wrestle with existing programs. The exploratory phase was planned within a two-year duration (1989-1990) with a requested program budget of KRW 400 million, but was only allocated with an initial budget of KRW 5.3 million in the first year, which only allowed to purchase pencils and papers.[759] Thus, the first year budget was truly regarded as seed money to explore the frugal limits of defense spending in a cynical sense. In terms of contending with other military programs, the senior heads in the Ministry of National Defense gave little attention to a trainer development while having to deal with high visibility programs like main battle tank upgrades, missile procurements, next generation

757 Ibid., p. 177.
758 Ibid., p. 180.
759 전영훈, T-50 개발: 기초연구단계 – 탐색개발단계, KSAS 매거진, 제 5 권 1 호, 2011, p. 17.

naval destroyers and submarines, and so forth. The adjudicating offices for drafting the Midterm Defense Plans argued that the tremendous resource commitments required for indigenously developing a high risk aircraft program defies the impending threat conditions of the Peninsular Wide Theater Campaign Contingency Planning. However, in a turnaround situation, the KTX-2 program advocates successfully linked the aircraft development needs with the KFP defense offsets, and inserted the idea of a possible government audit if the defense authorities neglected the offset option, which would eliminate the industrial upgrading potentials of the domestic economy. Under pressure of a conceivable state-led audit and subsequent public scrutiny, the defense authorities formally conceded with the development proposal. In December 1992, the KTX-2 became a formal development program and entered into the official stages of concept refinement. Hence, the program name changed from KTX-2 to the T-50 Advanced Supersonic Jet Trainer, 'T' implying trainer and '50' celebrating the 50th Anniversary of the Air Force.[760]

7.2.2. Technical Assessment and Readiness Level at the Time of the T-50

In order to conduct thousands of iterations of test and evaluation over the aircraft before rolling into the first product in October 2005, the program authorities had to conclude the development phase of the program no later than June 2003. In this regard, the design phases of the program had to conclude at least around the first half of 2002. In the early phases of the program, the number of qualified engineers that can adequately cover the design aspects of the aircraft, from concept development to detailed system requirements, accounted for around 100 within ADD, Air Force, and Samsung Aerospace. With the almost nonsensically condensed program milestones amid a serious shortage in qualified manpower, the given advice was to increase the system design engineers to 1,000. The program recruited professional system engineers from the automotive and shipbuilding sector, and had to provide an intensive fast-track training course on aeronautical engineering basics and aerodynamics.

7.2.3. Choosing a Co-Development Partner

The initial assessment of the T-50 development cost during the beginning of the program in 1990 ranged around USD 1 billion. Although an assessment, the dollar figures were never an affordable price tag for a late industrialized economy. In order to save cost while securing additional overseas export markets, the idea to expand the T-50 into an international cooperative development program was being socialized within the senior defense leadership group. In the summer of 1993, after recognizing the Spanish Air Force also had a growing appetite for an advanced jet trainer, the Ministry of National Defense, represented by ADD, proactively engaged with the Spanish CASA and Lockheed Martin to review the feasibilities of further refining the trainer needs into a trilateral effort. The three stakeholders

[760] Ibid., p. 19.

conducted a joint review board the same year and agreed to start coordinating until July 1994 over the details of the aircraft performance requirements and work breakdown structure. At first, the decision was to share the cost by Korea (50%), CASA (40%), and Lockheed Martin (10%). In terms of the work breakdown structure, Korea would take 50% responsibility in manufacturing the forebody and AFT fuselage, static test, subsystems, final assembly, and flight test. CASA would take 50% responsibility in the main wing, avionics, stress test, final assembly, and flight test. Lockheed would cover the main airframe and flight control. However, because of the difference in system requirement within the Spanish Air Force, CASA renounced its participation and withdrew from the consortium in 1994. In order to maintain the work breakdown structure, ADD reached out to the German DASA. As the situation unfolded, CASA decided to rejoin the consortium in 1995. By this time, the T-50 has attracted much international publicity, other global contenders also strived to take part in the program. In the fall of 1995, the simmering heat of the T-50 induced the formation of a separate consortium among the European contenders, notably between CASA, DASA, and Denel. However, in the spring of 1996, the second consortium broke up over a disagreement on who shall assume the leading role.[761]

At the time being, foreign firms such as the British BAE, German DASA, and the Spanish CASA, continuously probed on the potentials of opening the Korean market to promote their products. BAE offered an upgraded variant of the Hawk 67 that included a modified fuselage and wing design. After returning to the T-50 scene as an independent member from the initial trilateral arrangement, CASA attempted to ally with a Korean firm to co-develop its ATX supersonic trainer and light attacker program. The proposal included a cooperative marketing campaign to sell the final product both at the Korean and Spanish Air Force. However, the CASA system requirement differed from that of the Korean Air Force, and the prospects of an advance trainer program was uncertain for the Spanish Air Force. After the collapse of the second consortium, DASA, in collaboration with the South African Denel, proposed the AT-2000, while commencing talks with Hyundai Space and Aviation for a possible local production deal. However, the aircraft did not fully develop into a final program, but still remained at the drawing board as a paper aircraft at the time of the proposal. DASA also proposed a cooperative marketing effort to sell the aircraft at all three markets – Korea, Germany, and South Africa. But, the requirement for a trainer aircraft at South Africa also appeared foggy. Challenges over prime contractor selection also became an issue by other companies vying to participate in the program. Domestic aircraft-manufacturing firms that were eliminated from the T-50 bidding competition objected the government’s unilateral decision over vendor selection by raising serious petition to the process. Hyundai Space and Aviation called into question the insufficient legal basis of awarding the contract to Samsung Aerospace, for which the firm argued the selection defied the rules of fare competition. Hyundai especially posed the problem of possible restrictions on exporting the aircraft to third countries

[761] 한국항공우주산업, T-50 의 꿈과 도전, 2003, pp. 24-27.

under the provisions written in the memorandum of understanding signed with the U.S. Government.[762] For the purpose of the T-50, Hyundai had partnered with the German DASA and commenced a marketing campaign to co-produce the proposed AT-2000 supersonic jet-trainer project.[763] As the T-50 stumbled on the roadblock during the lead agency transition period between 1996 and 1997, As the chances of cancelling indigenous development was looming during the lead agency transition period of 1996-1997, DASA returned with a more advanced product, the Ranger 2000 jet trainer, but under a significantly affordable price tag, with high hopes to partner with ADD and Samsung Aerospace.[764]

Understanding the fierce competition in both areas of selecting international partners and domestic contenders, while trying to salvage the T-50 program, the Korea Development Institute (KDI) conducted a feasibility review until the second half of 1997 under the directive of the Deputy Prime Minister in Economics. KDI at the time did not view the Samsung Aerospace-Lockheed Martin partnership as a fair trade, and strongly urged to select the co-development partner through a more transparent competitive bidding process. For this reason, KDI did not approach the T-50 program with a friendly attitude in both an economic and technological sense.[765] The recommendation made to the Deputy Prime Minister of Economic Affairs in July 1997 reflected the negative perspectives of the development identified in the impact factors to the economy, high risk factors of indigenous development, and the inherent problems with the selection process of international partners. In order to reduce the risk factors, the KDI report strongly asserted for more industry commitment, which opposed the conventional practice of having the government covering the entire nonrecurring development costs. In this aspect, the KDI report insisted that the commercial vendors should also take part in the investment scheme to induce stronger commitment into the program and share development risks. Especially Samsung Aerospace was pressured to invest a meaningful portion into the program. Based on these recommendations, the T-50 development proposal was forwarded to the Aerospace Industry Development Policy Committee (AIDPC) the same month, where the Committee all ruled in favor of inaugurating the T-50 co-development effort as a formal R&D program of record. As a result of the KDI feasibility studies and the AIDPC decision, the total share of the T-50 development composed of a 70% public investment supplemented with a 30% investment from Samsung Aerospace and Lockheed Martin (Samsung 17% and Lockheed 13%). The arrangement was for the government to reimburse the 30% development investment share from the two companies after the program entered into full scale production. Lockheed Martin originally expressed reluctance on the idea of partaking some financial obligations in the program. But the business forecast of the international trainer market, which projected a potential sales opportunity between 2,500-3,000 jet trainers in the next two decades, encouraged

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762 연합뉴스, “초점: 국방부-현대, 방위력 개선사업 놓고 전면전,” 1997.11.18.
763 Andrzej Jeziorski, “DASA prepares for AT-2000 definition go-ahead,” Flight Global, July 9, 1997.
764 Andrzej Jeziorski, “DASA hopes to salvage Ranger with KTX-II deal,” Flight Global, February 7, 1998.
765 Flight Global, “South Korea reconsiders KTX-II,” January 1, 1997.

Lockheed to share the development load.[766] Hence, the acquisition strategy of the T-50, which designated Samsung Aerospace, later KAI, as the prime contractor and lead system developer of the program and Lockheed Martin as the co-development partner, was formally approved for execution.[767]

7.2.4. Program Milestones: Major Stakeholders in the T-50

The T-50 started under the auspices of a state driven concept development exercise where ADD took the initial lead in project initiation. ADD researchers were at the receiving end of learning advanced technology and skills from the two defense offset arrangements obtained from the KFP and Hawk trainer procurement. However, to the surprise of many, in the summer of 1995, the Ministry of National Defense detached from the traditional practices of state-led defense R&D programs and issued a solicitation offer to both ADD and Samsung Aerospace in a move to select the system developer of the program. The objective was to introduce competition for improved program efficiency and generate spinoffs into other business sectors. Normally, system development roles were assigned to ADD where the prime contractor of the program merely performed in limited R&D capacities. The core responsibilities of the prime contractor were mostly focused on building production capacities where the priority was given on component localization. This state led R&D arrangement was perhaps commonly accepted in the early days of industrialization when Korean firms did not possess the requisite capacities to perform complex R&D projects compared to the better resources and higher technology standards of government research institutes. However, the old arrangement granted the government's exclusive ownership of the proprietary rights produced from the development efforts, where the manufacturing firms, or the prime contractor of the program, only gain limited access into core technology areas. Such arrangement constrains potential development aspects of the program, of which expanding into systems upgrades and shelf life extension schemes becomes troublesome. The prime contractor does not grasp the opportunity to accumulate expertise from understanding the core technological elements of the system that would've been acquired through earlier system development processes. On the other hand, most of the core technology retained by the GRIs rarely sees light in further diffusion into other commercial opportunities. In this regard, the trickle down effects of state driven defense R&D programs resulted in disappointing outcomes. Such public concerns underscore the abrupt change in designating the entity of primary responsibility for lead system development in the T-50, which signified a transformation in state-led defense R&D governance.[768]

Although the system development lead transitioned from ADD to Samsung Aerospace in 1995, the actual development phase did not commence until October 1997. During the two year break period,

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766 Michael Mecham, "Korea Aerospace Industries and Lockheed Martin," Aviation Week & Space Technology, February 28, 2000.
767 이주성 외, 국방산업 기술추격을 위한 R&D 거버넌스 전략연구: T-50 개발사례를 중심으로, 과학기술정책연구원 정책자료 2008-03, pp. 79-81.
768 한영희, 김호성, "국방획득정책과 T-50 고등훈련기 연구개발의 성공사례," 한국혁신학회지, 제 7 권 1 호, 2012, p. 129.

ADD and Samsung went through a phased transition effort to maintain the accomplishment of the exploratory development efforts as well as to retain the R&D workforce. The reason identified to date of the two year break period involves reluctance to enter into the full-fledged development phase of the program and the continued attempt to bring down the entire program by replacing the trainer concept with a foreign substitute. Between 1992 and 1996, the government committed nearly KRW 70 billion in direct investments throughout the exploratory phases of refining the concept. But the astronomical program budget, initially estimated approximately USD 2 billion, hesitated the decision authorities from giving the marching orders for program execution. In order to alleviate the financial concerns over the program, under the provision of the National Financial Act that stipulates the need to scrutinize national R&D projects exceeding KRW 50 billion, the Ministry of Finance and Economy directed the Korea Development Institute to perform a feasibility review over the program in 1997. Concerned over a possible program cancellation, the Ministry of National Defense warned the financial authorities that the cost already deployed into the T-50 in both direct and indirect terms amounted over KRW 1.5 trillion. Hence, a stalemate or a possible cancelation of the program would result in the government losing the substantial commitments previously obligated. Perhaps having this in mind, the KDI feasibility review recommended to continue the development project.[769]

Period	Phases	Lead Agency	Activities
Apr 1989 – Jul 1992	Requirement Generation/ Concept Refinement	ADD Offsets: $400M Budget: ₩35B	• ADD requests program development (Apr 1989) • Air Force purchases initial batch (20 aircrafts, Nov 1989) • MOU signed on offsets and tech transfer (BAE, May 1990) • Technology Assistance Agreement (TAA) and Implementation Contract signed (ADD – General Dynamics, Jul 1992)
Oct 1992 – Dec 1995	Technology Development		• U.S. Government approves TAA (Nov 1992) • System development plan drafted (Jun 1995) – Samsung Aerospace selected as prime contractor for industry led R&D project
Jan 1996 – Oct 1997	***Lead Agency Transition***	***ADD ↕ Samsung Aerospace*** ***Budget: ₩15B***	***• Memorandum signed for lead agency change (May 1996)*** ***• Program feasibility studies (KDI, Oct 1996 – Jun 1997)*** ***• Supporting agreements between SSA-Lockheed Martin (Sep 1997)*** ***• System development plan approved (Oct 1997)***
Oct 1997 – Sep 2005	System Development	Samsung Aerospace (KAI) Budget: ₩2.2T	• U.S. Government export licenses approved (Nov 1997) • External configuration confirmed (Aug 1999) • Industry merger, KAI created (Oct 1999) • First prototype rollout (Oct 2001)
Oct 2001 – Dec 2011	T&A/ Production	KAI Budget: ₩3.3T	• Full rate production initiated (Nov 2003)

Table 54. Key Development Milestones
Source: 공군본부, T-50 연구개발사업 추진현황 보고, 국회 국방위원회 보고, 2003; 전영훈, T-50 끝없는 도전, 행복한 마음, 2011.

The Ministry of National Defense controlled the program budget and coordinated interagency units, whereas the Air Force took the lead agency role in the overall aspects of program management. The Aircraft Program Group (APG) assumed responsibility for supervising requirement planning, technology management, configuration and quality management, integrated logistics support development, and so forth. The APG led the general decision making process in program costs, schedule,

[769] 연합뉴스, "한국형고등훈련기 개발사업 재개, 내용과 배경," 1997.7.3.

performance and integrated systems. The Agency of Defense Development (ADD) initially took part in exploratory roles regarding concept refinement and technology development before the defense authorities decided to transition the system development responsibilities over to Samsung Aerospace, later KAI, the prime contractor of the program. Even after the transition, ADD served in supervisory and assistance capacities in close collaboration with the prime contractor in terms of managing technology acquisition objectives, preliminary and critical design review stages, further application of acquired technologies, and Test & Evaluation roles. The Defense Agency for Technology and Quality (DTaQ) performed quality control responsibilities during the low-rate initial production and subsequent full-rate production and deployment phases of the program.[770]

The prime contractor of the T-50, Samsung Aerospace, later KAI, assumed the largest responsibility in system design, development, and manufacturing. Under the terms of the program contract with the Air Force, the prime contractor served comprehensively in roles proceeding with key program milestones, ranging from systems engineering, prototyping and demonstration, production and deployment, and sustainment phases. The prime contractor routinely collaborated with its international co-development partner, Lockheed Martin, in all aspects of the evolutionary progression of the program. Subcontractor supply chain management also fell under the auspices of the prime contractor, which included 6 major domestic subcontractors such as Hanwha, LIG Nex1, and Samsung Techwin, and the 489 international subcontractors and parts providers such as the Israeli ELTA Systems, General Electric, Honeywell, Martin Baker, and so forth.[771]

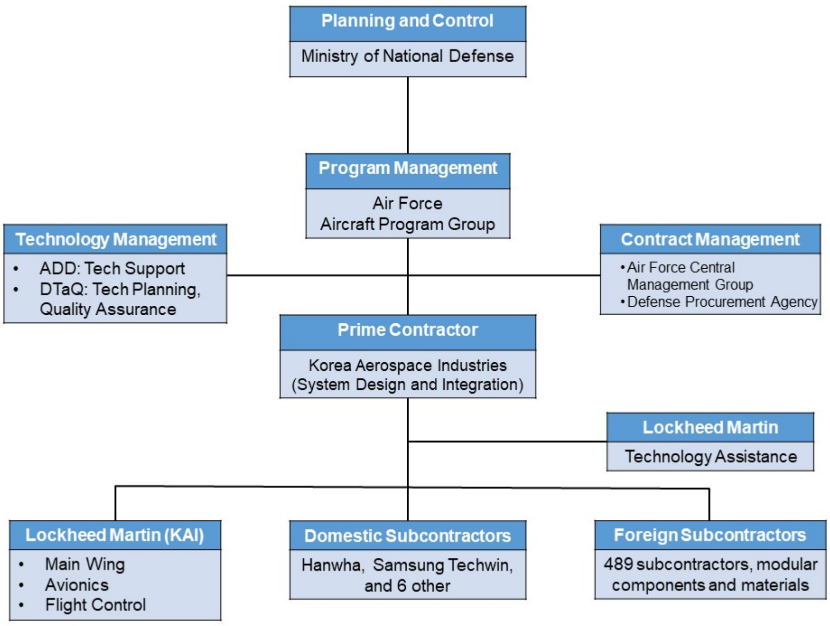

Figure 23. T-50 Program Management Structure
***Source**: 공군본부, T-50 연구개발사업 추진현황 보고, 국회 국방위원회 보고, 2003*

[770] 공군본부, KTX-2 사업관리 개요 및 진행, 국회 국방위원회 보고, 2002.
[771] 공군본부, T-50 연구개발사업 추진현황 보고, 국회 국방위원회 보고, 2003.

In January 1996, after transitioning the system development responsibilities from ADD to Samsung Aerospace (KAI), the program entered into the system development phase. But because of the KDI feasibility studies, the official beginning of the system design and engineering phases started in October 1997. The design period took about 33 months until July 2000, followed by a three year prototypes and demonstration sequence until August 2002. After successfully going through performance tradeoffs on prototyping, the program entered into dedicated operational test & evaluation in parallel with the low-rate initial production of four prototypes for nearly five and a half years until September 2005. Upon conclusion of the system development phase, the program entered into low-rate initial production with December 2003. The subsequent full rate production and deployment followed in March 2006. Concurrent engineering practices were applied in each major development phases in order to save cost and shorten program schedules. The initial operational test & evaluation period took especially longer than the actual system design and engineering phases, due to the high demand for product safety and reliability over aircraft manufacturing. Especially, considering the high thresholds on safety standards, test flights are conducted conservatively, which requires long test hours in both flight and ground testing stages. Also, the workshop level engineers and supervisors did not have prior experience in conducting the required test sequences, thus were mostly new to the game of evaluating the complete specifications for a new aircraft. Such situation directly impacted on the T-50 program since there were no prior experiences in performing a test flight on an aircraft from its own design and production effort.[772]

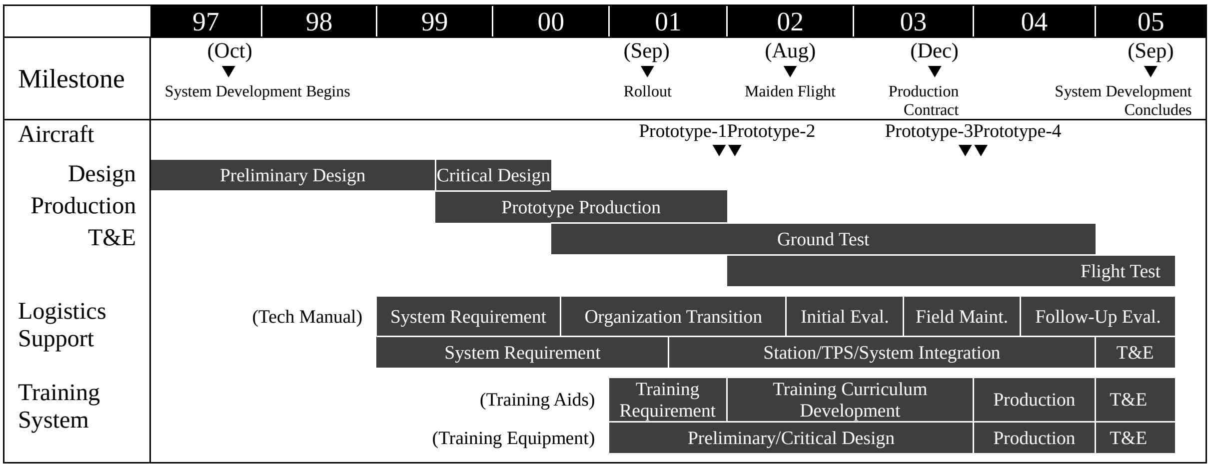

Table 55. T-50 Program Milestone *Source: KAI Updates on KTX-2 (2005)*

7.2.5. Capacity Building Process

International Technology Transfers through Defense Offset Arrangements

In a highly advanced technology system, strategically aligning with Tier-One countries or firms in regards to engaging in co-development or co-development programs is one of the most commonly sought out catch-up strategies for late entrants in these sector. Especially, firms share common

772 한국항공우주산업, “T-50 사업현황 소개,” 2005.

objectives and interest through strategic alliances, which mutually supplements technological insufficiencies, provides opportunities to absorb each other's improved capacities, and internalizes the learning effects from these arrangements.[773]

In this regard, strategic alliances between Tier-One and Tier-Two firms or countries have been a frequently pursued strategy in the global aircraft-manufacturing sector. Especially considering aerospace being a highly asset specific sector, special skill sets, infrastructure, and compliance. Under internationally set rules and regulations, strategic alliance is considered a viable option to reduce upfront investments and overhead costs. Inter-personnel exchanges, or in other words stickiness, are highly respected in developing complex product systems such as in aerospace, where the learning and innovation process is performed through the transferring of tacit knowledge opposed to codified documents. In this aspect, the higher degree of a firm's absorptive capacity interacts as a force multiplier throughout the learning process.[774] Strategic alliances for co-development programs are established to serve for these purposes.

The T-50 was a product of technology transfers derived from multiple defense offset programs with foreign partners. At first, earlier aircraft procurement programs provided some meaningful sectoral manufacturing knowledge. The Boeing P-3C maritime patrol aircraft provided basic level wind tunnel testing skill, while the CASA CN-235 medium-range transporter provided technical information on composite structural design and fly-by-wire flight control systems. Secondly, the intermittent trainer solution (Hawk-67) proposed by BAE generated an offset package that allowed a team of 24 researchers and 3 test pilot candidates to attend a yearlong training program provided at the BAE production laboratory located at Brough. The collaboration with BAE assisted the determination of the early configuration design of the aircraft. Most notable from the BAE experience included the learning of computer aided design techniques through a design software called CAPS. The high demand of integrating various engineering disciplines into a single aircraft vehicle requires a multilayered process of reaching a design optimum in each development phase. Especially in conceptual design stages when assessing candidate configurations, the insurmountable task of applying conventional design tools with simplified decision parameters for analysis raises the need for a synthesized computational method. In this regard, computer assisted design and analysis tools have been integral for shortening the learning period of concept design and configuration management for the Korean team at BAE. The design team's effort in acquiring the source code of the CAPS software allowed the program to incorporate both design analysis and verification instruments in the early design phases before maturing the conceptual draft of the outer mold line configuration.[775] The collaboration with BAE over the CAPS software expanded into other design elements of the program. Most of the BAE technology transfers derived from the

773 Peter J. Lane and Michael Lubatkin, "Relative Absorptive Capacity and Interorganizational Learning," Strategic Management Journal, Vol. 19, 1998, pp. 461-463.
774 Gabriel Szulanski, "Exploring Internal Stickiness: Impediments to the Transfer of Best Practice Within the Firm," Strategic Management Journal, Vol. 17, 1996, pp. 27-30.
775 전영훈, T-50: 끝없는 도전, 행복한 마음, 2011, pp. 70-75.

baseline performance features of the Hawk-67, which was designed as a subsonic jet trainer. Associated design skills supported by the software were transferred to the design team, such as in system requirement review analytics, avionics conceptual design and interface, structural design and analysis, airworthiness certification, wing design and molding, propulsion systems integration, and so forth.[776]

But the majority of the technology derived from the offset agreement between the Korean Government and General Dynamics, which later merged into Lockheed Martin after the formal inauguration of the T-50. The alliance relationship between KAI and Lockheed Martin proceeded as a co-development contract where the two firms shared the workload in developing some requisite components. As the prime contractor of the program, KAI purchased the requisite technological subjects, such as in system integration level engineering and manufacturing processes, under a technology assistance agreement with Lockheed. At the time, the domestic aircraft-manufacturing sector had no experience in building a full scale aircraft with its own technology. The foundation of the engineering and manufacturing base derived mostly from the license production of the KF-16 fighter. In a parallel effort, the sector absorbed the experiences from developing the KT-1 Basic Trainer. A small but meaningful experience in basic design capacities added up from the country's attempt to co-develop a mid-sized regional commercial airliner in the early 1990s. In this regard, the strategic alliance with Lockheed Martin was imperative for KAI in the course of learning critical engineering and manufacturing experiences. Although the lead system development entity of the program was KAI, Lockheed Martin took the lead in developing a portion of some innovative components such as the main wing, flight control system, and avionics. Lockheed provided most of the technology for system design and integration process since KAI lacked the adequate experience levels in this respect.

Strategic Alliance with Lockheed Martin

The strategic alliance between KAI and Lockheed Martin originated from the 30% defense offset value under the KFP arrangement with the formerly General Dynamics-Fort Worth Division. Lockheed Martin provided technology assistance in full spectrum of the program, which included component/system design and engineering, system integration and production knowhow, and the provision of test equipment for product evaluation. The technology acquisition strategy composed of different layers in terms of advisory services, co-development through strategic alliances, and support of technology data.

Technology advisory services started in the exploratory phases of the program. In November 1992, a team of scientists and engineers from ADD, Air Force, and Samsung Aerospace journeyed to Fort Worth Texas, the location of the primary F-16 system design and production facility. The objective of the team was to acquire requisite knowledge on system design and manufacturing technology through a one-on-one apprenticeship with a U.S. engineer, which developed into a close binding comradery

776 조달본부, 절충교역 20 년사, 국방부, 2003, p. 67.

derived as a by-product of strong kinship as professional technicians in aeronautical sciences.[777] Regardless of such relationship building efforts, Lockheed expressed extreme reluctance in disclosing core technology. A notable aspect of international technology transfers takes place in the workshop level interactions of the program. A team of experienced engineers from Lockheed were dispatched to KAI to provide the required technology assistance under the mutually agreed provisos of the contract. The duration of these engineers collaborating with KAI and other program authorities ranged from 1 to 6 years in maximum, which mostly covered the system development phase and partially the low rate initial production phase of the program. In addition to the in-country engineering team, Lockheed provided a total of four iterations of examinations on the system design and development through a team composed of senior engineers and program managers called the Senior Design Review team. Restrictions on technology transfers appeared evident in sensitive core technology areas where Lockheed maintained a competitive advantage in the global market. Avionics and flight control systems required additional negotiation efforts, cost, and U.S. Government disclosure approval in order for KAI to obtain the respective engineering skills. Fortunately, substantial ranges of technology sections provided from Lockheed evolved from the F-16 baseline configuration, which made it more convenient for KAI to learn the process while having to go through minimal trial and error. Because of the complex nature of developing aircrafts that involve sophisticated integration work of multiple modules and subsystems, detailed design and engineering technology cannot be fully transferred through codified engineering schematics or technology manuals. Essential knowledge and skill sets are tacitly transmitted in the workshop level through dynamically interacting with relevant departments and engineers on the floor. In this aspect, apprenticeship type learning practices serves a major conduit for growing technology absorptiveness, which facilitates further progression into transferring critical technology. In the workshop level, the number of engineers dispatched from Lockheed to KAI totaled approximately 100 in size throughout the co-development period, at which the duration per person committed into providing advisory services averaged around 31 months, depending on the level of complexity and difficulty. In this regard, the duration of advisory service provided per person over highly complicated subunit areas such as aircraft design and analysis averaged around two years, whereas relatively less complex system such as machinery averaged around two years.[778]

[777] 고성표, “밀착 진단: 한국 항공우주산업 현주소 – T-50 개발 비화,” 월간중앙 200601 호, 2006.
[778] KAI internal program updates on KTX-2.

Subject	Advisory Period per Person	Average Personnel	Annual Numbers	Remarks
Fuselage	35 months	26	75.8	Shared with design and analysis
Propulsion System	48 months	3	12	
Cockpit	32 moths	17	45.3	
Avionics	35 months	4	11.7	Primary responsibility under Lockheed
Flight Control	32 months	4	10.7	Primary responsibility under Lockheed
Design/Analysis	47 months	4	15.7	Shared with other airframes
Machinery	23 months	9	17.3	
Test & Evaluation	31 months	11	28.4	
System Integration	32 months	8	21.3	
Other	52 months	13	56.3	
Average (Total)	31 months	99	294.5	

Table 56. Advisory Services Provided by Lockheed Martin to KAI ***Source: KAI internal report***

Secondly, the co-development arrangement in component development – such as in main wing, avionics, flight control – through the KAI-Lockheed strategic alliance comprised the other layer of technology acquisition. However, due to the security barriers existing in the core technology categories over these items, the quantity of technology transfers was limited. The three components subject to the co-development effort constituted the core of aircraft technologies, in which the U.S. Government imposed heavy restrictions in transferring engineering know-how or manufacturing skills to foreign entities as an effort to sustain its global predominance in aerospace technology. The program authorities had to obtain U.S. Government approval in order to gain access into the subject technology information, which cost time and additional efforts. Also, in terms of securing intellectual property rights of the subject items, the program authorities had to pay significant costs to acquire the requisite technological packages, which were also controlled under U.S. Government export control adjudications. As a result, the only technology available for transfer to the T-50 program was in repair and maintenance level technical data in terms of components and software, which precluded access into the core technology elements required for new developments or upgrades.[779]

The third layer of technology acquisition considers the provision of technology data information. This layer involves the previous defense offset packages of the KFP, which evolved into the baseline Letter of Exchange between the Korean and U.S. government in 1996. Series of U.S. Government reviews on technology transfers followed the baseline memorandum. The signed memorandums between Samsung Aerospace (KAI) and Lockheed Martin include the Teaming Agreement, Technology Assistance Agreement (TAA), Technical Assistance Subcontract, and a Workshare Subcontract. The Teaming Agreement covers the exclusive cooperative relationship between Samsung and Lockheed within the agreed parameters of investment, joint marketing, production workshare, and other areas in support of the program. The TAA comprehensively included advisory services, technical data, knowledge and skillsets, development workshare, and other aspects required for system development. Technical Assistant Subcontract defines the scope and scale of technology data and advisory services in dollar value of USD 240 million. The Workshare Subcontract include a USD

[779] 안영수, 김성배, 전략적 제휴를 통한 첨단기술산업의 기술획득 성공 결정요인 분석과 정책과제: 항공기 공동 개발사업을 중심으로, 산업연구원, 2006, p. 89.

240 million worth of workshare in avionics and flight control modules, associated with a USD 138 million worth main wing production arrangement. Accordingly, the total investment from the Korean Government and Samsung Aerospace paid to Lockheed Martin for technology transfer and associated services totaled USD 498 million. About 50% of Lockheed Martin's investment into the program would be refunded after the program enters into full production, whereas the other 50% would be returned by international export cases. Thus, the program authorities strived to involve Lockheed Martin into the program one way or another.[780]

But because of the substantial scale of contract obligations, which reached nearly USD 600 million, the review period took much longer than regular export control cases. In regards to export control decisions in the U.S., if the export value of the subject defense article or service exceeds USD 50 million, it becomes subject to additional scrutiny, which also involves Congressional notification and reviews. The review process itself took nearly a one-year period until final approval on 12 November, 1996. However, the approved export license contained 23 provisos that restricted the further use of the respective technology covered under the TAA. The restrictive composition sparked off a potential conflict between the two governments in regards to interpreting the restrictive provisos of the TAA. In an effort to explore a more reasonable option in a certain engineering field of the program, KAI issued a Request for Proposal (RfP) to third country contractors in France and Germany, opting for an alternative solution to reduce cost. However, noticing the inclusion of some controlled information in the RfP, Lockheed Martin filed a voluntary disclosure to the U.S. State Department in January 1999, claiming that Samsung Aerospace violated U.S. export control regulations. The situation could've worsen into a serious dispute between the two governments with a potential of the U.S. State Department rescinding all approved export licenses under the program, associated with levying a huge penalty fee against both the Korean Government and Samsung Aerospace. The worst case scenario was averted under the constant exertions by the Korean Government and Samsung Aerospace, but the situation showcases the restrictive condition of U.S. export control laws and the potential impacts on program implementation.[781]

Accumulated Experiences through Engineering and Manufacturing

The adoption of concurrent engineering methods facilitated the program authorities to curtail about three months from the design and prototyping phase of the schedule. In conjunction with concurrent engineering practices, the employment of a computer aided design and engineering software called the Computer Aided Tridimensional Interactive Application (CATIA) enabled to reduce about sixteen months from the entire schedule – eight months in basic design, five months in prototype

[780] Ibid., pp. 71-74.
[781] 한국항공우주산업, T-50 의 꿈과 도전, 2003, pp. 49-51.

development, and three months in aircraft production from originally scheduled process.[782]

The relational capital built up through subunit teams, as well as Lockheed's technology assistance teams, constantly upgraded the knowledge base of KAI, which further translated into the overall segments of the T-50 development process. In terms of subunit teams, KAI attempted to form an interdisciplinary unit composition that organized similar subject matter experts under an optimally constructed team unit. For instance, a development unit would be practically composed of engineers under the discipline of aeronautics/mechanics (71%), electronics/electrics (17%), metallurgy (5%), computer/communication (4%), and materials (2%). In the case of building partnership between KAI and Lockheed engineers, the two parties used common office spaces to effectively update the progression in learning, sharing workloads, and augmented areas that needed supplemental efforts.[783] In respect to knowledge management routines, program authorities took the initiative to proactively share knowledge and information obtained throughout the development process with other teams and departments. KAI officials created, stored, and shared the knowledge and experiences acquired through the aspects of relational capital by employing three exercises. At first, regarding information obtained through official learning channels, the respective materials were registered, categorized, stored, and made available for reference. Secondly, information obtained through personal channels were uploaded on KAI's internal network server for common usage into various applications. Especially, proper incentives were awarded to those who actively uploaded meaningful information. Lastly, internal learning groups in the form of small unit social gatherings that actively utilized the shared information grew in greater numbers as time progressed. These gatherings were organized spontaneously between engineers and technicians to collectively study and research the lessons learned from the subjects derived from each engineering stages. Such aspect made possible the most effective use and accumulation of the technical data, materials, and experiences acquired during the scope of the program. Until 2003 when the program was just about to enter the full scale production phase, the number of learning groups grew out to almost 200, the number of participating engineers totaled nearly 600, and the number of research papers published amounted nearly 130 per year. The results of these voluntary studying efforts were further compiled and refined by collectively discussing the subject matter throughout public seminars or research forums held within the program management organizations. Consequently, the workshop level efforts contributed to exploiting the knowledge and experiences acquired during the development phases, and promoted the prospects of technology diffusion for better success of the program.[784]

In a program management perspective, the presence of on-site program management offices dispatched from the Air Force Program Management Group served in critical liaison responsibilities

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782 안영수, "국제 기업간 전략적 제휴에 의한 항공기산업의 기술이전 사례연구", 한국항공운항학회, 14 권 4 호, 2006, p. 52.

783 안영수, 김성배, 한미간 T-50 항공기 공동개발을 위한 전략적 제휴 분석과 정책과제, 산업연구원 정책자료 2007-71, 2007, pp. 87-90.

784 Ibid., p. 94.

between the defense acquisition planners and system developers. Design changes and technical modification required swift decision making at the highest program management level in order for the floor level to expeditiously move into subsequent stages of the program sequence. The on-site program management element effectively covered this

In a contract management perspective, the T-50 had to weather out a number of turbulences occurring from both external and internal causes. Regarding the detailed contract management structure of the program, the Ministry of National Defense served in coordinating and controlling roles between all entities involved in the program. As the program manager of the T-50, the Air Force established contracts with the prime contractor (KAI), international co-developer (Lockheed Martin), and other domestic and foreign subcontractors. The implementing subcontracts in workshare and technology assistance were established between KAI and Lockheed Martin that defined the scope of specialized engineering and manufacturing tasks, in addition to cooperative marketing efforts to international customers. In terms of the disruptive factors that occurred in the initial stages of the program, the Asian Financial Crisis caused major delays in obligating adequate development funds while proceeding into major program milestones. Shortly after the defense authorities approved the full implementation of the program in July 1997, the Asian Financial Crisis instigated the chain reaction of failing companies, followed by the collapse of the domestic banking system, created significant chaos within the economy. Thus, the T-60 program experienced a yearlong delay in transitioning from the exploratory stage to the system development stage. Ensuing to the program delay, the restructuring process of the domestic aircraft-manufacturing sector, which consolidated three Chaebol firms into a single corporate entity, necessitated a streak of contract revisions. The flexibility and the agility of the T-50 program to the changing circumstances of the market and government position was possible since the lead agency of the program transitioned from government to private entity.[785]

Follow-up Variants and Market Opportunities

The T-50 further evolved into a trainer/light attack aircraft (TA-50), and fighter variant (FA-50) that performs multirole combat missions in air strikes and air superiority. The evolutionary design of the trainer into the TA-50 and FA-50 provided extra opportunities in modifying the conceptual engineering features while maintaining the baseline design of the aircraft. The FA-50 shares an identical platform configuration with the T-50 while accommodated some modifications to incorporate the radar warning receiver and chaft/flare dispensing system to detect radio emissions and improve electronic warfare capabilities. In addition to these performance standards, the FA-50 also incorporated tactical data links (Link-16), radar detection (EL/M-2032 multimode fire control radar), armaments (air-to-air/ground missiles, JDAM and sensor fused weapons), night vision imaging system, and so forth. With a performance feature considered more advance than the F-5E/F combat fighters but less than the F-16,

785 강근복 외, “T-50 연구개발사업의 성과 및 파급효과 분석,” 한국정책분석평가학회 용역보고서, 2006, p. 117.

the FA-50 will eventually phase out the current F-5 fleet of the Korean Air Force.[786]

The two derivatives of the T-50 remained in the drawing boards until 2009 when the defense authorities decided to pursue the attack and combat variants of the trainer by awarding a green light on the program with a USD 306 million contract. At this point, KAI had grave concerns over the looming risks of suspending the T-50 production line after the delivery of its last order in 2012. In this regard, KAI and its subcontractors were desperate for a follow-up contract to sustain the production capacities and accumulate system development knowhow and experiences.[787] For the same reason, the defense authorities approved the additional purchase of the TA-50 in 2017 in order to fulfill advanced pilot training requirements and continue to sustain industrial production capacities. At this point, the introduction of 40 F-35 Lightning-II Joint Strike Fighters and the prospective development of the KF-X presented the extra requirements to introduce advance level tactical training needs.[788] Additional discussions are made over the possibility of expanding the derivatives to advanced electronic warfare and reconnaissance aircrafts, dubbed the EA-50 and RA-50, in consideration of replacing the current electronic attack air fleet.[789]

The total production of the T-50 domestic variants as of 2018 accounts for 144 aircrafts, with an additional introduction of twenty (20) TA-50 trainer/light attackers scheduled for delivery after 2020. As shown in Table 57, the overseas export quantities to date records a total of 64 aircrafts with an additional contract of sixteen (16) aircrafts to five customer countries. The export value over these 64 aircrafts amounts USD 2.93 billion. As such, the total production to date totals 208 aircrafts with an additional 38 aircrafts underway. The T-50 is eyed by some other countries considering to introduce a multirole platform that can perform in both training and combat mission roles. In April 2015, Pakistan has initiated plans to purchase a lead in fighter trainer with supersonic performance features to revamp its trainer and tactical fighter needs. The Pakistani defense authorities signed a memorandum with the Korean Defense Agency for Technology & Quality (DTaQ) to mutually establish quality standards as a preparatory move towards procuring the T-50. Currently, the program has entered into competition with a trainer variant produced by the Turkish Aerospace Industry (TAI), which has made the prospects of the T-50 selection a bit foggy.[790]

Variant	Korea	Indonesia	Philippines	Iraq	Thailand	Total
T-50	50	12		24	12 (+4)	98 (+4)
T-50B	12					12
TA-50	22 (+20)	4				26 (+20)
FA-50	60		12 (+12)			72 (+12)
Total	144 (+20)	16	12 (+12)	24	12 (+4)	208 (+36)

Table 57. T-50 Production and Export Status

786 KAI introductory material on T-50 Golden Eagle, September 2013.
787 Siva Govindasamy, "South Korea orders KAI FA-50 light attack fighter prototypes," Flight Global, 7 January, 2009.
788 Jon Grevatt, "South Korea to order additional TA-50 trainer/light attack aircraft," HIS Jane's Defence Industry, September 26, 2017.
789 Knowles J., "South Korea to Develop EA Aircraft," Journal of Electronic Defense, 2007.
790 Usman Ansari, "Pakistan Eyes T-50 as Trainer Option," Defense News, April 19, 2015.

The unique nature of the international armaments market requires the concerted efforts between the government and industry to penetrate the high barriers pre-established by its competitors, and also the customer country. International defense exports mostly associate defense ties between the exporting and importing countries that forms collaborative relationships through not only the product itself, but also in areas such as tactical training, technical repair and overhaul work, infrastructure constructions, technology transfers, and other various conduits of mutual benefit in the form of defense offset packages. In order to expand the export opportunities for improved bilateral relationship, the Korean Government waged a full scale promotion campaign to potential customer countries that expressed interest over procuring the advanced jet trainer. Some cases were successful, some were not. The T-50 export to Indonesia contained both positive and negative aspects of defense export initiatives between public and private entities. Indonesia announced its plans of introducing an advanced jet trainer capability in March 2010, and entered into a competitive bidding process with international aircraft manufacturing firms. In addition to KAI's T-50, the Russian YAK-130, Czech L-159, and the Italian M-346 intermingled in the bid for a contract valued over USD 400 million. Despite the relatively high price tag of the KAI T-50 jet trainer, the aircraft was selected as a preferred bidder in April 2011, and was subsequently awarded the final contract the following month. The selection of a Korean defense product in the Indonesian defense market, which predominantly consists of Russian origin products, was a surprise deal to international spectators. The T-50 export to Indonesia was an outcome of a united interagency collaboration between the military (MND/DAPA), commerce (MOTIE/KOTRA), and industry (KAI).[791] However, some limitations over the Indonesian case points out that the export was not truly a successful outcome in a sense of fulfilling commercial objectives, but a result of a series of defense offset trade arrangements between the two countries. At the time of the T-50 sale, the Korean Government agreed to purchase four (4) CN-235 medium transport aircrafts manufactured by PT Dirgantara Indonesia (DI) as an offset deal.[792] At the time, there were a number of bilateral discussions on defense industry cooperation between Seoul and Jakarta that considered the export and co-development of submarines, advanced fighters, basic trainers, ground maneuver equipment, and so forth.[793] The Indonesian case also went through major hiccups caused by international export control measures imposed from the U.S. Government. As Jakarta was included in the U.S. State Department's partial sanctions list on arms exports, the request to authorize the usage of radar source codes was denied, which precluded the full scale operation of the TA-50 capability. The alternate solution provided was to use commercial source codes in lieu of encrypted military issued source codes. But the employment of non-encrypted commercial source codes would make the aircraft vulnerable to jamming attacks.[794] An opinion against the U.S. export control policies over the T-50 export to Indonesia argues that the T-50

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791 청와대 뉴스, “KAI, T-50 인도네시아 수출 계약 성사,” 2011.5.25.
792 Esther Samboh, “RI seeks to exchange planes with South Korea,” The Jakarta Post, May 20, 2011.
793 The Jakarta Post, “PT DI Delivers Last CN-235 to Korea Coast Guard,” March 9, 2012.
794 정성택, “인디 수출 FA-50, 미견제로 발묶여,” 2014.9.16.

export license denial contradicts the U.S. Government position on conventional arms transfers, as Jakarta and Washington D.C. agreed in 2011 to provide 24 Lockheed Martin F-16 Fighting Falcons regenerated and refurbished to an upgraded Block 52 standard, equipped with advanced radars and armaments.[795] Thus, the argument highlights the constraints from U.S. export control policies have underlining intentions to benefit U.S. defense firms over international competitive contracts.

The cost-benefit of the T-50 export was also in question. As previously stated, the successful export of the aircraft to Indonesia was indebted to a defense offset arrangement where the Korean Government agreed to purchase four medium range CN-235 transporters in return of selling sixteen T-50 to the Indonesian Air Force. Regarding its medium size and range, the CN-235 does not have much utility in regards to force enhancements to the Korean Air Force other than regular transport missions. Relevant engineering and manufacturing technologies, worth a value of USD 110 million, was already transferred to Korea as a defense offset package from the twelve CN-235 introduced earlier in the mid-1990s from the original equipment manufacturer of the aircraft, the European aerospace giant CASA. Therefore, there were no benefits in a technology transfer standpoint from the Indonesian variant of the CN-235.[796] In terms of the T-50 work breakdown structure, the contract states that KAI will manufacture two models from its production line, while the remaining 14 aircrafts will be assembled in Indonesia. Additionally, the export contract obliged KAI to provide a yearlong support package of integrated logistics and other technical services at no costs. In this regard, although the price per aircraft was comparatively higher than its competitors, the entire support arrangement included in the T-50 export package countervailed the disadvantages in the price competition. Nevertheless, at the end of the day it was KAI who had to absorb all the costs incurred in the export deal.[797]

The prospects of additional export opportunities to other countries do not look all-so encouraging either. The attempt to cue in the T-50 to international customers, such as Poland, Israel, UAE, Singapore, all failed because of the aircraft's high price tag. The T-50 price revealed to the pubic amounts USD 25 million per unit, which makes the aircraft comparatively higher than other competing models such as the Italian M-346 (USD 24.5 million), or the Russian Yak-130 and Chinese L-15 (both around USD 15 million). The primary reason for the costly price tag relates to the high performance feature built-up around the aircraft propelled with a supersonic thrust. The T-50 was designed to perform multiple roles in mission areas as an advanced pilot trainer, light attack, and to a certain extent an air

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795 Mike Yeo, "F-16 fighter jets to begin journey to Indonesia following US regeneration work," Defense News, December 8, 2017.

796 The original manufacturer of the CN-235 is the Spanish CASA. Indonesia introduced the CN-235 in the early 1990s through a co-production agreement with CASA. Before the 2011 T-50 export, Korea purchased the CN-235 in three phases. First phase introduced 12 aircrafts through a direct purchase from CASA in 1991. The second phase purchased 8 aircrafts through a defense offset trade with Indonesia in the mid-1990s over a sale of KT-1 and military vehicles, and lastly was another offset trade in 2008 for the Korean Coast Guards. 이형삼, "추적: 의혹투성이 공군 수송기 CN-235 도입사업," 신동아, 1999 년 9 월호.

797 KAI intended to fully exploit the Indonesian export case as an opportunity to introduce the T-50 in the international market. Therefore, the firm accepted to bear the business losses from this export. 이철현, "T-50 고등훈련기, 왜 바다 못건너나," 시사저널, 2012.3.12.

superiority fighter. In order to accommodate all these functions, the T-50 had to incorporate fourth generation avionics such as advanced fire control radars and precision guided weapons, which is considered too much for a simple trainer aircraft.[798] The criticism over these exceeding expectations culminated on the inability to devise a reasonable force requirement in the initial stages of the program as the Air Force conceptually inserted performance functions more than a regular trainer capability can absorb. These factors appeared obvious in the unsuccessful bid to sell the T-50 to UAE in 2009. Among the many reasons for the ill-fated attempt to market the Golden Eagle to Dubai, a notable aspect appeared on the fact where the T-50 did not hold the requisite training capability compared to its arch rival, the Aermacchi M-346. The training capabilities of the M-346 include an integrated training system that connects the aircraft with ground based control systems, simulators, mission support systems, and so forth. It was especially known that UAE expressed special interest over the Embedded Tactical Training Simulation (ETTS) of the M-346 that enables a real-time interactive training capability for pilots, a training feature the T-50 Golden Eagle does not have.[799] The T-50 export bids to other countries, such as Israel, Singapore, and Poland, were frustrated for similar reasons considering exorbitant cost and relatively lesser trainer functions. In an effort to overcome the price challenges, the Korean Government localized the aircraft T&E and accreditation process, which is expected to scale down USD 10.5 million from the per unit cost of the aircraft. The localization of the accreditation process, led by the Korea Testing Laboratory under MOTIE, will cover the testing of the high intensity radio frequency and electromagnetic pulse resistance of aircrafts, which used to be outsourced to foreign entities.[800]

7.2.6. Structural Limitations and Program Constraints

Inherent restraints in a program management and technology transfer perspectives caused by export control restrictions and government decision making have limited the potentials for some fully expansive developmental activities over the aircraft. At first, the technical restraints of the T-50 in an export control perspective has become even more contentious in the aspects of improving flight performances and overseas export opportunities in relations with U.S. Government conventional arms transfer policies. In order to maintain U.S. military supremacy and technology advantage, engineering efforts to improve aircraft tactical capabilities were capped within the performance levels below the F-16. For instance, with the intent to incorporate advanced Active Electronically Scanned Array (AESA) radars for the FA-50 combat aircraft, the program authorities attempted to apply the compact Vixen-500E radars developed by the European Leonardo-Finmeccanica (previously Selex at the time). However, the U.S. export control authorities refused to issue the technology transfer license because

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[798] Sebastien Roblin, “FA-50 Golden Eagle: The Low-Cost Fighter that Might See Some Serious Combat,” The National Interest, September 11, 2016.

[799] 이수영, “한국우주항공 UAE 에 T-50 수출 실채 15 억 달러 날렸다,” 일요서울, 2009.3.3.

[800] 홍정원, “고등훈련기 T-50 대당 112 억원 싸진다…KTL, 항공기 시험인증기술 국산화,” 아시아투데이, 2016.6.11.

the system integration requirements of the Vixen-500E radar would necessitate the disclosure of Lockheed's proprietary source code information to a non-U.S. company. The program authorities sought for other options of including an American AESA radar, but none of the radars available in the market at the time were suitable in size to meet the compact requirements of the FA-50.[801] Thus, the program authorities abandoned the idea of introducing an AESA capability and selected the Israeli EL/M-2032 multimode planar array fire control radar under the condition the Israeli company would enter into a coproduction arrangement with a Korean defense contractor (LIG Nex1), of which the installation work onto the aircraft to be performed by a U.S. company as part of meeting the provisos outlined by the U.S. Government and Lockheed Martin.[802]

The U.S. Government and Lockheed Martin exercised its proprietary rights over most of the technology transferred to KAI and the Korean Government by narrowly limiting the extended usage of the program data to only the T-50 variants and other U.S.-origin combat aircrafts such as the F-5 and F-16. In order to apply the program data to other systems or platforms, KAI or the Korean Government had to obtain prior approval from the U.S. Department of State through a revised export licensing process.[803] Also, the substantial technology assistance from Lockheed Martin has subjected the T-50 under the restraints of U.S. Arms Export Control Act, which consequently placed any attempts for international marketing efforts under the scrutiny and approval of U.S. export control authorities. According to the Government MOU that defines the roles of U.S. Government technology assistance, the final aircraft product must obtain an export license issued by the U.S. Department of State before signing an export contract with a foreign customer. Additionally, although the program authorities had high aspirations of introducing the product into the U.S. defense market, the sales prospects of the T-50 would become impossible if another U.S. firm develops an aircraft with similar performance features.[804] Another case that demonstrates the reality of the T-50 being subject to U.S. export control measures was the frustration of the T-50B Black Eagle Aerobotic Team performing in the Zuhai Airshow at China in 2014. With the concerns of a potential unintended disclosure of sensitive U.S. military technologies applied in the T-50B aircraft, the U.S. Department of State denied the Korean Government's request to fly the aircraft in the airshow.[805]

Secondly, continued delays in government decision making during the early periods of the program also resulted in exacerbating developmental uncertainty during critical moments. Between 1993 and 1994, the conditions were ripe to further materialize the trainer requirement into a formal program of record. Samsung Aerospace proceeded with the KF-16 license production, while the auditing authorities strongly insisted to execute the 30% offset obligations deriving from the KFP. Additionally, the government, represented by ADD, signed a series of memorandums with Lockheed

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801 김귀근, "김성회, 경공격기 개발사업 차질," 연합뉴스, 2008.9.8.
802 Arie Egozi, "South Korea picks Israeli radar for FA-50 fighter," Flight Global, September 23, 2009.
803 KAI internal material on T-50 avionics, subsystems, flight control, structures and engines.
804 김권용, "확대경: 현대-삼성 공중전 격화," 연합뉴스, 1997.11.18.
805 고발뉴스, "국산전투기, 창조경제 성공모델인가 국제망신인가," 2014.11.3.

Martin (at the time General Dynamics) that specified the conditions of technology transfer and co-development efforts. In this regard, the surrounding situation was shaped ready for full program execution. The initiatives outlined over the trainer development in this regard were an absolute opportunity that would certainly sustain the development and production capacity of the aircraft-manufacturing sector as a successor program to the KF-16. However, although the industrial situation clearly indicated the need to formalize a follow-up program of the KF-16 license production after program conclusion in 2000, the authorities did not make a decision on the exact production quantities until July 1997. Because of such delays in the early phases, concept refinement and technology maturation did not takeoff into full speed during the early stages of the program.[806] Such delays caused the possible suspension of the aircraft production lines at Samsung Aerospace (KAI) after the KF-16 program concluded in 2000. In order to sustain the production capacities until the T-50 production officially came up to speed, the program authorities were compelled to order 20 additional KF-16 fighters. Oddly enough, the end user of the aircraft, Air force, refused to accept the additional production batches, claiming the new deployments will have grave impacts to the force structure of the air power landscape within the overall theater campaign plan. But eventually the additional production took place for the sake of salvaging the existing aircraft-manufacturing facilities.[807]

Thirdly, interagency participation and coordination was nonexistent. Despite the grandiose scale and scope of the development aspects, the program did not actively reach out to other key players within the interagency process. Accounting for an astronomical development budget over KRW 2 trillion, which made the T-50 the single most expensive development program in the history of Korea at the time, the development authorities decided to use the given resources narrowly available within the defense establishment alone, without showing efforts of incorporating the competencies affordable from other innovation sectors, where the program became a sole product of military endeavors. Hence, although the program required a high degree of mastery in technologically complex systems, the expertise from the Ministry of Science and Technology or the Ministry of Trade, Industry, and Energy was not appreciated at all. The participation of private sector competencies also remained low. University level R&D capacities were not offered a position in the development process in the course of exploiting the opportunities provided in the engineering and manufacturing phases of the program. In a provisional manner, the interagency aspects of the subsequent Korea Helicopter Program (KHP) poses a stark comparison in this regard where the KHP matured as a collaborative effort between the defense and industrial authorities within the interagency/regional arrangement. Assigning the Air Force as the lead program management agency was meaningful in a sense of portraying the exact customer needs into the system requirement and product performance features. But since the Air Force was not professionally trained and experienced in managing a highly complex development program, the overall

806 연합뉴스, "초점: 국방위 방위산업 육성 장기전략 촉구," 1996.10.14.
807 황대일, "FX 사업 추진 둘러싸고 정부-공군 대립," 연합뉴스, 1999.5.12.

management itself at the national side had to rely on the prime contractor (KAI) and its international partner (Lockheed Martin), which obstructed the refinement of government program management skills over aircraft products.[808]

Due to the multiple risk factors associated with developing highly complex product systems, the program costs preplanned for the engineering phases experiences in many cases a steep increase throughout the development process. The T-50 was no exemption from avoiding such cost increasing pitfalls. The T-50 engineering phase was divided in two phases, of which Phase 1 mainly covered the system development and airframe manufacturing process, whereas Phase 2 segment covered the support elements of the program including the development of training systems and integrated logistics. The Phase 1 program costs increased over 25.3% from the initial KRW 1.69 trillion to KRW 2.11 trillion. The major reason of the cost increase attributes from the Asian Financial Crisis, which soared the exchange rate from KRW 857 to KRW 1,179. The program area that experienced the highest increase was in design analysis and prototype development. The Financial Crisis also caused a six-month delay in the program in order for the program authorities to recalibrate its program budget in accordance with the changing uncertainties of the economic situation unfolding.[809]

7.3. Chapter Conclusion

Government intervention in contractor selection practices distorted the prospects of nurturing competence with the domestic industrial hierarchies. Instead of instituting regulative market control measures while spontaneously promoting firm capacities, collusive state-business relations still prevailed, which inappropriately manipulated market dynamics from evolving the aircraft manufacturing sector into the higher ends of competition.

Opening the exclusive contract privileges previously monopolized between Korean Air and Samsung Aerospace to other firms in the mid-1980s by easing existing entry barriers motivated Chaebol firms like Daewoo and Hyundai to diversify into the emerging aircraft manufacturing business. Especially in the case of Daewoo during Peace Bridge-I, the firm exerted full commitment by investing substantial corporate resources into technologically high risk areas while submitting to apparent financial damages with hopes to win subsequent contracts of the KFP. Daewoo also entered into the KT-1 Basic Trainer to further accumulate sector specific knowledge and skillsets with sincere anticipations to become a competitive player in this market. Nonetheless, government defense authorities awarded the contract to Samsung Aerospace instead, thus hoarding the long investments and accumulated experiences of Daewoo's long devotion. Such inconsistencies in government competition policy deteriorated firm performances in financial statements, which later swamped the Korean aircraft manufacturing firms into the Asian Financial Crisis. In this aspect, the government showed

808 강근복 외., pp. 110-114.
809 조남훈 외, T-50 1/2 단계 비용분석 연구, 한국국방연구원, 2002, p. 28.

incompetence in regulating or governing spontaneously grown innovation activities, while placing itself into controversy by collusive state-business relationship with a particular Chaebol firm. Alongside with the continued disconnect between each fighter development program and offset trade arrangement, the aircraft-manufacturing business has relinquished even the faintest expectations of energetically building up its domestic sectoral capacities for innovation.

The impromptu evolution of the fixed-wing sector, however, has supplemented some home grown foundational capacities within the workshop level, which further expanded and intensified through the industrial consolidation process of the aircraft-manufacturing sector after the Financial Crisis. These critical elements gathered from these multiple developmental experiences compiled into the first indigenous initiative to build a supersonic jet trainer and light attack combat aircraft. With the absorptive capacities accumulated from other sectors in program management and engineering, the T-50 development efforts showed apparent accomplishments as a fast follower in the sector. From 1997 to 2002, although under a co-development arrangement with Lockheed Martin, the system development phase of the aircraft took a little over five years. The timeline of the full rate production and deployment phase defied the odds of program failure anticipated from its critiques, which projected the development phase may take over a decade for completion. Surprised to see the fast products of system development unfolding, Lockheed Martin, the original technology provider of the aircraft, dispatched a team from its R&D headquarters to KAI to examine the enabling factors of such fast paced engineering and manufacturing of the aircraft. Notably, included in the Lockheed team was the senior engineer who designed and built the F-35 Lightning-II itself. Such product was a result of professionalism and enthusiasm by workshop level engineers and technicians, striving to craft an indigenous aircraft.[810] Featured commonality in engines between the KT-1 Basic Trainer Aircraft and the KUH Surion Utility Helicopter also assisted the progress of technology sharing and diffusion. The PT6A-62 Turboprop Engine run by the KT-1 shares substantial technical commonalities with the T-700 Turboshaft Engine associated with the Surion Helicopter, since the two engines originate from similar gas turbine structures.[811] The T-50 was the first program that designated the primary system development responsibilities to the prime contractor. This was a huge transition from previous program management practices, in which the government normally designated ADD as the lead system development agency for indigenous development programs while assigning the domestic industry to take over the production piece. Thus, transitioning the system development responsibilities to Samsung Aerospace, now KAI, was a ringing flare for transforming the landscape of defense acquisition programs in terms of the work breakdown structure.

Regretfully, the sole idea of completing the development within a constrained timeline, which further suffered from delays in government decision making over risk assessments, have forced the

[810] 최경운, “5 년만에 T-50 만들어내니 무시하던 록히드 우리가 잘못 봤다,” 조선일보, 2011.4.13.
[811] 국방대학교, 함정 항공전력 방위력개선사업의 경제적 효과분석, 방위사업청 연구용역보고서, 2010 년 12 월 10 일, p. 93.

program development efforts to hastily incorporate foreign technology and components instead of building long-term firm capacities. In regards to the condensed program milestone, Lockheed strongly insisted a one-year, if not at least 6 months, extension of the design phase. The request was fully authentic considering the complex nature of aircraft design, which was imperative to carefully account for all the high risks factors occurring in each development phase. On the other hand, a one-year extension was unacceptable to the program authorities considering the given timeline for initially operating capability scheduled in 2005. Consequently, the T-50 development could not avoid public criticisms for its low localization rates and subjugation into foreign intellectual property rights in technologies and critical components.

Chapter 8. Case Studies –The Korea Helicopter Program, KUH-Surion

8.1. Sources of Capacity Building in the Rotor Wing Sector – From 500MD to MPH

Despite the need of a military heliborne lift capability, the decision to go with an indigenous model constantly stalled in a snail's pace for the Korean military and the aircraft-manufacturing sector. Considering the voluminous scale of rotor wing demand pull in military aviation, which accounted for almost 300 helicopters fully in operation, the sector was gifted with multiple opportunities to accumulate requisite knowledge and technical experiences through a phased developmental approach ranging from license production to full scale development projects. However, decision authorities selected to purchase foreign platforms instead of nurturing the domestic industrial base, awarded contracts intermittently to new entrants based on political ties instead of sustaining the existing production and development capacities, and even disposed of what was left from the limited production capacities established since the late 1970s based on inconsistent industrial policies. This sector reviews the brief history of military helicopter development programs before the launching of the Korea Multi-Role Helicopter Program (KMH) in 2001.

The sheer magnitude of cost incurred in developing aeronautical technologies is an unbearable burden for low developed economies. Whatsoever, the arms race between the two Koreas and the country's requirement to field vast numbers of tactical helicopters for operational purposes created a sizeable market that would suffice the economy of scale for developing helicopters. Most of the technologies were acquired through technology transfers from license manufacturing arrangements and foreign offset deals. The below table illustrates the sources of technology acquisition in the rotor wing sector before the KMH program.

	Sources of Technology	Technology Acquired
Hughes MD500 (co-production under license)	• License manufacturing by Korean Airlines • Machine work, sheet metal worker • Final assembly, test flight	• Forge wielding • Assembly works • Test and evaluation
AH-1S (foreign purchase)	• Technology offset deal • Main body manufacturing • Repair and maintenance	• Main body manufacturing • Depot level maintenance
CH-47D (foreign purchase)	• Technology offset deal • Component/equipment production • Aerodynamics, machine design technical training	• Main body, engine production • Structural mechanics, pilot training, wind tunnel tests
UH-60P (co-production under license)	• License manufacturing • Main body and related components • Substructure assembly, flight test	• Component manufacturing, assembly technology • System integration of mission equipment, test and evaluation
Lynx (foreign purchase)	• Technology offset deal • Component production, depot level maintenance • System concept and component concept technologies	• System concept design • Technology data • Applied design data on blade development
BO-105 (co-production under license)	• License manufacturing • System integration (mission equipment) and certification • Final assembly, test flight	• Main body assembly • Final assembly, test flight • System integration

Table 58. Sources of Technology Acquisition

Source: KHP Program Management Office, Defense Acquisition and Program Administration, 2006

8.1.1 Capacity Building in the Early Stages: License Assembly of Hughes 500MD Defender

Before the early 2000s, the technological foundations of the domestic rotor wing sector derived from the license manufacturing experiences of foreign models or producing components through defense offset trade arrangements subcontracted with overseas partners. Since the 1970s, heliborne airlift capabilities, first introduced in deep jungle guerrilla warfare during the Vietnam War era, transformed the tactics and doctrine of the Korean military. In order to apply the air assault counter-guerrilla warfare tactics learned from the combat experiences in the Southeast Asian campaigns, the Korean military introduced three helicopter variants from the United States through grant-aid programs during the mid-1970s; UH-1H Huey Light Utility Transport, 500MD Light Armed Reconnaissance, and AH-1J Cobra Light Attack.

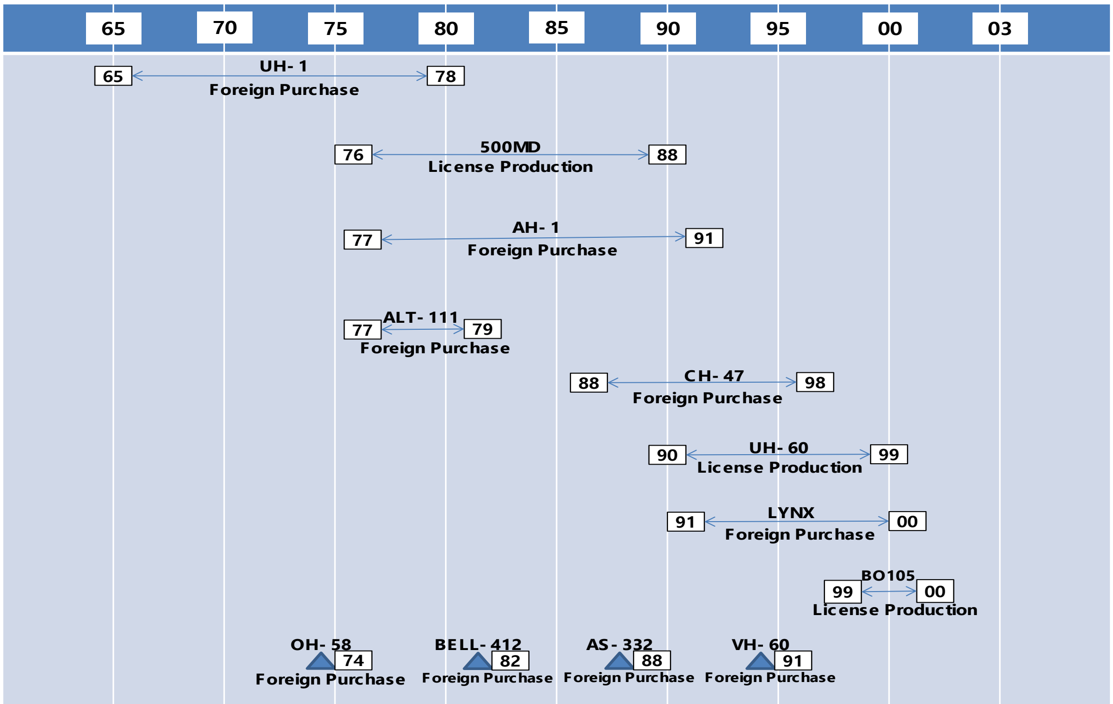

Figure 24. Korean Helicopter Development Programs

At the time, the military top brass expressed firm determination to go domestic with helicopter production as part of the country's strong drive into developing a robust heavy and chemical industry. However, cost factors propelled platform selection. The high price tag associated with the AH-1J Cobra stimulated the procurement authorities to directly purchase the helicopter instead of paving ways for local production. The most preferred utility platform was the UH-1H Huey, which grown popularity and familiarity to the Korean military based on the performances from its Vietnam experience. In the meantime, within the U.S. military, Hueys were retiring from its line of duty and being replaced by UH-60 Black Hawks. Huge numbers of second hand UH-1H Hueys were being released to the market at a very affordable price. The UH-1H price tag offered by the U.S. Government was substantially lower than the regular market price. The affordability of the UH-1H encouraged the Korean military to directly purchase the aircraft instead of coproducing it, which would've eventually cost threefold. Hence, the only platform remaining for local production was the Light Armed Reconnaissance capability, which was under competition between the Hughes 500MD and the Bell OH-58 Kiowa. The coproduction contract was subsequently awarded to the Hughes 500MD attributed to its air-to-air outperformance against the North Korean Antonov AN-2 the much inexpensive offerings from OEM, Hughes Helicopter.[812]

Up until the 1980s, most of the defense technology was provided through U.S. military grant-aid programs entitled under Technology Data Packages (TDP). About 91.8% of the TDPs were in conventional small arms such as rifles, crew served weapons, ammunition, tactical communication, and so forth. However, for apparent reasons, the U.S. refused to provide technologies and design concepts for further sophisticated weapon systems such as maneuver vehicles, aircrafts, air defense guidance systems, etc. Thus the technology introduction channels altered from grant-aid to license manufacturing, which placed the Korean R&D and manufacturing base under U.S. close observation and technology restrictions.[813]

Table 59. TDP Introduced by Year

Year	1971 - 80	1981	1982	1983	1984	Total
Cases	677	85	56	22	13	853

About 91.8% (783) of the TDPs consists of conventional small arms

The Korean Army selected the Hughes 500MD Defender for its localized helicopter production program in 1975. The 500MD was selected for its improved survivability and reduced infrared emission devices, with additional armament loading capabilities. Korean Air and Hughes Helicopters signed the license manufacturing contract in February 1976, and the first 500MD Defender rolled out to the public in May 1977. Following the license production of the 500MD, the chopper expanded its mission scope from airlift/armed reconnaissance to anti-tank, scout and escort missions for attack helicopters, search and rescue, MEDEVAC, etc. Putting into account the extended mission statements of 500MD, the production volume also increased from the initial 100 units to a total of 308 units throughout a six phased production milestone. Also, Korean Air produced about 516 fuselages as a Semi-Knockdown assembly order to support Hughes Helicopter's overseas export programs. These efforts substantially improved the production base of the local aircraft-manufacturing sector.[814]

In the early phase of the program, the development efforts suffered from low technological achievements as the workload assigned to Korean Air pertained to low-skill subassembly work of airframe production. Critical components such as rotor blade manufacturing, transmission development, and engine production were covered by Hughes Helicopter, where Korean Air merely served in roles

812 Cho Myeong-Chin, Restructuring of Korea's Defense Aerospace Industry: Challenges and Opportunities, BICC Paper 28, 2003, p. 25.
813 홍성범, 민군겸용 패러다임과 기술개발전략, 정책보고 94-01, 과학기술정책관리연구소, p. 76.
814 KAL 의 25 년 항공우주사업 첫 국산헬기 500MD, 경제풍월, 2003 년 12 월호.

for final assembly. Through a phased effort by Korean Air, the localization components increased from 1,369 items to nearly 3,300 items in total, accounting for 42% in helicopter cost value. Approximately 70 mid-to-senior level engineers were trained from the 500MD coproduction program. The 500MD Defender composed of a utility airlift role, which loaded 4 passengers, and an armed reconnaissance role, which equipped with 7.62mm machine gun and a 2.75-inch rocket pod. The Korean Army took the initiative and upgraded the 500MD with advanced avionics, high performing engine and rotor blade, and an all-weather armament system to include the TOW-2A Anti-Tank Missiles with an investment of about $3 million.[815] The Korean Army retained the proprietary rights over the TOW-2A armament upgrade investments into the helicopter. In this regard, Korean Air collected a royalty fee of $20,000 per helicopter production when the 500MD/TOW was to be sold overseas. For instance, the Israeli Self Defense Force paid the Korean Government nearly $600,000 as royalty fees for purchasing 30 units of 500MD/TOW Helicopters. In addition to the royalty fee earnings from the TOW reconfiguration, Korean Air earned approximately $20 million in producing 500MD helicopter airframes for Hughes Helicopter between 1981 and 1993.[816]

8.1.2. Helicopter Experience (HX) Programs

The anticipated product life cycle of the helicopters introduced up until the mid-1980s were about to end starting in the early 2000s. In order to promptly replace these helicopters before reaching the shelf life, the defense authorities launched three major helicopter procurement programs in 1987 dubbed the H-X (Helicopter Experiment) Program. The H-X consisted of three major helicopter development programs; Heavy-weight H-X (UH-60), Mid-weight H-X (UH-1H replacement), and the Light-weight H-X (KLH/Bo-105).[817] Contract awards over the three H-X Programs became the source of cutthroat excessive competition among domestic aircraft-manufacturing firms, but also presented good opportunities to leverage advanced aeronautical technologies from participating foreign vendors. However, the H-X Programs were poorly managed by the defense acquisition authorities, which became severely complicated by program overlaps in aircraft performance types, hindered technology accumulation by inconsistent contract awards, and poor contribution to improving sector specific technological readiness levels.[818] The mismanagement of the three H-X Programs interrupted the developmental progression of the rotor-wing sector, which served troublesome for paving future foundations of the indigenous Surion-Korea Utility Helicopter Program.

The Heavy-weight H-X was initiated in July 1987 as a license manufacturing program. Two domestic companies, Korean Air and Samsung Aerospace, allied with foreign firms and competed for the contract award. Korean Air joined forces with Sikorsky by proposing the UH-60 model whereas

[815] Korea Aerospace Industry, Korea Aerospace Industries Association 2015, KAIA Promotion Materials during the 2015 Aerospace and Defense Exhibition, 2015, p.15.
[816] 대한항공, 대한항공 20 년사, 1991, p. 32-38.
[817] 매일경제, “헬기 정부구매 계약경쟁,” 1988.8.29.
[818] 주호석, “항공기 국산화 어디로(하): HX 사업,” 매일경제, 1990.11.14.

Samsung Aerospace associated with the Bell 214ST. In September 1990, the Ministry of National Defense awarded the contract to the Korean Air – Sikorsky consortium with a program budget of KRW 1 trillion over a two phased development deal. From 1991 to 1995, the program’s first phase manufactured 81 units of UH-60 helicopters over a gradual development scheme of purchasing eight complete sets of helicopters directly from Sikorsky in its first step, and the subsequent steps of having Korean Air assume more roles in semi-knockdown final assembly work and producing localized components. The second phase manufacturing program lasted from 1995 to 1999 and delivered 57 units of helicopters to the Korean Armed Forces.

	Manufacturing Steps	Local Workshare	Units	Program Cost (₩ million)	Localization Rate			
					Cost	Item	Total Item	Localized Item
Phase 1 Introduction	Step 1	Direct Purchase	8	601,614	31.5%	48%	11,675	5,466
	Step 2	Final Assembly	12					
	Step 3A	Rear Fuselage	8					
	Step 3B	Front Fuselage	9					
	Step 4	Center Fuselage	44					
	Subtotal		81					
Phase 2	Step 4	Center Fuselage	57	455,455	35.4%	52%	11,675	6,067
Total			138	1,057,069	--			

Table 60. Heavy-weight H-X Program Statistics (UH-60)
Source: 2013 Ministry of National Defense Report to the National Assembly

Korean Air has been criticized for its low commitment in achieving higher technological performance standards from the aircraft-manufacturing business. Having been operating the country’s largest air transport fleet, the corporate identity of Korean Air was focused more on aviation logistics than aircraft manufacturing. Nevertheless, the government strongly urged Korean Air to invest in the aircraft manufacturing sector as a return to the exclusive benefits the company has been enjoying from the public-private collusive business arrangements in aviation services. Withstanding the financial losses anticipated from investing in aircraft-manufacturing, Korean Air accepted the offer ostensibly for ‘nationalistic’ or ‘patriotic’ motivations.[819] However, the decision to invest into aircraft manufacturing was obviously driven by concerns of losing its exclusive position in the domestic air logistics market, which was granted and protected through the collusive links with high political authorities. Hence, an overview of Korean Air’s investment portfolio into major military aircraft programs shows that it mostly consists of purchases for land and facility to house the manufacturing capacities whereas the level of emphasis given into technology acquisition remained insignificant. In this regard, despite Korean Air’s privileged position to accumulate requisite technology in the field, the 42% localization of the 500MD Defender and 35.4% localization of the UH-60 were considered

[819] 조중훈, “항공운송사업의 역할과 발전,” 군사논단 제 9 호, 1997 년 겨울, p. 281

comparatively lower than other competing companies in the market.[820]

Unit: KRW 100 million

Land & Facilities	Equipment	R&D	Total
101 (63%)	56 (35%)	4.4 (2%)	161 (100%)

Table 61. Korean Air Investment Portfolio in Aircraft Manufacturing (1981-1983)
Source: *대한항공, 대한항공 20 년사, 1991, p. 279.*

Whatsoever, the domestic rotor-wing sector wasn't able to fully reap out the benefits from license manufacturing the UH-60 not only because of Korean Air's low commitment to technological development, but also because of the government's inconsistent and discontinuous policy over contract awards. During the Phase 1 manufacturing of the helicopters, Korean Air was also awarded the contract to license manufacture the T700 engine integrated into the UH-60. However, on 22 November 1993, the Heavy-weight H-X Program Evaluation Committee that composed of members from MND, ADD, KIDA, and DQAA, decided to change the engine manufacturer from Korean Air to Samsung Aerospace for stated reasons of streamlining the production processes between final engine assembly/integration/test, component manufacturing, and depot level maintenance. In this regard, the Committee suggested Korean Air to transfer all engine related proprietary rights to Samsung Aerospace considering the license production contract with General Electric, and the tools and equipment purchased for engine manufacturing. The Committee argued that all equipment purchases and licensing fees were paid from government funding, therefore should be returned to government ownership, and should not remain under the ownership of Korean Air.[821]

Apparently, the decision backfired on Korean Air, where the aircraft firm claimed that the decision proclaims preferential treatment to Samsung Aerospace, a relatively late comer in the business who disqualified earlier from the contract award competition over the UH-60 Program. Samsung Aerospace claimed that as the country's sole company that specializes in aircraft engines, the company is more than qualified against Korean Air over the license manufacturing of the T700 engine. Also, based on its experience and accumulated skill set in the aircraft engine business, Samsung assessed that it should take an additional investment of KRW 6 billion into building new engineering facilities for the T700. In terms of the cost assessment over engine manufacturing, Samsung argued that it would take Korean Air more than KRW 10 billion to build the same facility, which would incur additional cost and most likely increase the eventual price tag of the helicopter in general.[822] As a result, the Committee changed the T700 contractor to Samsung Aerospace for the Phase 2 production of the helicopters. But Samsung had to renegotiate a new arrangement with General Electric for the manufacturing license, since Korean Air persistently protested to give-up its original technology assistance arrangements with the American firm. In the long run, Samsung only had to invest an additional KRW 3 billion to augment

[820] Samsung Aerospace marked 62% in localization in the KF-16 Fighter Program and 41% localization in its jet engine, and Daewoo Heavy Industries reached a 60% level in the KTX-1 Program.
[821] 매일경제, "삼성에 면허 이전 거부 대한항공 UH-60 헬기 엔진 양도 불가 주장," 1993.11.23.
[822] 경향신문, "군헬기 조립업체 변경 파문," 1993.11.23.

its pre-established facilities to manufacture the T700 engines.[823]

The third Light-weight H-X, dubbed the Korea Light Helicopter (KLH) Program, was first announced in July 1990 with a program objective to replace the earlier 500MD Defenders and to augment armed reconnaissance capabilities in support of armor maneuver tactics. The fate of the KLH program was doomed with a number of reasons for failure due to a result of continued indecisiveness and inconsistencies of generating war fighter's needs, disconnections and incoherence between defense acquisition and industrial policies, cutthroat competition over an ill-defined force requirement, which eventually caused huge business losses and ineffective technological accumulation. The program portrayed inadequate and unprofessional management practices in generating warfighter requirements, which constantly depicted discordances in policy coordination between force planners, defense R&D institutes, defense acquisition program managers, and industry planners. The program objective was to fulfill three mission areas listed below.

1) Support the Army's heavy attack helicopter fleet (AH-X: AH-64 Apache) in scout missions (cancelled)
2) Support the Army's main attack helicopter fleet (AH-1S Cobra) in scout missions
3) Replace the aging 500MD light utility helicopter

The warfighter requirement for the first and third objective was cancelled because the Army's doctrine continued to change without presenting a coherent operational picture into its theater wide aviation operations.[824] The program acquisition strategy was to develop 147 scout helicopters under foreign license in support of the existing 5 AH-1S attack squadrons and the proposed heavy attack helicopter squadrons for the future AH-X (Apache) program. The multiple changes in Required Operational Capabilities (ROC) reduced the number of helicopters all the way down to 12 units.[825] The constant changes in force requirements, which were drafted by the Korean Army, represented the lack of professionally translating warfighter requirements into a coherent force structure planning document.

Initial competition for contract award was fierce, at which six domestic firms, allied with foreign partners, severely clashed in an intense battle game against each other. Samsung Aerospace lined up with the Aerospatiale's A365 model, while Daewoo Heavy Industries chose West Germany's Messerschmitt-Bölkow-Blohm (MBB) Bo-105. Other firms such as Korean Air joined forces with the McDonald Douglas MK520, and Hyundai Space and Aviation partnered with Bell's 406CS. Lastly, a new entrant into the market, Sammi-Augusta, established a 50:50 joint venture with the Italian Augusta Helicopters to co-produce the A109 model.[826] On July 1990, Daewoo Heavy Industries was awarded

823 박대호, "삼성항공 대형 헬기엔진 생산," 경향신문, 1995.6.3.
824 Army Headquarters, Program Updates to the National Assembly, 13 August, 2007.
825 Ministry of National Defense, Korea Light Helicopter Program Update to the National Assembly, August 10, 2012.
826 장성효, "차세대 헬기사업(HX) 주계약업체 월내 선정," 중앙일보, 1990.7.9.

the KLH contract with a program budget of KRW 300 billion, and subsequently invested over KRW 150 billion in equipment tools and facilities with an ambitious objective to become a world class helicopter manufacturer until 2010.[827]

However, with the AH-X program being cancelled and the 500MD replacement type branching out of the KLH and becoming a separate program of its own, the number of scout helicopters planned under the program quantities subsequently reduced to 54 units. What made matters worse was the Army constantly changing its doctrine on maneuver tactics, which discredited a close air support scout function associated with the main attack helicopter squadrons. Such uncertainties in aviation doctrinal development brought the number of KLH orders down to 36 in 1994. Without a proper scale economy, the unit price of the helicopter increased nearly 5 times the original sale value. The tradeoff for the cost increase was performance and technology development, where Daewoo had to purchase major component modules directly from MBB instead of localizing the technology. Because of this aspect, the Bo-105 failed the preflight acceptance test three times in a row by ADD, which raised skepticism over the purchasing of the helicopter in the first place. There were also some allegations that ADD deliberately failed the Bo-105 in order to convince acquisition authorities to directly pursue the 500MD replacement program instead of the KLH.[828]

Period	Required Units	Justification
Dec. 1988	147	• Armed reconnaissance for AH-1 Squadrons • Augment 500MD shortages
Oct. 1990	106	• Armed reconnaissance for AH-1 Squadrons: 57 • Armed reconnaissance for AH-X Squadrons: 36 • Reserved: 10 • Pilot training: 3
Jun. 1992	86	• Armed reconnaissance for AH-1 Squadrons: 52 • Armed reconnaissance for AH-X Squadrons: 26 • Reserved: 6 • Pilot training: 2
Dec. 1992	54	• Armed reconnaissance for AH-1 Squadrons: 36 • Armed reconnaissance for AH-X Squadrons: 18
Apr. 1994	36	• Armed reconnaissance for AH-1 Squadrons: 36
Nov. 1997	12	• Scout functions for AH-1 Squadrons: 12

Table 62. Changes in KLH Requirements
***Source:* KLH Program Update to the National Assembly, August 10, 2012.**

The performance features also showed disappointing qualities where the Bo-105 lacked anti-tank missile launching functions because of the tradeoffs made between cost and airlift weight. The substantial reduction of helicopter units, from 147 to 12, became costly to repair and maintain a separate batch of the Bo-105 engines. The basic engine designed for the Bo-105 was the 550 horse powered 250-C28C turboshaft engine. In order for the Army to maintain economy of scale with the maintenance cost of the engines, it changed the 250-C28C to the 420 horse powered 250-C20B engine, which was the same engine installed in the 500MD Defender. Because of the degraded airlift power with lesser performing engines, the Bo-105 was not capable of loading additional armaments onto the platform.

827 매일경제, "대우중공업, 항공기 종합생산체제 추진," 1995.12.4.
828 National Defense Committee Proceedings during the National Assembly Audits, 21 October, 1990.

Therefore, the wording 'armed reconnaissance' was eliminated from the Bo-105 title and simply became a scout helicopter with no anti-tank heavy armament capability.[829] This became a representative case of illicit collusion between politics and industry in the history of Korean defense acquisition, by means of changing required operational capabilities generated from warfighter needs in order to sustain corporate business operations. Eventually, attributed to the changing tactical requirements of the Army, compounded with the moratorium in public finances from the 1997 Asian Financial Crisis, the decisions culminated into the near cancellation of the KLH in late 1996. With the sunken cost already committed into the KLH program, Daewoo became desperate and was prompted to lobby extensively towards the senior military leadership to prevent complete program cancellation. The program survived with producing only 12 scout helicopters, but it resulted in simply achieving local assembly skills of the Bo-105 with no recognizable technology obtained from system development.[830]

The objective of the mid-weighted HX program was to replace the aging UH-1H fleet with an indigenous version. The Samsung Aerospace-Bell Helicopter partnership and the Daewoo Heavy Industry-Sikorsky consortium competed for the program. Samsung arranged a deal with Bell to license manufacture a derivative of the widely popular Bell-407 model at the time. However, the authorities continued to delay the decision over the mid-weighted HX, which resulted in the eventual cancellation of the entire program in 1992 for reasons undisclosed. Reportedly, both Samsung and Daewoo had to endure approximately KRW 15 billion in business losses for committing resources upfront in preparation of the contract award.[831] But Samsung Aerospace's objective to become an aircraft-manufacturing giant persevered. The Samsung-Bell partnership later evolved into the commercial utility program in the mid-1990s. The Multi-Purpose Helicopter Program (MPH) that emerged was initially raised by the Ministry of Commerce and Industry with an objective to indigenously develop a light-weighted eight (8) passenger helicopter. In the spring of 1996, after withstanding the losses from the mid-weighted HX program, Samsung Aerospace registered for the domestic license production of the Bell 407 single-engine utility helicopter as part of responding to the MPH program needs. Samsung intended to upgrade the 407 model with a twin-engine 6,000 lbs. class mid-weight helicopter and dubbed it the SB427 model, a derivative of the original Bell-407 configurative platform.[832] The license production of the SB427 provided Samsung the responsibility for development and manufacturing of the fuselage, cabin wiring, and fuel system, which was worth approximately $300 million.[833] In order for Samsung to prove its commitment in aircraft-manufacturing, the company headquarters dispatched approximately 50 engineers and technicians to the Bell Helicopter R&D center for technology transfer

[829] 최훈, "군장비 도입 때 업체 봐주기 의혹," 중앙일보, 1996.10.21.
[830] 조진수, "국산헬리콥터산업 성공 가능성은?" 월간조선, 2017 년 1 월호.
[831] 매일경제, "방산기술 사장 우려," 1994.6.13.
[832] 동아일보, "삼성 경헬기 생산 허용," 1996.2.24.
[833] Bell 427 Multipurpose Utility Helicopter, Aerospace-Technology, available online at https://en.wikipedia.org/wiki/Bell_427

and technical training in system design and engineering. An additional 40 technicians from Samsung joined the training to acquire knowledge and skills in test and evaluation.[834] The program later merged with the military's intent to replace 200 light-weighted 500MD/TOW Anti-Tank and AH-1S Attack Helicopters through the indigenous development of a commonality platform. In 2001, the MPH performance requirements later absorbed the cancelled mid-weighted HX (UH-1H replacement) program, which made the MPH a more lucrative business agenda for both Government Research Institutes and other business entities instead of pursuing the largely downsized KLH. Unfortunately, the MPH program that seemed to present promising business opportunities for the domestic rotorcraft sector was condemned with the nation's economic condition. In 1998, in order to cut corners in light of the Asian Financial Crisis, the decision authorities completely cancelled the MPH program.[835]

The discordances between the military and commercial authorities up until the late 1990s in regards to the drafting of a strategic industrial roadmap for the rotorcraft sector was a source of serious business losses and setbacks in technological accumulation and sectoral progress. Further complications caused by the Asian Financial Crisis subsequently resulted in the huge overhauling of the entire aircraft-manufacturing sector. Military requirements were shortsighted with negligible considerations towards building technological competence. Industrial authorities showed amateurism in picking national champions and were incapable of providing concentrated support in financial terms and technological assistance. Because of this flustered indecisiveness in industrial policies, business conglomerates engaged in the aircraft-manufacturing sector became involved in a dog-eat-dog cutthroat competition, which brought about nothing but miserable failures in obtaining both a well-formed military force structure and a technologically competitive aerospace industry.

8.2. Korea Helicopter Program (KHP)

The Korea Helicopter Program (KHP) was initiated as a concerted effort between military and high-tech industrial authorities that included the military (MND), industrial (MOTIE), S&T (MOST), the prime contractor (KAI: Korea Aerospace Industries), and other commercial entities engaged in aircraft-manufacturing. It was a highly complex program, both organizationally and commodity wise, with the sole purpose to indigenously develop and deliver the first Korean made helicopter. This section will review the background, major program milestones, key linkages that enabled technology transfers and capacity building, and implications to innovation potentials throughout the entire process of the development efforts.

[834] 이상철, "한국의 헬기개발 기술현황과 육성을 위한 제안," 항공산업연구 제 46 집, 1998, pp. 41-43.

[835] The MPH program was re-engineered several years after its cancellation and revived as the Korea Multi-Purpose Helicopter (KMH) in 2001. 최우영, "한국 항공기산업의 발전과정과 현황," 항공우주산업기술동향 제 9 권 1 호, 2011, p. 32.

8.2.1. Development Motivations and Objectives

The government authorities in the late 1990s started to view the need to develop an indigenous helicopter unrestrained from foreign technology control that provided fully reliable integrated logistical support. Korea had a sizable domestic helicopter demand pull of around 1,000 in operations, at which military helicopters constituted nearly 700. Thus, the domestic helicopter market formed a well sized economy of scale. However, Korea did not hold a distinctively indigenous helicopter of its own despite the fact of carrying the world's 7^{th} largest helicopter fleet. Around that period, although carrying a much smaller heliborne aviation force, Japan already completed the full deployment of its own scout/observation helicopter, the Kawasaki OH-1 Ninja, in the late 1990s, which was entirely engineered and manufactured by Japanese technology.[836]

Industrial forces from MOTIE and MOST also perceived the need to sustain the domestic rotor-wing sector with more production orders. Military orders for the license manufacturing of the UH-60 utility helicopter was about to dry up in 2000. Although there were potential programs such as the MPH or KLH under development or in the drawing board, the overall rotor-wing sector at the moment received only intermittent orders in MRO work from the military. Therefore, there was an urgent need to find new business opportunities to keep up the production lines moving. On the other hand, albeit the comparatively small scale against the military market, the commercial aviation needs were growing in big percentages in the early 2000s. The growth of commercial rotorcraft aviation during the ten-year period between 1994 and 2003 reached a 7.1% increase, with the public sector such as the Forestry Service, Police Force, and Coast Guard growing higher by 9.3%. Especially, the middle-weight helicopters in the 18,000lb class category, which constituted only 2.4% among all commercial helicopters, were growing in demand. The demand pull from the market increased up to 85.7% during this period, compared to the global trend of 20%. More importantly, the public sector was leading the growth patterns by marking a 122% rate of increase. Based on these trends, the number of commercial helicopters operating in both public and private sectors was projected to increase to about 3.4 times the numbers of in 2003.[837] In this regard, senior government officials, both from the military leadership and industrial authorities, shared a common understanding over the need to build-up the domestic rotor-wing sector for fulfilling both military and commercial objectives.

The indigenous development program formally started as the Korea Multi-Purpose Helicopter Program (KMH) in 2001 after picking up the remaining components from the previously cancelled MPH, with a target development plan to locally manufacture both utility and attack functions simultaneously for a total of 477 (299: utilities, 178: attack) helicopters.[838] With an estimated program budget of KRW 15 trillion, the largest in the history of Korean weapon systems development at the time

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836 Interview with a former senior executive from the Korea Helicopter Program Development Group, 5 July, 2012

837 안영수, "국내헬기시장의 구조 분석과 중장기 발전전략," KIET 산업경제분석, 2005 년 12 월, pp. 42-45.

838 KMH laid out a phased development plan, or a concurrent procurement strategy, which was to complete the utility prototype first between 2004~2010 (6 years), followed by developing the attack prototype between 2004~2012 (8 years)

being, the KMH intended to consolidate the utility and attack version helicopters into a commonly designed platform to streamline and simplify the complex helicopter fleet of various kinds. Also, KMH intended to reduce the ever growing O&M costs of the helicopters by obtaining compatibility of key components such as in mission equipment packages, power transmission, and so forth through shared design and engineering configuration between the utility and attack variants. As such, the design scheme was to combine the utility functions of the antiquating Bell UH-1H and Hughes 500MD Scout helicopter, and incorporate the attack functions of the antiquating AH-1S Cobra and 500MD Tow Light Armed Reconnaissance helicopter into a commonly designed platform sharing commonalities in engines, rotor blades, airframe, and other control components.

The domestic industry also complied with such growing business opportunities. In 2005, the Federation of Korea Industries (FKI) and the Ministry of Commerce, Industry, and Energy jointly announced the aircraft industry as one of the areas that shall drive the Korean economy for the next ten years. The aircraft industry will accomplish this status through the domestic research and development of major military acquisition programs such as the Korean helicopter (KHP) and fighter (KFX) program. The consolidated entity of major conglomerates from 1999, KAI was the heir apparent to be awarded the government contract for these future development opportunities. At the critical juncture of the KHP program, the FKI believed that the current domestic market demand of these aircrafts from the South Korean military will both mature the technical work force as well as the capacity of the industry.[839]

In this regard, the KHP was anticipated to have a significant spin-off effect to the local Korean economy, which was worth KRW 9.2 trillion and creating 50,000 new jobs for the Korean aircraft industry.[840] The substantial capital invested to the program is believed to make comprehensive strides in areas such as in principal components and materials, automobiles, control systems, information technology, and energy.

The intention for consolidating different mission area helicopters to a common platform, in order to achieve efficiency in logistics and O&M, adheres to a recent trend in the global aircraft industry.[841] Such trend of maintaining high-commonality in utility/attack approach is found in the continued development case of the Bell UH-1Y Huey and AH-1Z Super Cobras for the U.S. Marines, which shares a compatibility ratio of 70% in airframe and subcomponents.[842] The Eurocopter Group follows a similar approach in different variants of modular design within their tactical transport and naval helicopter fleet as well.[843] The primary reason to combine different mission platforms is to share essential components which include drive train, rotor head, tail boom, avionics, software and controls

839 Yoo In-ho, "Automotives, Shipbuilding, Aerospace As An Engine Of Economic Growth The Next Decade," Financial News [Korean text], 2005. 11. 15.
840 DAPA defense program update to the National Assembly, [Korean text], August 29, 2006
841 Bell Helicopter Homepage, http://www.bellhelicopter.com/en_US/SupportServices/Support_Services.html
842 The commonality rate of the Bell UH-1Y and AH-1Z in core functional areas is expected at 84%
843 See "Eurocopter hands over first NH90 to Swedish Air Force in Paris Air Show Ceremony," http://www.eurocopter.com/bourget/medias/news/pdf/1st-Swedish_NH90_Delivery-GB.pdf and "Eurocopter upgrades its most affordable twin to enter Market in 2007: More performance for similar cost" http://www.eads.net/1024/en/pressdb/archiv/2006/2006/20060227_ec_as555np.html

in order to save costs and resources through reducing redundancy in research and development and in follow-up logistical support and maintenance needs. Such design and engineering practice in commonality within the UH-1Y and AH-1Z program is expected to save the U.S. Marine Corps approximately $3 billion in operating and support costs over the 30-year expected lifespan. The practice of sharing a common platform was believed to reduce 30% of resources compared to the option of developing separate platforms for each attack and utility missions.[844]

However, this line of thought has been seriously challenged by heavy cost over-runs and schedule delays due to difficulties in design and systems engineering in the development phase of the program.[845] The ill-fated development and subsequent cancellation of the Boeing-Sikorsky RAH-66 Comanche helicopter, the U.S. Army's stealthy light-attack/armed-reconnaissance capability, encapsulates a case where a program accommodating too many operational functions can go farther but fare worse. Having to absorb the horrific technical challenges still far to overcome while tolerating the diminishing operational needs of light-attack/armed reconnaissance helicopters proven from the real combat grounds in Iraq and Afghanistan, lesser options remained for the U.S. Army but to cancel the 22 year $6.9 billion development project in 2004.[846]

8.2.2. Technical Assessment and Readiness Level of the Rotor-Wing Sector before the KHP

As of 2006 in the very start of program, Korea's technology readiness level in the overall rotor-wing manufacturing sector industry has marked 65% to that of its competitors in Northern America and Western Europe. Korea has shown its strength in the category of unmanned aerial vehicles, reaching almost 90% in every field, whereas technology types in other aircraft areas such as regional commuter jets and helicopters scored around 70% or less.[847]

The degree of technological maturity in the rotor wing sector was considered to reach almost 80% in the category of manufacturing skills and infrastructure compared to its forerunning competitors. Most of its strong points were identified in engine and component manufacturing. However, in order to technologically advance into the levels of North American and Western European countries, Korea still needs to acquire further skills and knowledge in system design and integration engineering, in which it still shows significantly low maturity levels around 60%.[848]

	Product Development	Indigenous Component Support	Manufacturing and Infrastructure	Quality Assurance	Total
Business Jets	60	70	75	85	73
Unmanned Aerial Vehicles	90	80	90	90	88
Helicopters	60	65	80	60	65

Table 63. MOCIE, 2006 Techno-report, December 2006

[844] John C. Milliman, "First All-up AH-1Z, 2nd UH-1Y Make Initial Ground Runs," Navy Times, 21 Aug, 2002
[845] USMC Helos Breach Cost Overrun Laws, available online at http://www.military.com/features/0,15240,183604,00.html?ESRC=marinenews.RSS
[846] Dan Ward, "Real Lessons from an Unreal Helicopter," TIME, 25 May, 2012.
[847] Ministry of Commerce, Industry, and Energy, Techno-Report, December 2012
[848] Ibid.

As of June 2002 immediately after the approval of the KMH, the two primary public research laboratories, Agency of Defense Development (ADD) and Korea Aerospace Research Institute (KARI), that took the lead in system design and technology development, accounted for about 454 in R&D manpower, in which 298 researchers obtained prior experience in aircraft design and development.[849]

	Experienced Technicians	Additional Manpower	Total
Helicopter Airframe	186	106	292
Mission Equipment	112	50	162
Total	298	156	454
	65.64%	34.36%	100%

Table 64. ADD and KARI R&D Manpower Rotor-Wing Development
***Source:** 어하준, 고병성, "다목적헬기(KMH) 개발사업에 관한 연구," 국방정책연구, 2002 년 겨울*

The industrial base around the same period that were able to support the development efforts in airframe and mission equipment accounted approximately 20 companies. The primary contractor of the program, KAI, was supported by Korean Air in airframe components, and other mission equipment modules such as in avionics, integrated flight data processing and control, multi-function display, etc., were supported Samsung Thales, LIG Nex1, Huneed Technologies, and so forth. About 1,667 engineering and manufacturing workforce was available to support the helicopter development process, with about 657 experienced technicians who had prior involvement in helicopter development in the past.[850]

Technical Field		Company Name
Aircraft Development		KAI, Korean Air
Airframe	Main Body/Wing	KAI, Korean Air, Soosung Airframe
	Other Components	WIA, Dongmyung Heavy Industries, Korea Lost-Wax, Dongseo Mechanics, Hanwha, Cheonji Industries, Seojin Instech
Mission Equipment		Samsung Thales, LIG Nex1, Huneed Technologies
Composite Materials		Korea Fiber, Hanwha, Oriental Manufacturing, Sun Aerosys
Engine		Samsung Techwin
MRO		KAI, Korean Air, Korea-Bell Helicopter

Table 65. Domestic Helicopter and Mission Equipment Manufacturers
***Source:** 어하준, 고병성, "다목적헬기(KMH) 개발사업에 관한 연구," 국방정책연구, 2002 년 겨울*

Because of such low anticipation in technological readiness levels, the KHP was mostly criticized for the developmental scope and risk factors in the preliminary stage of the program. The Korean aircraft-manufacturing sector, both fixed-wing and rotor-wing, lacked experience in critical design and engineering skills. Normally, the technological progression of a late starter mostly follows a four phased evolution through foreign direct purchase-license engineering or co-production-system upgrade-indigenous development.[851] In this aspect, the preliminary phases ranging between license manufacturing and system upgrades were considered a principle in the normal developmental

849 어하준, 고병성, "다목적헬기(KMH) 개발사업에 관한 연구," 국방정책연구, 2002 년 겨울, p. 14.
850 Ibid., p. 15.
851 The Second Phase Upgrade of the KOREA Navy P-3 Reconnaissance Aircraft Project adheres to such evolutionary development as it recently contracted L-3 Communications for system upgrade. The contract accompanies significant technology transfer of some critical design technology for mission equipment, system analysis and system design technology for the tactical support center, analytic technology for logistical support and other key mission equipment. *Monthly Aerospace,* [Korean text] pp. 34-35.

procedures in aircraft-manufacturing. Most second tiered foreign helicopter manufacturers such as the Kawasaki OH-1, Denel Rooivalk, and HAL LCH, all went through this routine developmental process. KHP skips the third stage and moves directly into the later most sophisticated and demanding phase. Technology acquired through indigenous research and development was limited, which was a restraining factor in building competence over system design and structural analysis skills.

In order to overcome these deficiencies, the acquisition strategy of the KHP was to execute the program as a cooperative development effort by strategically aligning with an established foreign partner in this sector. Thereby, KHP became a classic example of a country seeking to leap forward the routine developmental phases by joining forces with a forerunner in the industry. To the surprise of the international business community, on December of 2006, the Korean Government announced that it will conclude on a joint venture with the European helicopter mogul, Eurocopter, under a 50-50 percent ownership for co-developing, international marketing, the utility variant of the KHP program.[852]

8.2.3. Program Milestones: Major Stakeholders in the KHP

The Korea Helicopter Program evolved from the consolidation of different program needs that emerged throughout the process of determining the exact operational and commercial requirements of the domestic rotor-wing sector. The program underwent a number of changes in the lead development agency, which varied from industry driven to government driven, military driven to commercially driven, indigenous development driven to foreign procurement driven, etc.

Regarding the performance specifics, as noted in previous sections of this chapter, the KHP picked up the remnants of the KLH and the MPH program, of which both became either substantially downsized or completely cancelled. The operational needs of the KLH required a maximum takeoff weight of 6,000 lbs. equipped to perform scout and light attack missions. The principal agent for program development in the KLH was driven by industry (Daewoo Heavy Industries), with limited government (ADD) involvement. As mention before, the availability of a larger attack platform placed lesser priorities on a scout/light attack helicopter, which reduced the total numbers from 130 to 12. The commercial/industrial authorities, led by the Ministry of Commerce, Industry, and Energy, in collaboration with the Agency of Defense Development, picked up from the KLH and added the commercial lift requirements from the market, which devised the slightly heavier MPH program (8,000 lbs). The program objective was to develop 200 multi-purpose helicopters that can serve in both military and commercial capacities. After program cancellation due to the Asian Financial Crisis, the MPH absorbed the force structure needs of an attack variant, and progressed into the Korea Multi-Role Helicopter (KMH) Program in 2001. The KMH consolidated the utility and attack operational requirements of the military and commercial entities with a larger takeoff weight of 15,000 lbs.

[852] Surion: Eurocopter's KHP/KUH Helicopter Deal, *Defense Industry Daily*, available online at http://www.defenseindustrydaily.com/korea-approves-eurocopters-khp-helicopter-deal-02325/

Technological development would be driven by industry, while the government provided oversight and technological assistance. However, because of the technological risk factors associated with concurrently developing a utility and attack variant simultaneously, the program authorities separated the two platforms into an independent development program, which became the Korea Helicopter Program (KHP) for the utility version and the Korea Attack Helicopter (KAH, later Light Attack Helicopter) in 2005.

Year	Name	Max Takeoff Weight	Configuration	Lead Agency	Program Method	Quantities *(Initial)*	Result
1988	KLH	6,000 lbs.	Scout/light attack	Industry (Daewoo)	License Manufacturing	130/12	Reduced to Local production of twelve Bo-105
1995	MPH	8,000 lbs.	Multiple functions	Gov (ADD)	Indigenous Development	200/0	Cancelled, replaced to KMH
2001	KMH	15,000 lbs.	Utility/Attack (Concurrent Development)	Industry (KAI)	Indigenous Development	250/250	Utility/Attack separated, transformed to KHP
2004	KHP	19,000 lbs.	Utility/Attack (Sequential Development)	Industry (KAI)	International Co-Development	250/250	Utility (Surion): 19,000 lbs. Attack (LAH): 10,000 lbs.

Table 66. KHP Program Evolution

In June 2001, after reflecting all required operational concepts suggested from the military and the economic ripple effects into the aircraft-manufacturing sector, 186th Joint Chiefs of Staff Council finally approved the KMH program. The Aerospace Industry Development Policy Council, convened by MOCIE in March 2003, also supported the further progression of the KMH Program under the collaboration between MND and MOCIE.

During subsequent review sessions considering the program management structure of the KMH, the defense acquisition authorities decided a work breakdown structure where the government (MND) would take responsibility over material solution analysis and concept exploration/development while the industry (KAI) would take over the system design and development phases. Within the purview of Policy Working Group under the Executive Program Management Committee, the authorities decided to develop the utility transport version first and the attack version at a later time after reviewing the development progress of the utility version. The objective was to optimize commonalities in platform and subcomponents between the utility and attack variants.[853]

Indigenous development programs were always challenged by foreign platforms because of not only the high price tag necessitated in the procurement, but also the developmental risks associated with the indigenous option. Foreign platforms from western advanced aerospace firms had a proven record of technological reliability and combat readiness through the number of experiences in the warzone. At the time of the KMH proposal, the Korean Army was in a predicament between building force structures opposed to supporting the local economy. The Attack Helicopter Experiment Program (AH-X) was an attack platform aspired by the Korean Army for many years since its first force requirement generation in 1990. It provides a day and night all-weather capability that strikes deep into the second echelons of enemy forces. Various platforms such as the Boeing AH-64D Apache Longbow, Bell AH-1Z, Kamov

[853] DAPA defense program update to the National Assembly, [Korean text], August 29, 2006

KA-52K competed for program selection, with the Korean Army most preferring the Apache option. The program was always in conflict with domestic programs because of the unbearable program costs competing for priority over other programs. In the process of program development, the astronomical cost of introducing two squadrons worth of 36 attack helicopters, on top of the shockwaves of the Asian Financial Crisis of 1997, the AH-X suffered some ordeals until the defense authorities decided to delay the program in order to support the development of the KHP.[854]

The strong justification to launch the development program was not only on the military and economic impact factors, but also on the actual business opportunities presented in the market. Although Korea is a late comer in the global rotor-wing industry, there seems to have been still some leeway in the market space where Korean helicopter products can competitively rise as a global player. The global rotor-wing market is segmented into many areas such as in military – commercial, utility – attack variants, heavy weights – middle weights, and so forth. Most of the forerunners in this field, such as Boeing, Bell, Sikorsky, Augusta-Westland, Eurocopter, etc., compete in the heavy weight sectors of the industry. However, there exists almost no competition in the middle weight markets, at which point the KHP becomes an attractive marketable item. According to a Teal Group report on the global rotor-wing market, the overall demand will likely increase about 23% from 1,156 units to 1,502 units between 2004 and 2013.[855] Among the 1,502 units, approximately 90% are the variants that go to the global heavy weights in the market. The remaining 10%, or an annual average of 150 helicopters, are mostly middle sized helicopters weighing approximately 13,000~15,000lbs per unit, in which no visible contender, other than the KHP program, was identifiably competing for. Another source marked a potential quantity of 250 units per year for missile sized helicopters could be marketable worldwide.[856] Therefore, with the extensive marketing campaign from the government and Korean firms, the KHP program will be able to reap some significant profits in this global niche market. In terms of the domestic market, the utility variant from the KHP program has secured a stable quantity of 250 helicopters until 2018, which is worth KRW 9.1 trillion accounting for its lifecycle costs.

At the exploratory phase of the program, the KMH confronted significant criticism from the budget offices and public opinion groups over the astronomical figures in cost elements.[857] The KMH was at first proposed with total program cost of KRW 6.23 trillion within a six-year period, broken down by a development cost of KRW 750 billion and manufacturing cost of KRW 5.4 trillion. However, the cost figures and program duration varied between different assessment methods that caused confusion and skepticism over the program's public credentials. In this regard, in order to come up with a consensus in carrying out the program, a third party assessment that could deliver an objective perspective in program cost and feasibility analysis was recommended. Hence, three public

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854 오동룡, "사상최대의 전력증강사업 – 기로에 선 육군 헬기사업," 월간조선, 2003 년 9 월호.
855 Teal Group, Short Term Market Forecast of the Global Rotor Wing Industry, published March 2004, p. 3.
856 Eurocopter's KHP/KUH Helicopter Deal
857 최현주, "30 조원 국책사업 결정이 경미한 사안인가," 참여연대 평화군축센터, 2003.9.29.

organizations – Korea Development Institute (KDI), Board of Audit and Inspection (BAI), and the National Assembly Budget Office (NABO) – conducted an interim feasibility analysis of the program.

The KDI assessment ruled the KMH with positive ripple effects into the economy. From December 2002 to June 2003, KDI reviewed technological, economic, and policy implications of the program, in which the feasibility study recommended a cooperative development under an international partnership, with a higher percentage in R&D responsibilities, provided that the domestic market assures about 500 helicopters in sales prospects, would increase the success factors of the program.[858] The BAI assessment, conducted from December 2003 to April 2004, reviewed the appropriateness of force requirement quantities, program success potentials and substitutability, and economic impact. The BAI results conveyed negative ramifications, which expressed concerns in excessive requirements quantities, non-substitutable options in case of program delay or failure, and low feasibility in indigenous development against foreign procurement. The NABO review was basically a public scrutiny of the two previous feasibility studies, which reconfirmed the need to pursue the indigenous development option.[859]

(Unit: KRW trillion)

Performance Category		KMH Development		Foreign Procurement (C)	Differences	
		KDI (A)	BAI (B)		KDI (A-C)	BAI (B-C)
Life Cycle Costs	Development	2.4	2.5	-	2.4	2.5
	Production (470 units)	13.4	19.2	9.6~11.3	2.1~3.8	7.9~9.6
	Maintenance Cost (30 years)	14.9	17	15.3~18.4	0.4~3.5	1.4~1.7
	Total	30.7	38.7	24.9~29.7	1.0~5.8	9.0~13.8
Value Added Effect to the Economy		9.8	12.5	2.4~2.9	6.9~7.4	9.6~10.1

Table 67. Comparison of Feasibility Studies between KDI and BAI (Considering both Utility and Attack Variants)
Source:* *국회예산정책처, 국방 KHP 사업 사전평가, 2005

After a yearlong postponement of the program because of the feasibility studies, the program was resumed after going through significant reconstruction work. The suggestions from the feasibility studies were elevated to the highest executive level at the Presidential Office, in which the authorities became reluctant to pursue the parallel strategy of developing the utility and attack variant together due to the high cost and technological risk factors. Following an intensive review process, the National Security Council decided to separate the KMH into a utility variant (KHP: Korea Helicopter Program) and an attack variant (KAH: Korea Attack Helicopter), while giving first priority to the KHP. The KAH was to be initiated following a thorough progress assessment of the KHP.[860] A subsequent feasibility study over the development of the utility variant conducted by the Korea Industrial Development Institute in 2005 estimated a R&D cost of KRW 1.31 trillion, and a full scale production cost of KRW 4.16 trillion for a total of 245 helicopters. The life cycle cost of the 245 helicopters was estimated KRW 3.64 trillion over a 30-year period. Thus, the total life cycle cost, combining all three elements of the

858 국회예산정책처, 국방 KHP 사업 사전평가, 2005, p. 94
859 Ibid., p. 95.
860 이정훈, “KMH 욕심 줄이고 실속비행 하나,” 주간동아, 2004 년 460 호.

program life cycle, estimated KRW 9.1 trillion. In this case, the substitute effect of developing an indigenous version opposed to a foreign procurement, was approximately KRW 2 trillion in value. The total industrial impact effect to the local economy was approximately KRW 13.87 trillion, which accounted for both production inducements and economic value added.[861]

Due to the separation of the utility and attack variant, the program budget also substantially shrank from the initially estimated KRW 15 trillion to KRW 5 trillion. The acquisition strategy also changed from indigenous development to a hybrid strategy of indigenous development supported by international cooperative efforts, which accommodated both proposals submitted separately from ADD (indigenous development) and KAI (international cooperation). Hereinafter, the official title of the program changed from KMH to KHP.[862] The separation of the two platforms also relaxed the aggressive development objective, which at first targeted for a localization rate of over 70% in all associated systems and components, down to a rate of 50% anticipating for an improved technological readiness level after learning from advanced international partners in the rotor-wing sector.[863]

The KHP was a total package solution that incorporated three integrated elements of the program – aircraft systems (KUH: Korea Utility Helicopter), integrated logistical support system (ILS), and training system. Two cabinet ministries – MND/DAPA and MOCIE (later MKE and subsequently MOTIE) have formed an inter-agency joint consortium in order to develop a helicopter that shared the performance features of both military and commercial applications. The program duration for development ranged a 6-year period, from June 2006 to June 2012. The total program budget – including RDT&E, production, and a 30 year life-cycle management cost for O&M – was estimated as KRW 9.1 trillion, which made KHP the single most expensive government funded program in the history of Korea.[864] The breakdown of the total budget reports KRW 1.3 trillion for RDT&E, KRW 4.9 trillion for production, and KRW 3.63 trillion for life-cycle management cost. The scope of the KHP is also unique as it crosses government sections from military to commercial, domestic supply to international export, military controlled technology to dual use technology, etc. MND and MOCIE each share the burden to 61% and 39% of the program budget. The military controlled Agency of Defense Development takes charge of developing 15 key components of the helicopter that are mainly in use for the military such as the mission equipment package. The Korean Aerospace Research Institute develops 18 dual use key components such as in power transmission and flight control that constitute the core elements of the main helicopter platform.

Total Development Cost	Government Investment			Industry (KAI)
	Total	MND (DAPA)	MOCIE (KARI)	
KRW 1.296 trillion	KRW 1.0872 trillion	KRW 697 billion	KRW 390.2 billion	KRW 208.8 billion

Table 68. Breakdown of the KHP RDT&E Budget
Source: Defense Acquisition Program Administration, September 2006

861 한국산업개발연구원, 한국형헬기개발사업(KHP)의 경제성 분석, 2005.5.31, p. 128-136.
862 국방부, “한국형헬기 기동형 우선 개발, 연말쯤 착수,” 국정브리핑, 2005.2.19.
863 박병진, “한국형 헬기 사업비 10 조 축소,” 세계일보, 2005.2.18.
864 백영훈 외, 한국형헬기개발사업(KHP)의 경제성 분석, 한국산업개발연구원, 2005, p. 109.

Because of the need to manage a complex development project with the largest appropriated program budget in the history of Korean weapon systems development, in addition to incorporating critical technological resources dispersed throughout different government agencies and commercial entities in the most consistent way possible, the defense authorities perceived the need to establish an organization exclusively for the KHP that can effectively manage and mitigate program challenges. In September 2002, MND established the KMH Program Management Group under its acquisition branch. In accordance with Executive Order No. 18156, the KMH Program Management Group was formally established and was initially placed under supervision of the Minister of National Defense. Considering the gravity of developmental and coordinative challenges, a Deputy Minister level official was appointed as Chief of the Group, of which the Chief would exercise overarching authorities to coordinate and manage the flawless execution of the program between the military (MND), industry (MOCIE), and corporate businesses (KAI and subcontractors).[865]

Due to the need to comprehensively reach out to various stakeholders to coordinate competing priorities and requirements, the status of the Group was elevated to a national level program management office in January 2004. In July 2005, in order to reflect the changes made to program sequences in terms of developing the utility variant first followed by the attack variant afterwards, the name of the group formally changed to the Korea Helicopter Program Group, and was placed under supervision of the Commissioner of the Defense Acquisition Program Administration in accordance with the structural changes made on the country's defense acquisition system.[866]

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[865] 대통령령 제 18156 호, 한국형다목적헬기개발사업단규정, 2003.12.11.

[866] 대통령령 제 18948 호, 한국형헬기개발사업단규정, 2005.7.15.

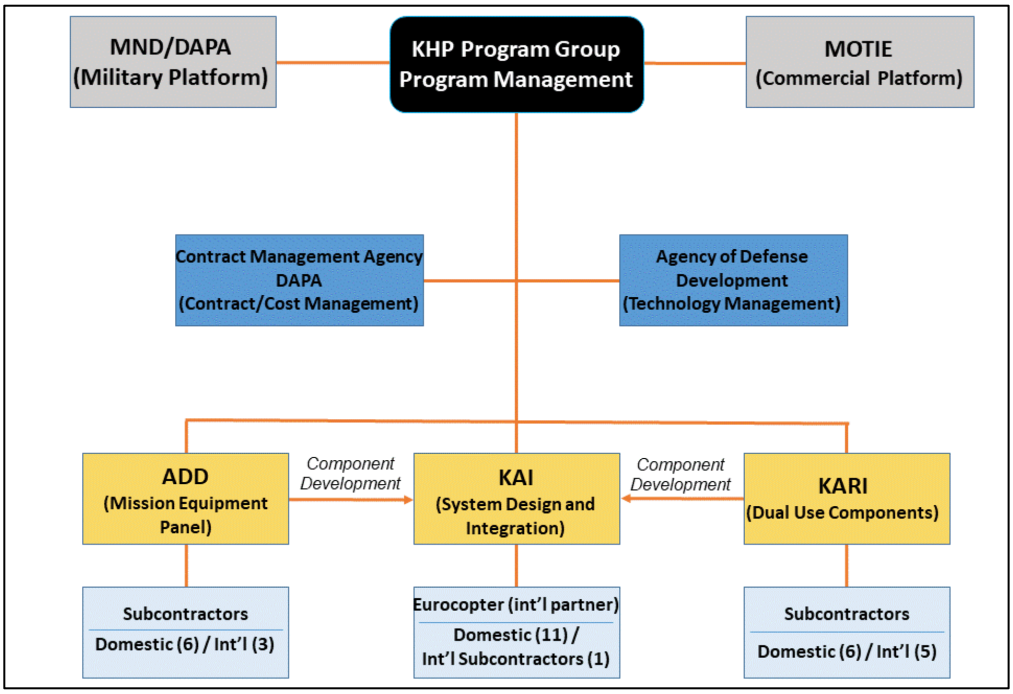

Figure 25. KHP Program Management System
Source: Reproduced from DAPA KHP Updates to the National Assembly, June 2012.

The KHP Program Group retained overall responsibility in managing and coordinating various tasks conducted by each subject entity in charge of its respective development segment. The military authorities, MND/DAPA, supervised the development of military capabilities in the program, whereas industrial technocrats such as MOTIE and other S&T authorities, managed the commercial piece of the program. DAPA managed all contract related matters in terms of payment schedules, offset trades, compliances to operational requirements, and so forth, through its Contract Management Agency. ADD, which is also an autonomous GRI under DAPA oversight, managed the development and coordination of technology with all developmental partners in overarching aspects of the KHP. The central repository of all development efforts resided within the prime contractor KAI in regards to system design and integration, component development with subcontractors, government relations, and so forth. ADD shared the development piece of military specific components whereas KARI took responsibility of developing dual-use components that had direct commercial application. Eurocopter Group, as the technology provider of the program, assisted with the design, production, test and evaluation, and quality assurance of the program with KAI.[867]

Choosing a Co-Development Partner

Because of the shortfalls in technological readiness levels, it was imperative for the program to collaborate with a highly competent international partner. International co-development efforts were a global industry trend for the development of new aircrafts considering the high development costs and

867 Ibid.

technological risks. The selection guidelines, reflected in the official Request for Proposal (RfP), underscored a foreign partner that provides adequate technological assistance for developing systems and components properly assessed to be built indigenously. In order to address the need to build technological capacities for the local aircraft-manufacturing sector, the program manifested a 30% extra weighted value in the contractor evaluation categories of technology transfers and assistance, intellectual proprietary rights and ownership, etc. It required the foreign partner to clearly and definitely understand the program work breakdown structure where the international co-development partner should assist the prime contractor (KAI) in achieving the suggested level of technological readiness and component localization rates. Because of the separation of the attack variant from the original development plan, the KHP also required an aggressive offset trade package that included the transfer of technology to build an attack helicopter as a follow-up program of the Korea Utility Helicopter (KUH).[868]

At first, foreign aerospace moguls expressed keen interests into the program, but they also kept strong restraints to prevent the emergence of a potential competitor in the market. Foreign firms not only showed deep concerns on the potential entry of a new contender in the global rotor-wing sector, but also expressed discomfort over the possible loss of a huge regional market. The idea of losing the world's 7th largest helicopter market by assisting the development of an indigenous variant was obviously not in the business forecasts of these aerospace firms. In this regard, a number of foreign firms attempted to discourage senior Korean program officials and KAI executives over the KHP endeavors by presenting better license production deals or improved integrated logistics support packages. One firm produced a detailed booklet dubbed the "Dark History Book", which illustrated previous cases of development missteps the company went through, and warned the program executives over the prospects of failure regarding the highly risky and unrealistic development schedule of the KHP.[869]

The seven companies that attended the KHP Information Session, which was held at the KAI headquarters on 15 April, 2005, were Bell, Boeing Sikorsky, AugustaWestland, Eurocopter, Rosoboronexport, and Kazan. Only three rotorcraft firms – AugustaWestland, Bell, Eurocopter – responded with their respective development proposal for the program. The other four firms did not respond with a proposal after foreseeing the high risk factors associated with the program. However, AugustaWestland and Bell Helicopters refused to submit further details of the co-development proposal, at which the two firms demanded exclusive negotiating rights, under the premises that they would win the final contract award. Bell withdrew from the competitive bidding process, while the program authorities automatically disqualified AugustaWestland for not responding to the additional RfP

[868] KHP 사업단, 한국형헬기사업 사업설명회 자료, 방위사업청, 2005.4.15, p. 32.
[869] Interview with a former KHP official, 15 September, 2012.

requirements.[870] The highlights of the proposal were as follows[871]:

- AugustaWestland
  - Proposed a 50:50 co-development of the A-149 platform, which was virtually a license production arrangement. This entirely differed from the original co-development RfP.
  - KAI has limited involvement in critical design, test and evaluation, whereas most of the development rights reside within AugustaWestland.
  - Expressed the firm had no intention to compete in a trilateral composition with the other two firms, and demanded to sign a Head of Agreement in advance for exclusive pre-contract privileges in preparation of preliminary negotiations.
- Bell Helicopters
  - Proposed an overhaul of the UH-1Y platform, which was essentially a license production offer. This also differed from the original co-development RfP.
  - Bell argued the ambitious 6-year development timeframe is unattainable in terms of cost and development period. Therefore, Bell advised the UH-1Y overhaul as the only viable option that can fulfill the aggressive timeline.
  - Bell obtains overall responsibility of the core technology applied such as integrated design and manufacturing, structural design changes, avionics integration. KAI has limited authority in reconfiguring airframe and engine model.
  - Only when Bell is selected as the preferred bidder of the program shall the firm provide further details of the technology transfer package.
- Eurocopter
  - Responded with a RfP that complied with the program guidelines in terms of technology assistance and co-development efforts.
  - Shall proceed with the international cooperative development by assisting the production of an indigenous Korean configuration.
  - In terms of technology ownership, KAI obtains 85% and Eurocopter obtains 15% of the KHP.
  - Shall transfer all technology that are not subject to export license control.

Since Eurocopter solely responded among the three companies in accordance with the RfP, the program authorities selected the European firm as the priority bidder and entered into subsequent negotiation phases. Eventually, KAI and Eurocopter agreed on a total contract cost of EUR 202 million for technology transfers and assistance. Under the category of Recurring Costs on transferred

[870] DAPA, KHP Update to the National Assembly, 1 September, 2005.
[871] 김기정, “한국 헬기 사업의 진행과 역사,” 제 7 회 KAI 항공우주논문상, pp. 51-53.

technology investment, the reimbursement arrangement for Eurocopter concluded with a 70% disbursement in a ten-year payment schedule, under the condition of a successful product development and full scale manufacturing. The remaining 30% installments should be paid from the joint marketing efforts of the KUH to international customers.[872] This arrangement was believed to keep Eurocopter committed into the Engineering & Manufacturing Development (EMD) phase of the program as well as to the overseas exporting campaigns.

The selection of Eurocopter as a development partner for the KHP signified the Korean Government's strong willingness to put industrial development and capacity building first against the traditional alliance politics of prioritizing U.S. defense products, under the cloak of enhancing coalition interoperability. Purchasing U.S. defense products certainly had benefits in a sense of sharing concurrent spare parts and rendering repair services with its alliance partner in the perspectives of effectively managing the product life cycle. In this regard, most spectators anticipated Bell Helicopters as the most likely co-development partner to win the contract. But by carefully scrutinizing the RfP, the Korean Government's intention revealed stronger commitment in building industrial capacities and sectoral competitiveness through picking the best option for assisting industrial growth.

However, Eurocopter was also seemingly reluctant to transfer critical technologies for obvious reasons of protecting its technological competitiveness. The three representative high value product modules, which the KHP strongly insisted to localize, were the production technology of the main rotor blade, aircraft flight control system, and power transmission system. These were considered critical technologies that would allow the Korean firms to develop new variants of helicopters with its own initiatives. Eurocopter partially provided the requisite knowledge and technology for the rotor-blade and power transmission system, but strongly refused to even initiate discussion on the aircraft flight control system. Instead of providing the technology, Eurocopter offered a counter-trade, which is a form of an offset deal, to purchase the flight control systems. In this regard, the initial program objective to acquire about 63.8% of the technology preconditions for aircraft flight control systems resulted in obtaining zero technology from Eurocopter.[873]

Program Management Methods: Deploying Concurrent Engineering Practices

In a normal case, the average time period for advanced western aerospace firms to develop a new helicopter model takes around 8 to 10 years. To fulfill the urgent warfighter requirements of the military services in regards to the rapidly retiring helicopter fleet of the Korean Army, the KHP Program Group suggested an ambitious development timeline of six years (73 months). In this regard, it was imperative for the program management authorities to closely monitor the program costs and key compliance with key milestones in order to prevent any possible setbacks caused by cost increases or

[872] Special Terms and Conditions of Technical Assistance Agreement between Korea Aerospace Industries and Eurocopter for Preliminary Design and Full Scale Development of Korean Utility Helicopter, December 16, 2005, p. 21.
[873] 최승욱·최현수, "소형 민군용 헬기 개발 1 조 6000 억 사업 위기," 국민일보, 2016.9.26.

late deliveries.

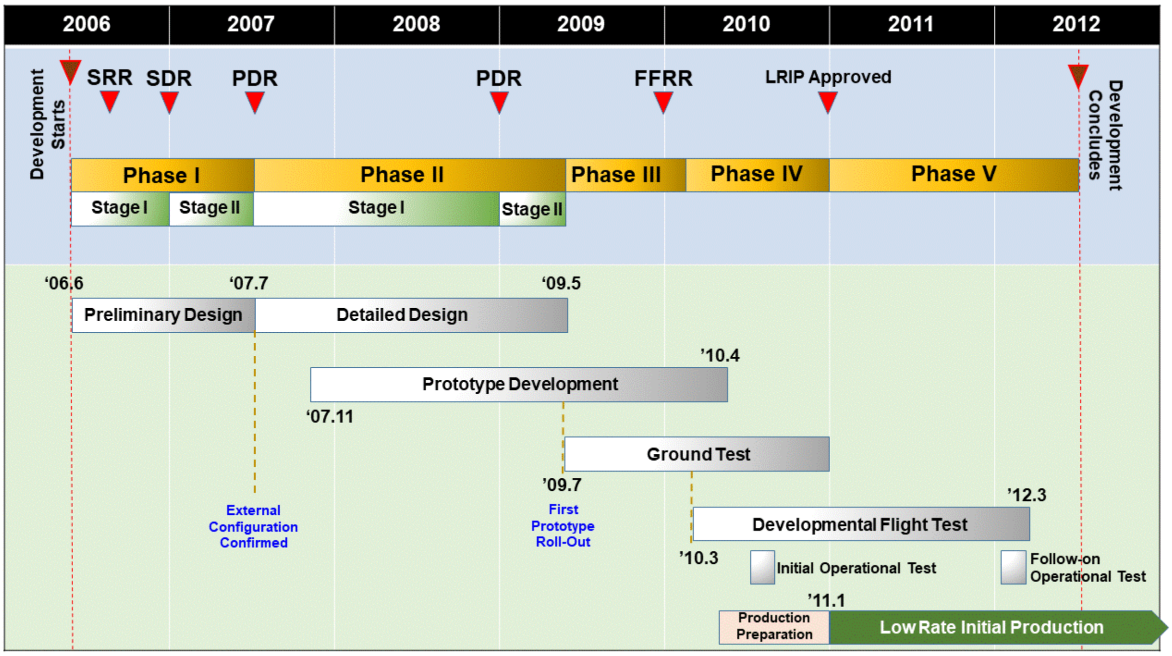

Figure 26. KHP Program Development Milestones Applying Concurrent Engineering Methods
Source: Reproduced from DAPA KHP Updates to the National Assembly, June 2012.

The Defense Acquisition Program Administration perceived the need to deploy objective based scientific program management techniques in order to effectively manage highly complexed development programs. In this regard, program management methods were instituted into formal regulations associated with guidebooks that provided implementation instructions.[874] The KHP Program Group employed a concurrent engineering design concept as a response to the impending technological challenges entailed under such constrained timeline. In order to effectively manage the various risk factors inherent in complex product systems, there was a need to routinely scrutinize program performances and review the accuracies of follow-up actions. Thus, the concurrent engineering concept applied methods of systems engineering (SE) to manage the entire life cycle of the program, earned value management (EVM) to control timelines and phases, cost as an independent variable (CAIV) to monitor unit costs and O&M, etc. All these methodologies were assigned to each program entities based on the work breakdown structure (WBS) instituted by the KHP Program Group.

The Systems engineering method is a commonly deployed practice when developing products that require substantial integration work over a distinctive number of different systems into a single platform. The KHP Development Group proactively applied the engineering method in the early phases of developing the KUH. The program authorities drafted the Systems engineering Management Plan (SEMP) as a baseline guidance document that reflected the procedural aspects of engineering systems, subsystems, and components, under the prospects of a total life cycle management perspective. The

[874] 방위사업청, 시스템엔지니어링 가이드북 Version 1.0, 2007, pp. 9-13; 방위사업청, 방위사업청 훈령 제 13 호: 방위력개선사업관리규정, 2006, p. 39.

SEMP applied U.S. military specific technological standards (MIL-STD-499A) and built up the experiences from previous aircraft development cases such as the F-16, KT-1, and T-50. These elements were thoroughly analyzed and implemented the into the Preliminary Design Review phase, in which allocated the baseline to insure the operational effectiveness of the system. The decision and control processes in the design phase were managed through sequential series of formal technical review sessions, starting from the system requirement review phase all the way towards test readiness review phase.[875]

Earned Value Management (EVM) is a method where the program manager calibrates the assigned workload actually performed beyond the initial review of cost and schedule reports. It is a method that measures the project by the progress accomplished. After reviewing the progress and performances, the program manager makes an assessment on the total cost and program schedule in accordance with the trend analysis of the evaluated data.[876] By employing the EVM method, the program authorities managed to track the major schedules and costs in accordance with the original development plan. At first, until December 2009, the program managed to stay on time within the given parameters in costs. However, after 2010, the program experienced schedule delays and cost overruns. These violations against the baseline planning documents were closely measured and monitored by applying the EVM practice.[877]

No matter how much objective based scientific principles were applied in the SEMP, coordination challenges emerged throughout practicing systems engineering methods. The utmost issue chronically identified was the synchronization of different system requirement viewpoints occurring throughout the design phase. Military operational requirements frequently confronted challenges in ways of interpreting the needs into a technological language with the system engineers. Such synchronization in development concepts would've been highly appreciated in the early stages of the design reviews, but the differences still remained even during preliminary design review sessions.[878]

In addition to these limiting factors, the cost deviation between the initial development cost estimates and the actual cost incurred showed an increase of 24.8% by KRW 321 billion. The systems engineering program management methods handled the overall schedule in track within the projected 73-month timeline, which prevented additional possibilities of cost overruns caused by program delays. Among the 24.8% cost increase that incurred during the engineering and manufacturing development phase, the losses occurred from foreign-exchange differences between Korean Won and European Euros amounted about 10%, which accounted for KRW 130 billion in total development costs. The major cause of the cost deviation, or cost overruns, from the exchange rate was the 30% valuation of the Euro from the original forecast. The genuine culprit viewed as the true element for a cost overrun nested in

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875 KHP 사업단, 수리온 개발사업에 적용된 과학적 사업관리기법, 방위사업청, 2010, pp. 71-76.
876 Chance W. Reichel, Earned Value Management Systems (EVMS), conference paper presented at PMI Global Congress, 2006.
877 KHP 사업단, 수리온 개발사업에 적용된 과학적 사업관리기법, p. 488.
878 Ibid., p. 239.

the remaining 14.8%, or KRW 191 billion, which occurred from engineering changes made in the design process and the alterations in concept design of the engine.[879]

Responsible Program Office	Planned Budget	Actual Cost	Cost Variance	
			Variance	Amount
KHP Development Group	₩34 billion	₩28.7 billion	-15.6%	-₩5.3 billion
KAI	₩721.3 billion	₩1.00 trillion	38.9%	₩280.9 billion
KARI	₩333.2 billion	₩374.3 billion	12.3%	₩41.1 billion
ADD	₩206.5 billion	₩211.1 billion	2.2%	₩4.6 billion
Total	₩1.295 trillion	₩1.61 trillion	24.8%	₩3.213 trillion

Table 69. KHP Development Cost Increases
Source: DAPA KHP Program Update to the National Assembly, August 2013.

8.2.4. Capacity Building Process

International Cooperation with Eurocopter

The KHP Development Group selected Eurocopter with a contract value worth EUR 202 million that included a co-development package of technology transfers and assistance, workshare agreement, and work breakdown structure. The technology assistance agreement valued EUR 102.5 million that amounted 3,497 man-months in staff plans related to systems engineering, configuration design, aerodynamics, fuel systems, avionics, and so forth. Technology transfer arrangements accounted for 293 items, which accounted for 293 technical items and development know-how. The workshare agreement comprised of building the gearbox (transmission), drive-shaft, flight control computer, and so on, with a contract value of EUR 100.2 million.[880] Thus, technology assistance provided from Eurocopter formed a critical element of the KHP development.

As the KHP entered the design phase, the program authorities exerted full-fledged efforts to acquire the requisite knowledge and skills through the collaborative arrangements with Eurocopter. From June 2006 to July 2007, a team comprised of 40 scientists and engineers, gathered from KAI, KARI, ADD, and the KHP Development Group, were dispatched to the Eurocopter headquarters office in Marignane, France. The team was titled the Overseas Design Built Team (ODBT), and served in roles of absorbing advanced knowledge and skills required for fulfilling the technology transfer process. The ODBT worked with Eurocopter to accomplish the conceptual drawings and preliminary design phase within the constrained program timeline. Considering the shortfalls in technological competence and skills, it was imperative for the KHP Development Group, through the ODBT, to fully utilize Eurocopter’s advanced experience and infrastructure, before finishing the preliminary design phase milestones within the given timeframe. The ODBT teamed up with the Eurocopter Technology Assistance Team and conducted tradeoff studies by each application field to reach the landmarks of the final configuration design. Most of the existing helicopter structural features of Eurocopter derived from the AS532 Cougar family-design were applied in the new designing efforts of the KHP, which exerted

[879] DAPA, KHP Program Update to the National Assembly, August 2013.
[880] Contract with Eurocopter Regarding KHP Development (Summary), KAI, December 16, 2005.

critical influence in shaping the initial configuration. The ODBT worked in close relation with the Korea Design Center (KDC), located at the KAI Headquarters, which functioned as the overall control office in laying out the integrated architecture of the helicopter throughout the entire design process.[881]

At first, the KHP Development Group intended to design a uniquely indigenous configuration that minimally replicated an existing design. On the contrary, Eurocopter proposed its twin-engine AS532 Cougar medium-weight helicopter as the basic structure of the KHP. Eurocopter argued that it should take at least three years to adequately test the new design features of a helicopter before entering into full scale development. In this regard, the program authorities had no option but to agree with the suggested AS532 Cougar configuration.[882]

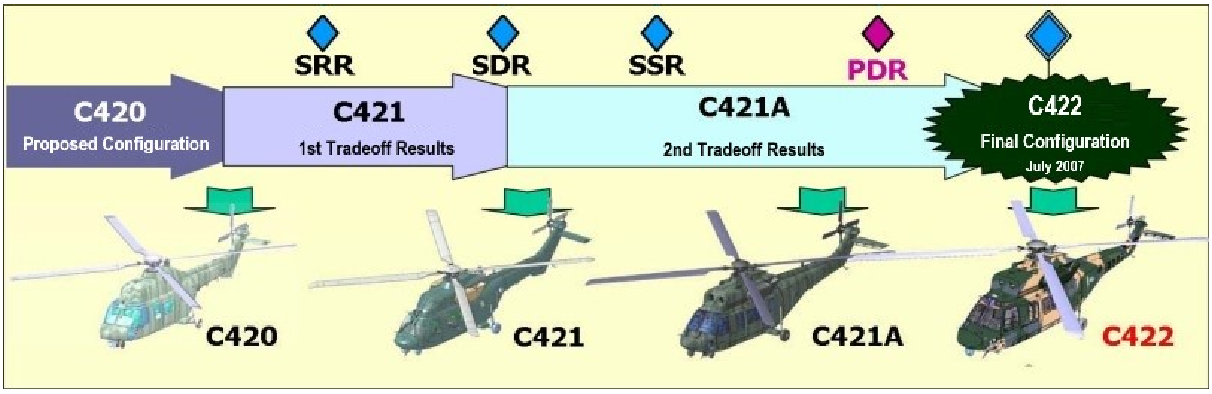

Figure 27. KUH Configuration Changes ***Source: KHP 사업단, KHP 사업추진현황, 2013.10.***

**SRR: System Requirement Review*
**SDR: System Design Review*
**SSR: Software Specification Review*
**PDR: Preliminary Design Review*

Even after the program authorities selected the AS532 Cougar as the starting configuration of the KUH, further tradeoff studies ran into serious disagreements with Eurocopter in areas related with development risks and business interests. The program authorities preferred to start the design process with the C421 configuration, but Eurocopter insisted an altered configuration named C421A. The surface reason raised by Eurocopter pondered on the vibration caused from the aerodynamic composition of the main airframe in accordance with the manifested operational requirement document. According to the concerns of the Technology Assistant Team, even experienced rotorcraft manufacturers from Eurocopter had never altered the basic configuration of the Cougar despite going through multiple system upgrades and overhaul processes. Both Eurocopter and the ODBT went along pretty well with each other during the beginning phases of the configuration design and tradeoff studies. The Eurocopter Technology Assistant Team at the moment actively supported 16 iterations of tradeoff studies over the widened body C420 configuration. However, the cooperative stance changed after learning about required structural changes suggested to the baseline configuration. As the Korean

881 KHP 사업단, 수리온, 찬란한 비상, 그 도전과 성광의 발자취, 방위사업청, 2013, pp. 57-60.
882 최영진, 최초의 국산헬기 KUH 수리온, 서울신문, 2010.10.14.

military was accustomed to U.S. standard military equipment, the operational concept developed by the Army in consideration for the KHP had Sikorsky's UH-60 Black Hawk in mind. In this regard, the ODBT suggested to enlarge the width of the main airframe in order to accommodate the operational requirements of the program. The tradeoff studies conducted by the Korean Design Center stubbornly insisted for an American design over a European platform. This was a situation that Eurocopter could not easily accommodate.[883]

The circumstances even worsened after October 2006. With the turnover of Eurocopter's senior executive leadership, the cooperative stance of the Technology Assistant Team abruptly changed into a disobliging manner. The Cougar was originally built with a narrow body frame as a basic design feature, but the KHP design reflected the customer's proposition to build a wider body than its original configuration. This implied serious adjustment in aircraft design. Normally before the System Requirement Review (SRR) phase, it would take about three years in average to apply design changes made on the baseline design configuration. In the meantime, the program authorities demanded to immediately enter the SRR phase just after three months of signing the contract. At the time, French helicopter designers closely monitored the recent crashes of the Indian Army's Advanced Light Helicopter, and factored in the technical challenges of altering baseline configurations that did not went through appropriate review and tradeoff studies.[884] Having this in mind, the Eurocopter leadership had problems over the development risks associated with the program, and concerned the potential setbacks in program delays or development failures caused by altering the basic configuration may result in a penalty of non-fulfilling the payment schedule, of which the corporate headquarters would not entertain over the company's reputation.[885]

The program authority overcame the differences with the Korean Army by mitigating the distinctively European characteristics, which raised the original warfighter needs in the operational requirements. Throughout the SRR phase, the Army showed commitment in all aspects of the development process, from the crafting of avionics to gunfire resistance design. Especially, active duty service members in the Army aviation fleet provided insightful recommendations and flexibly accommodated to customary differences between American and European designed helicopters. In order to actively apply the technical adjustments, the program authorities organized an interim team within the KHP Development Group called the Cockpit Review Team (CRT).[886] Also, the system design components of the program were subsequently augmented by experienced system designers and engineers from the T-50 Golden Eagle Program. The shortened development period of the KHP has always placed every phases of the program under a tight development period, especially with the shortfalls in system engineers during the technology maturation and engineering & manufacturing

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883 한국항공우주산업㈜, 수리온: 최초의 국산헬기 KUH-1 개발 스토리, WASCO, 2014, p. 93.
884 Report of the Committee of Inquiry: Accident to BSF (Air wing) DHRUV Helicopter VT-BSN at Raipur Airporton 15th January 2012, April 22, 2013.
885 Interview with a former senior executive from the Korea Helicopter Program Development Group, 5 July, 2012
886 한국항공우주산업㈜, p. 98.

development phase. As the T-50 development concluded and entered into full rate production, the T-50 engineers were reassigned to KHP design team and assisted the program milestones accordingly.[887] Based on these experiences, the Korea Aerospace Industries received the AP10120 Engineering Authority Delegation from Airbus in February 2015, which was the first of its kind for an Asian based aircraft-manufacturing firm.[888]

The technology transfer process underwent some difficulties provoked by workshop level cultural differences and corporate level competitive constraints. In the cultural aspects, the program authorities had to overcome the different approaches towards formally codified knowledge against customary tacit knowledge. Based on the number of bilateral arrangements in technology transfer and assistance, the ODBT initially expected to receive engineering schematics or technical documents that contained detailed descriptions of each respective technical field. Such expectation originates from the fact that most scientists and engineers of the KHP were more accustomed to the American way of building aeronautical artifacts, which highly focused on a system of engineering procedure based on standardized documents and technical manuals, codified as 'MIL SPEC' documents. On the contrary, the European approach towards aircraft manufacturing highly honored individual experience and workshop level coordination, in which the value extensively required a long gestation period for capacity building. European aerospace firms mostly come from a history of cultural heritage, which gives higher respect to experienced engineers and technicians than structurally codified blueprints. Especially, in regards to the first flight of the earlier AS532 Cougar model dated back to 1977, the evolutionary aspects of helicopter development in Eurocopter spanned over three decades of accumulated knowledge and experience. This implied that the technical learning process of Eurocopter's human resource base mostly depended on tacit knowledge passed down by experienced engineers than codified knowledge recorded in document form. Unfortunately, time was of essence for the KHP, since the design phase had to conclude before the suggested 73 months, or otherwise the program would incur additional cost increases.[889]

In the corporate level, the program authorities collided with the Eurocopter corporate headquarters over the gross weight of the helicopter. At first, the KHP started with a primary mission weight of 15,000 lbs. however, as the program entered into System Design Reviews (SDR), after reflecting the multiple tradeoff studies in system design, the primary weight increased to 16,250 lbs. (7 tons). However, the program authorities wanted to accommodate more capabilities into this mid-weighted helicopter such as radar warning receivers, countermeasure dispensers, MEDEVAC, amphibious landing operations, and so forth. Putting these elements into consideration, the helicopter's maximum takeoff weight increased to 19,700 lbs. (9 tons). This was unacceptable to Eurocopter for such increase in weight will place the KHP in competition with its own Cougar variants in the

887 성상훈, "한국항공산업, 제 2 의 조선산업 된다," 디펜스뉴스, 2015.3.14.
888 문병기, "KAI, 아시아 최초 에어버스 설계 승인권 획득," 중앙일보, 2015.2.12.
889 한국항공우주산업㈜, pp. 80-85.

international market. In order to arbitrate the on-going disputes in takeoff weights before the Preliminary Design Review in 2007, the program authorities intervened and negotiated directly with their defense acquisition counterpart in the French Government, the Direction Générale de l'Armement (DGA). The settlement was to adjust the max takeoff weight to 8.7 tons for internal weight limits, 9.0 tons for external weight limits, and perform the preliminary performance tests in a weight category of 7.5 tons.[890]

Accumulated Experiences through Engineering and Manufacturing

The culminated art form of aircraft manufacturing is the system integration phase of the program. This is where all millions of engineered components become integrated into one final masterpiece and function as a complete body of its own. The KHP went through a number of experimental approaches in the course of learning new technologies and applying old skills acquired from previous experiences. The development experience of the rotor blade offered opportunities and challenges in this respect. Rotor blade is a critical component that generates the lift-off power of the helicopter. Rotor blade design and manufacturing is an area that requires mastery in sophisticated molding and composite material technology. Only less than a dozen countries in the world are capable of indigenously designing and manufacturing this major end item. The KHP program authorities had high expectation over Eurocopter's effort to transfer necessary technology in order for KAI to localize the manufacturing process. Despite this expectation, the European firm disinclined to easily give away the technology. With an obvious intention to discourage a fast follower in aircraft-manufacturing, Eurocopter transferred mostly outdated and obsolete technology to KAI. In one case, the European firm chased a KAI engineer all the way to the airport and forcefully confiscated some basic level rotor blade technical materials furnished during the transfer process.[891] After obtaining foundation level knowledge and skills from Eurocopter, the KAI engineers self-taught themselves through collaborative efforts with its local subcontractors to mold the outer-frame of the resin-coated fiber-optic surface of the honeycomb core that holds nearly 80 different sub-materials from strong centrifugal forces. The short development period also pressed pressure on the engineers, in which even technicians from Eurocopter casted strong doubts on the slim chances of success. Nevertheless, after going through multiple iterations of trial and error, KAI engineers successfully developed and produced the main rotor blade with a much more sophisticated level than the product knowledge transferred from Eurocopter for less than two years of product research.[892]

The most challenging aspect in the system integration phase occurred when building the driving system. The driving system of a helicopter consists of the rotor blade, hub, engine, power transmission unit, and other supporting components. Since the driving system constitutes the most

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890 Ibid., pp. 116-126.
891 양낙규, "명장에게 길을 묻다-한국항공우주산업 문장수 책임연구원," 아시아경제, 2011.4.12.
892 정책브리핑, "수리온 나오기까지 애환 숨은 이야기," 2009.7.31.

delicate and sophisticated technology of a helicopter, most companies classify the relevant technologies as secret information under corporate proprietary rights. In this aspect, Eurocopter expressed strong hesitance in sharing detailed information related with developing the driving system. Compounding to the already insurmountable technical challenges, the program authorities selected the General Electric T700/701K turboshaft engine as the main power source of the KHP. The Cougar variants traditionally installed the Turbomeca Makila turbine engines as its main power source. The primary reason for the program authorities selecting T700/701K was for two reasons; 1) had more powerful thrust (1,855 takeoff power) over the Makila 1A1 (1,820 takeoff power), 2) Korean companies already possessed the requisite technology and manufacturing experience.[893] Whatsoever, the selection of the T700 engine confronted a number of technical challenges. Program authorities were comfortable with the T700 variants since the engines were already under license production by Samsung Techwin. It provided better reliability and maintainability than procuring a newer source. Most of all, the featured commonality in engines between the KT-1 Basic Trainer Aircraft and the KUH Surion Utility Helicopter also reinforced the decision to select the GE engine over the European variant. The PT6A-62 Turboprop Engine run by the KT-1 shares substantial technical commonalities with the T700 Turboshaft Engine since the two engines originate from similar gas turbine structures.[894]

The T700 engine was originally designed as a front-drive engine, which places the transmission at the front angle of the engine in order to effectively transmit the generated power into the drive system. However, the Cougar based configuration of the KUH required to place the engine at the opposition position from the transmission, in which the T700 had to be re-engineered as a rear-drive engine. This caused major complications in designing the drive system in relation with the power transmission unit. The power output generated from the engine transmits through a shaft that connects into the rotor blade system. The shaft constitutes a critical component in the transmission system.[895] However, because of the installation of the GE T700 engine instead of the Turbomeca Makila engine, the KUH system engineers discovered during the integration phase that the shaft in the transmission fell a half inch shorter than the basic design. After reviewing the transmission components and design schematics multiple times, the KUH engineers concluded to add a bolt to fit the shaft into the transmission unit. Even after resolving the problem with the transmission unit, the incompatibility between the engine and the airframe caused serious vibrations to the main body, which suspended the development of the helicopter until the engineers worked out an answer to the problem. Only after General Electric became involved in the vibration testing, and advised to overhaul the engine protection box, did the vibration problem went away.[896]

Considering the aspect of certifying the operational safety of the helicopter, three public

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893 "GE's T700 Engines To Power Korean Helicopter Program (KHP)," *GE Aviation Press Center. 19 July 2006*

894 국방대학교, 함정 항공전력 방위력개선사업의 경제적 효과분석, 방위사업청 연구용역보고서, 2010 년 12 월 10 일, p. 93.

895 김재환 외, “한국형 기동헬기 엔진 (T700/701K) 개발,” 한국추진공학회지 제 15 권 제 4 호, pp. 81-84.

896 한국항공우주산업㈜, pp. 191-197.

organizations performed the necessary airworthiness certification efforts over the KUH Surion in accordance with the Military Aircraft Airworthiness Certification Act, enacted in April 2009. The certification process was an imperative element to accredit the safety level of the helicopter to a status commensurate to international standards.

The Certification Planning Division under the Bureau of Analysis, Test, and Evaluation assumed overall responsibility in coordinating and controlling the certification process. It served as the final approving authority in each phase of the certification process. The KHP Development Group administered the programming and execution of the certification process in parallel with the program implementation process. It supervised each phase of the program in accordance with airworthiness standards and requirements. The Agency of Defense Development performed the verification process. After fulfilling the deficient areas identified during the survey, the KUH became fully airworthy certified for military operations in September 19, 2012.[897]

Follow-up Variants and Market Opportunities

The utility variant of the KHP for the military was assigned the project name Korea Utility Helicopter (KUH) Program. After soliciting names from an open contest, the KUH was given the name 'Surion', which combined the words of Eagle (Suri) and world (on) in traditional Korean.[898] KUH-Surion Spun off into other modifications in accordance with the different mission sets designated for required airlift capabilities. The first that followed was the amphibious derivative built for the Marine Corps. The new amphibious variant was given the name 'MUH-1 Marineon', which combined the titles of Marine and Surion. The Korean Navy signed a contract with KAI, with a given program budget of KRW 6.3 billion, to purchase 30 marine derivatives as an effort to establish a separate aviation squadron for the Korean Marine Corps. The Marineon shared a 96% commonality rate in platform and components with its original Surion variant, but added additional functions such as rotor-blade folding, anti-sea water corrosion coting, supplementary fuel tanks for extended flight distances, and other supporting devices that allow the helicopter to board on the Dokdo-class amphibious assault ship.[899]

The medical evacuation variant of the Surion has also made its maiden flight in January 2016 after incorporating medical rescue kits, such as stretcher props, survival recovery units, emergency medical service kits, etc., to the already completed Surion platform.[900] With an initial contract to purchase 8 MEDEVAC helicopters, the Korean Government expects to deploy a squadron of a total 20 helicopters until 2018, with a program budget of KRW 300 billion.[901] The Korean Army established a MEDEVAC Squadron in collaboration between the Armed Forces Medical Command and the Army

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897 KHP 사업단, 수리온, 찬란한 비상, 그 도전과 성광의 발자취, p. 350.
898 Lee Jeong Hoon, "Homegrown Helicopter Surion," The Dong-A-Ilbo, 24 June, 2010.
899 Greg Waldron, "KAI to Develop Amphibious Assault Variant of Surion," Flight Global, 18 April, 2013.
900 Korea Aerospace Industries, "KAI's Surion Medevac-version Helicopter Conducts its First Flight," KAI Press Release, 27 January, 2016.
901 홍정명, "기동헬기 수리온, 의무후송전용헬기로 재탄생," 경남신문, 2014.8.6.

Aviation Operations Command to build a professional medical first responder's unit composed of aircrews and medical service members. The medical derivative of the Surion, the 'Medion', is assigned under this squadron to support the required MEDEVAC needs.[902].

The National Policy Agency contracted a total of eight KUH helicopters (KUH-1P) overhauled to perform law enforcement missions, with an accumulated budget of KRW 129 billion from 2013 to 2017, with an objective to deploy 20 KUH-1P helicopters until 2030. The Korea Forestry Service has also contracted one KUH in 2015 to perform monitoring and fire-fighting duties. The Korea Forestry Service deploys the largest rotorcraft fleet in public service, with an operating squadron of 45 helicopters in service. It is the largest public customer after the military that has the potentials to purchase more KUH-Surion helicopters.[903] The Forestry Service intends to buy 15 more choppers until 2025, with a KRW 108 billion program budget. Chances are high for the Surion selection, but there are other competing requirements that needs to be overcome by KAI in order to win the contract deal from the Forestry Service.[904]

KHP Performance Outcomes through Knowledge Accumulation

Impact factors of the KHP measured jointly by the Defense Agency for Technology and Quality (DTaQ) and the Korea Industrial Development Institute (KID) showed positive effects to the domestic economy in terms of domestic production inducement, value added, and job creation. Table 13 annotates the economic effects attributed to the KHP R&D and production efforts, under the condition of the program reaching a 58.6% localization rate in component manufacturing. The technical ripple effects for the next ten years demonstrated a contribution of about KRW 5.32 trillion for aerospace, KRW 10.4 trillion for other defense sectors, and KRW 4.12 trillion for commercial sectors other than aerospace and defense.[905]

Unit: KRW 100 million

Impact Index	Development	Production	Sustainment
Cost (program cost)	16,100	67,141	42,546
Domestic Expenses	10,255	39,345	25,269
Production Inducement	16,876	61,927	39,773
Value Added	7,018	15,729	10,102
Job Creation	7,795 jobs	24,532 jobs	15,756 jobs

Table 70. KHP Economic Effects
Source: 이기영 외, "수리온 연구개발사업의 경제적 파급효과 분석," 한국항공우주학회지, 제44권, 2016.

After the introduction of the first batch of KUH-Surions to the military, an assessment conducted by DTaQ over the program outcomes of the KHP concluded that the efforts for knowledge accumulation and learning by doing has indeed payoff in building up the overall sectoral capacities of aircraft manufacturing. In a force build-up perspective, the KHP substantially contributed to enhancing

902 김귀근, "육군, 수리온 헬기 6 대 보유한 의무후송항공대 창설," 연합뉴스, 2015.5.1.
903 Yonhap News, "Surion Chopper to be used gby Korea Forestry Service," 2015.12.7.
904 Yonhap, "Forestry Service to buy more choppers to better fight forest fires," 2017.7.19.
905 이기영 외, "수리온 연구개발사업의 경제적 파급효과 분석," 한국항공우주학회지, 제 44 권, 2016, pp. 190-194.

the readiness posture of the military by the timely deployment of a critical airlift capability, obtaining an infrastructure for integrated logistics support and system upgrade, and becoming more self-reliant from foreign technological dependence. In an industrial perspective, the aircraft-manufacturing sector has secured a sizable market that can sustain the development competencies by generating local job opportunities for the thirty-year product life cycle of the helicopter, and contribute to promoting the domestic science and technology infrastructure in aerospace engineering. In an economic perspective, the domestic manufacturing of the helicopter significantly improved the trade balance in overseas rotorcraft purchases, and anticipates an effective technology spinoff effect into other business sectors such as automobiles, shipbuilding, ICT, and so forth.[906]

In a more analytical perspective, the DTaQ report assessed the program outcomes by employing Analytical Hierarchy Process (AHP) and Delphi methods in each technological readiness levels (TRL). From a scale measurement from 1 to 9, the country's TRL was assessed in the 8th level as of 2012, a two-step improvement from the previous Level-6 measured in 2005. Level-6 is a technological maturity stature where the program entities can perform intermediate level development of systems, subsystems, and prototypes. It does not include all technical aspects of the subject platform or system under assessment, at which it gives higher credibility to the performance of managing the development of related technology. Level-8 demonstrates a mastery level in system integration and test and evaluation. It shows a capability where the technical entities can sufficiently accomplish the given technical requirements and standards of the subject program of interest.[907]

Year	Overall Analysis (Delphi Analysis)			Overall Outcomes (AHP Analysis)	Technology Readiness Level (TRL)
	Design/Analysis	Production/Assembly	Test & Evaluation		
2005	56%	66%	61%	59%	Level-6
2012	77%	84%	83%	79%	Level-8

Table 71. Status of KHP Technological Improvement
Source: *홍현의 외, KHP 사업 기술수준 제고효과 조사분석, 국방기술품질원, 2008 년 12 월.*

8.2.5. Technical Defects, Program Imperfections, and Public Criticism over the KUH-Surion

Despite the technological and economic achievements of the program, the KUH-Surion experienced substantial technical challenges as it was pressed for a short development time. The 73-month development period evidently presented difficulties for both Eurocopter and the KHP Development Group in many aspects of the program. Despite the technological assistance the KUH-Surion received from a global aerospace giant, based on an already existing European baseline configuration, developing a new helicopter within such a compressed timeframe for a country newly catching-up in a high-tech complex product system caused considerable repercussions in a technical

906 홍현의 외, KHP 사업 기술수준 제고효과 조사분석, 국방기술품질원, 2008 년 12 월, pp. 20-24.
907 Ibid., p. 63.

domain and program management perspective.

At first, the compressed development timeline provided an insufficient gestation period for the program authorities to fully assimilate the opportunities provided from Eurocopter's technology transfer and assistance efforts. In this aspect, the number of core technology and components targeted for local development eventually had to be purchased from overseas sources. The development of the helicopter's transmission system was a classic example for this case. In July 2007, KAI subcontracted S&T Dynamic, a local precision machinery firm, to develop the engine transmission system of helicopter. S&T Dynamics subsequently signed a technology transfer arrangement with Eurocopter at the end of 2007 for engineering and manufacturing development. However, among the 450 components that constitute the transmission gear box, S&T Dynamics was only responsible to localize 134, or 30%, of those components. In a normal sense, as the sole subcontractor of the transmission system, S&T Dynamics should've engineered and manufactured the gear box under technology transfer and assistance from Eurocopter, and deliver the end product directly to the prime contractor, KAI. Nevertheless, the contract reads that S&T Dynamics shall deliver the manufactured components to Eurocopter, at which Eurocopter assembles the gear box and turn in the end product to KAI. There were also aspects of Eurocopter deliberately delaying the technology transfer process. According to S&T Dynamics, the turnaround period of receiving an official response for a memorandum from Eurocopter took more than one year, and the design plan frequently changed without providing advanced notice. At some instances, Eurocopter demanded to obtain quality certifications of certain products, which were not subject to any certification standards. Conclusively, because of these circumstantial constraints, S&T Dynamics was only capable of developing 80 out of the 134 components contracted with Eurocopter. What makes the matter worse is that Eurocopter refused to accept the components from S&T Dynamics, citing the original contract that reads the developer (S&T Dynamics) shall manufacture 134 components of the transmission gear box. In December 2014, the Board of Audit and Inspection investigated this contract arrangement and suggested a penalty charge of KRW 13.6 billion to Eurocopter for breaching the contract with the KHP Development Group. However, about KRW 10 billion of the penalty will have to be paid by S&T Dynamics because of the initial contract signed with Eurocopter.[908] This was a case where a combination of incomplete contractual terms and Eurcopter's reluctance to give up core technology resulted in an unsuccessful case in local development. Ensuing technical deficiencies mostly emerged from engine related power systems. Following the discrepancies of the transmission gear box, a number of technical defects were identified throughout the repair routines, which resulted in a crash incident of the fourth helicopter in 17 December 2015.

In terms of program imperfections and interagency coordination challenges, the KUH-Surion was airworthy certified by the military, but it did not acquire type certification by commercial entities, which restrained the aircraft from obtaining standard airworthiness certifications for both military and

[908] 김현예, "수리온 핵심장치 기술이전 안돼 국산화 실패," 중앙일보, 2014.12.13.

commercial platforms. Type certification is an authentication that verifies the conformity of the design and manufacturing process to publicly guided standards, which allows the aircraft to further proceed into the airworthiness certification. The issue of the Surion only qualifying the military airworthiness standards, but not the commercial standards of the FAA and EASA, limited the operations only to the military and law enforcement purposes. Other public entities, such as the Forestry Service and National Emergency Management Agency, were not eligible to purchase the helicopters into their aviation fleet.

8.3. Chapter Conclusion

The rotor-wing sector is an industrial area where the learning effects meaningfully accounts for future magnifying business opportunities. The constant creation of new business opportunities can bolster these learning effects into accumulated knowledge and experience, which can sustain this system of innovation. Thus, the key is to figure out how and where to find these new business opportunities.

The Korean Rotor Wing Industry shows a typical pattern of a late comer country willing to catch-up to the global industrial high grounds by exerting efforts both from the government and private industry realm. It has went through skipping the stage of the Original Equipment Manufacturer (OEM) in the evolutionary routine by moving directly into the phase of Original Brand Manufacturer (OBM), despite the prevailing risks and continued criticism from the international market.

The technological regimes show some resilience as the institutions to promote sustained growth in the market have been well established through legislation by law (Aerospace Industry Promotion Act), supported by a strong inter-cabinet decision making mechanism (Aerospace Industry Development Council), and followed by a concrete implementing body to execute the desired end state of the Korea Helicopter Program (KHP Program Management). In order to overcome the technological shortfalls, Korea made a smart move to co-develop the helicopter through a Joint Venture with Eurocopter, whereby reducing the risks of both technology maturity as well as export controls of sensitive defense related dual use technology.

However, Korea's future in the global aerospace market is highly dependent on how it leverages the US export control laws that are applied in the international transfer of arms. Korea has been technologically dependent to US controlled technology in defense and dual use technologies.[909] The major chunk of helicopters acquired from the United States, as well as sources of the technology base, constitutes almost 90% of the entire rotor wing fleet of Korea. The aerospace industry of the United States is notoriously well known for the strong protectionist policy it imposed into the transfer of US-origin defense articles and technologies to third parties.

The reason for planning the development phase in such a short period was in order to replace the retiring helicopter fleet of the Army, which already passed its shelf life at the time when the KHP

[909] Gil Bang Hee, "US Defense Technology Dominates Korean Arms Market," Sisa Press [Korean Text], available online at http://www.sisapress.com/news/quickViewArticleView.html?idxno=31248

discussion started. The root cause of this aspect originates from the delayed decision making of the program authorities at the beginning of the program itself. The initial required operational concept of the helicopter was raised in 1995, at the birth of the MPH program, but it took almost a decade, until 2004, for the program authorities to make the decision on the full execution of the KHP. The government was not able to exercise strong leadership due to the lack of an effective interagency coordination mechanism throughout the incubation phases of the program. The KHP experienced various changes during this period, the cancellation of the original MPH, the frequent changes of the ROC, the incorporation of different performance functions into a single platform, numerous stages of feasibility studies, and public disputes on the program benefits, just to name a few.

These policies are reflected in major control regimes such as the Missile Technology Control Regime (MTCR), International Traffic of Arms Regulation (ITAR), Critical Technology Plan (CTP), and the Foreign Military Sales Program (FMS), to name a few. These regimes impose harsh control measures to the host nation's industrial policy which fundamentally prohibits reverse engineering schemes and obstructs the fluid diffusion of technology into other sectors of the economy. Strong and biased dependence to US systems and technology led to Korean firms being restrained to US export licenses, as well as being subject to a number of Memorandum of Understandings that restricted the expansion of the acquired technologies to higher level of technological maturity. The primary reason for such biased selection was mainly for national security causes – the military alliance between the two countries and the strong demand of interoperability creating such predilection. The politics of interoperability was pervasive throughout the military, not only limited to defense systems and platforms but also to the organizational structure and human resource development as well. The Korean military was equipped with US origin defense articles and was trained and educated by US military doctrine and tactics. In this aspect, the decision to select Eurocopter as a partner firm to develop the indigenous helicopter program was itself regarded highly innovative in nature. In this regard, with the KUH prototype, or the Surion Helicopter, successfully going through its first maiden flight on September 2011, the rise of the Korean aerospace industry will be an interesting subject for future observation.

Chapter 9. Conclusion

This study intended to review the transitional aspects of innovation systems under the realm of state-business relations within the domain of high-technological products, in respect to the Schumpeterian Mark II technological regimes where complex engineering and manufacturing processes, alongside with regulatory control mechanisms, compounded with the complications of state-specific developmental challenges, have shaped unique systemic circumstances within the Korean innovation system from the national to the sectoral level of aircraft manufacturing. The main argument of the study asserts the need to effectively build cross sectoral coordinative mechanisms throughout the national, regional, and sectoral level of analysis, while exerting concerted efforts to overcome the multiple layers of hurdles against late entrants into technologically complex business areas. Consequently regarding an attainable solution for Korea successful accession into highly technological sectors, the paper necessitates the transitional efforts of transforming a rigid state-led innovation system into a spontaneously integrated coordinative institutional structure, which accommodates a broad spectrum of absorptive capacities and diffusion mechanisms tailored for developing complex product systems. This section examines the developmental efforts in high tech between the state and private sector throughout the arguments presented in the previous chapters, delineates the limits of this study, and presents a way ahead for future studies.

The complex nature of aircraft-manufacturing requires effective collaboration between the state controlled public authorities and market regulated private entities. In the Korean case, the government leadership in R&D planning throughout the overall construct of the respective development program was indispensable in the early stages of aircraft manufacturing. However, perceiving the need to more effectively employ private resources for enhanced diffusion and affluent commercialization for innovation, the transition of R&D responsibilities from government driven efforts to corporate lead implementation was considered turning point in the history of Korean industrial development. In respect to the universal sense of sectoral innovation, the long accumulated experience in R&D and manufacturing enabled global aerospace and defense giants to further improve and upgrade system development concepts and production processes. The earlier work breakdown structure in a development program where the Korean government (ADD) took the lead in system development and the industry assumed responsibility in the manufacturing process created formative gaps in technology transfers and accumulation, which subsequently hindered spontaneous sectoral growth potentials in corporate competitiveness. In this regard, the two aircraft development programs chaptered in this study, in which the institutional interactions in system development efforts driven by corporate capabilities, supported under government policies, showcases the future prospects of large scale national high tech projects. Throughout the system development phases of the two programs, the prime contractor of the program, KAI, has accumulated substantial technological knowhow and skills required for advanced development projects under the constrained circumstances of existing institutions. Complex product system like military aircrafts especially requires long gestation periods of development efforts and manufacturing experiences in order to further upgrade the sectoral competitiveness to the next level for sustained industrial development. No single entity can do it alone under the system integration concepts of complex product systems. But the number of attempts to fine-tune the developmental institutions in a way supportive towards innovation had to confront colossal challenges. The buzz word in this sense culminates in building coordinative institutions across all layers of the innovation engine. The comprehensive understanding of the system architecture in not only the aircraft itself, but also in integrated logistics support, training system for both engineers and product operators, and shelf-life extension elements, strongly demands for the establishment of inter/intra-agency coordination mechanisms that incorporate different stakeholders – spanning from national governance, regional interactions, and sectoral dynamics – into a synchronized planning and execution construct. In this regard, the Korean aircraft manufacturing sector strived to institute an innovation architecture outlining close coordinative relationships within multiple layers of innovation through a horizontally extensive networking interplay.

Still, because of the limited level of competence to compete in the commercial market, government sponsorship in R&D and contract awards for new entrants in the aircraft manufacturing sector still serve as an imperative growth factor, which is a general aspect also applicable to the global aerospace and defense domain. Building public and private entity competitiveness constitutes the two pillars of sectoral innovation systems in aircraft-manufacturing. Although rapidly expanding market dynamics have diminished government influence in industrial policy making in the developmental state theorem, public resources and assistance in aircraft manufacturing still remain imperative for second-tiered late entrants intending to attain a footprint into the field. Additionally, considering the complex nature of developing modern era aircrafts, parallel capacity building efforts in private sector R&D and manufacturing infrastructure sustains the other half of the pillar sustaining the sectoral innovation system.

The early history of the country's aircraft manufacturing effort show that the sector did not go through adequate developmental phases geared towards building foundational industrial capacities. The Aircraft Manufacturing Law that administered in-country aircraft production of certain types, was not structured to support technological progression, but was structured to simply execute air traffic control. The country was basically an aid-recipient economy, not capable of self-governing a national science and technology program, in which almost no administrative authorities existed that can supervise and execute such activities. Just like other countries with a sizeable aircraft manufacturing sector, the military was the only organization capable of establishing a manufacturing structure in the earliest stages of the Korean aircraft sector. Apparently, the catch-up pattern of the country's technical foundation pursued a general trend of building indigenous technical capacities through repair and overhaul work of foreign introduced equipment and technologies. At this stage, the technical assistance provided through foreign aid, primarily from the U.S. military, constituted the groundwork of building sector specific innovation capacities, but it was also a source of obstruction as the USG authorities disapproved and discouraged further development of non-standard indigenous aircrafts. At the national level, there was no systematic government support to nurture a manufacturing base in a scale commensurate to an industry level, of which most efforts focused on crafting a small cadre of technicians that were capable of performing routine maintenance work for the military. Although there was the Defense Science Laboratory at the Ministry level serving as the overarching entity for defense science research, there was no centralized authority from this echelon supervising or supporting the aircraft development of the Air Force and Navy maintenance units, in which most of the indigenously manufactured aircrafts were simply a product of assembly work from parts and pieces of disposed aircrafts spontaneously grown out from individual workshops. The motivation to establish a domestic technical workforce at this time was initiated by national security concerns instead of market forces. Therefore the technological spinoff was constrained to serving military purposes only with minimal trickle-down effects to the private sector. The technical base was built-up by a few pioneering individuals such as several officers with engineering backgrounds sponsored under wartime military leadership. There were also some surprising events where a nascent form of assembly work resulted in the creation of new functioning aircraft types, but these events never translated into industrial build-ups or a full-fledged production of aircrafts.

Proceeding into the golden ages of aircraft manufacturing during the late 70s and mid-80s, the institutional construct for capacity building in the aircraft-manufacturing sector strived to connect key players in R&D, industry, and military end users. However, there have been regrets over the effectiveness of building these institutional capacities in terms of observing actual policy enforcements and assessing real performance outcomes. Deregulated competition policy introduced new entrants into the sector, but did not produce the desired outcomes in terms of industrial upgrading and firm capacity building. Receding government influence in the market, signified by unregulated industrial competition over a finite share of the market, resulted in excessive business expansion that led to tremendous corporate losses while inducing limited contribution to building firm level competency. The industry was restructured into a highly monopolized structure where a single firm, KAI, has become the center of all development efforts whereby supported by a supply chain assisted by international forerunners such as Lockheed Martin and Eurocopter. In the late 80s and into the new millennium, throughout the intricate collaboration over a number of defense programs, the defense acquisition and national industrial apparatus endeavored to overcome the technological insufficiencies and resource shortages confronted in the Surion Utility Helicopter and the T-50 Advanced Trainer. Despite the efforts committed in the multiple phases of capacity building, the technological readiness levels and sectoral competitiveness in aircraft-manufacturing still have a long way to go before standing in par with first-tiered aerospace contenders. The critical reason for such shortfalls in capacities relates with the impending threat perception in national security where it makes it difficult to assure long gestation periods in R&D returns regarding force improvement programs. Thus a number of development programs were hastily conducted and relied heavily on foreign technological assistance. The structural restraints are highlighted in the below sections.

Dysfunctional Coordinating Mechanisms: Interagency Coordination Processes and R&D networks

Under the logical reasoning of national innovation systems, institutional networks are considered the most significant factor that interconnect a country's vibrant economic growth engine, represented through the critical linkages between R&D arrangements, production systems, and market dynamics. A country's S&T governance structure draws together the anchor tenets between the strategic components of the innovation architecture. Having this in mind, Korea's national S&T governance structure experiences systemic challenges in interagency coordination as the lead authority in R&D efforts transitioned from state controlled to industry dominated compositions. In this matter, vertically aligned bureaucratic stovepipes that used to stimulate economic growth during the era of fast followers have become troublesome in cooperative R&D programs with interagency and international partners, in some cases turning into severe roadblocks against technology diffusion and innovation. The critical disconnect between the defense R&D and the national S&T arrangement delineates the wretched reality of inadequate national level coordination.

Despite the fact of belatedly acknowledging the decoupled situation and thus incorporating the defense sector into the National Science and Technology Commission settlement, the integration into the planning and execution phase still has not fully taken place to date because of these prevalent barricades dividing the anchor tenets of potential innovation opportunities. In the aircraft-manufacturing sector, both driven by public and private sector development initiatives, the Aerospace Industry Development Policy Council (AIDPC) served as the forum with high expectations of bolstering interagency coordination and efficiently allocating vital resources to the sectoral subdivisions. However, the Council did not sufficiently grow its functional trustworthiness until the Asian Financial Crisis when the economic shockwaves obliterated the domestic aircraft-manufacturing sector. Before the Crisis, the Council was incapable of mitigating organizational differences, preventing inconsistent program decisions, and controlling distorted market forces from aggravating sectoral competitiveness. For instance, the Council could not adequately address the different objectives between the military and industrial authorities when planning and programming indigenous endeavors for building helicopters. In the case of major helicopter procurement programs, such as the UH-60P and Bo-105 license production, the military exerted no accounts over the industrial impacts of license production at all vis-à-vis force requirements, despite the government's prolonged declaration of exploiting these two defense acquisition programs as a springboard to enhance the country's aircraft-manufacturing sector.[910] Industrial authorities had high anticipations of the potential spinoffs from these development programs, but these aspirations did not translate into the military's required operational capability. The disparity

[910] Defense Acquisition Program Administration Update to the National Assembly on Rotor-Wing Force Structure and Development Programs, July 2006.

and insufficient coordinating relationship between the two cabinet ministries, compounded by the inability of the existing interagency coordination venues such as the AIDPC, resulted in low levels of component localization and marginal sectoral impacts on boosting technology competitiveness.

State-Business Relations: Ill-fated Industrial Competition Policies amid Receding Government Influences, Increasing Private Sector Interests, and Distortive Market Forces.

In the mid-1980s, during the de-regulation phases of the aircraft-manufacturing sector, the Korean government failed to effectively regulate and control cutthroat corporate competitions between the four major Chaebol firms. Recognizing receding state influence against market forces mashed in sectoral development policies, the government lifted strong protection barriers over existing aircraft-manufacturing firms and prematurely allowed more competition in the market before firms built sufficient engineering and manufacturing competencies regarding technological foundations and capital resources. The streamlined functional specialties earlier designated by the defense acquisition authorities in the early 1980s, at which designated Korean Air for engineering and manufacturing overall aircraft systems, and Samsung Aerospace for jet engine and propulsion systems, became nullified after permitting Daewoo and Hyundai into the finite domestic market space. Thus, without expanding the boundaries of domestic market demand in military aircrafts, the four chaebol firms plunged into a dumping war against each other with no prospects of technology accumulation and industrial upgrading.

The government decision making behavior in industrial competition policies, not only in aircraft manufacturing but in the overall industrial sectors in general, became a primary source of the Asian Financial Crisis of 1997. The industry structure after the 1997 Crisis still remains unresolved, at which the government controlled Korea Aerospace Industries and chaebol-run Korean Air continue to compete over a limited share of the domestic market. In a similar sense, regional innovation clusters compete over politics instead of technologically and economically optimized solutions. The piecemeal approach and unnecessary competition among local governments in hosting MRO businesses within its electoral constituencies raise concerns over the potentials of revisiting the pre-1997 government industrial policy on aircraft-manufacturing where ineffective government mitigation and adjudication efforts, overwhelmed by excessively ambitious corporate interests, eventually resulted in business failures and bankruptcies.

Cancellations and Manipulations: Delayed and Discontinued Development Projects

Innovation closes in incrementally, especially for capital intensive high technology sectors such as aerospace. Long gestation periods of mastering sophisticated technology and manufacturing processes takes a proponent up to high performing competitive levels in the international market. Thus, accumulated knowledge and experiences is greatly respected for sustaining the incremental innovation patterns in the sector. Whatsoever, defense acquisition authorities have continued to delay and discontinue critical aircraft development programs, and sometimes cancelled the entire development scheme in exchange of foreign substituting platforms.

As mentioned in previous paragraphs, the government abolished the initial competition structure of the aircraft-manufacturing sector dissected between Korean Air and Samsung Aerospace, and opened the playing ground to institute further competition among Chaebol firms without contemplating a coherent plan to nurture firm capacities and sectoral competence in technology and program management. Passive and narrow sighted commitments of Chaebol firms towards building sector specific R&D capacities and program management skills for aircraft-manufacturing resulted in mediocre performances comparative to other business fields. Considering the long incubation period for building modern aircrafts, in which the product life cycle extends into almost two to three decades, maintaining a certain pace in production without intermittent gaps between programs is imperative for sustaining technology readiness standards and workforce professionalism in both systems engineering and program management strengths. However, force improvement programs in aircrafts, administered by the defense acquisition authorities, have frequently left behind intermittent gaps in terms of R&D and production. The 6-year rift between the UH-60 license production and KUH-Surion development, substantial reduction of Bo-105 co-production from 147 helicopters to 12, disconnection between the KF-5E/F license production and KF-16 production, and sudden cancellation of the F-4 Phantom shelf life extension programs, all represent the discontinuities and lost opportunities in maintaining and sustaining a critical mass for sector specific workforce and manufacturing workloads.

Workshop Level Efforts

System upgrading processes allows the workshop level to mature the requisite technology and necessitates the incorporation of up-to-date novel technology through new system integration efforts. The process not only places respective weapon systems into the most modernized fashion possible, but also sustains the production base that withholds critical manpower. As discussed in chapter two, the general development path of aircraft-manufacturing spans within a sequentially phased framework of depot level repair works → license production with foreign assistance/component fabrication → system co-production → system design and manufacture. Regarding the long life cycle of an aircraft product, shelf life extension programs through system upgrade and airframe reinforcement work is considered an indispensable experience for late entrants in aircraft manufacturing in order to build sector specific capacities in system design and manufacturing work.

The B-52 Stratofortress Bomber of the U.S. Air Force represents the impact and effectiveness of continued upgrading efforts extending throughout decades. After its first rollout in 1954, the aircraft went through multiple stages of system upgrades and overhaul work, which still enables the B-52 to serve as a primary bomber capability in the U.S. Air Force air fleet. With the current defense build-up plan, the B-52 Stratofortress will continue to see service until well into the late 2040s, which makes some of the earlier airframes almost a 100 year design.[911] In the case of the international best seller F-16 fighter, ever since its first rollout in the late 1970s, the aircraft went through nearly 9 stages of system improvement efforts that include block upgrades (from variant 10 to 70), Shelf Life Extension Programs (SLEP), modifications tailored for customer needs, and various other re-engineering work.[912] In the case of the M1 Abrams Main Battle Tank, the product has gone through three iterations of system improvement since its first deployment in 1980. The US Army has plans for three more upgrade programs for the tank in the coming end of this decade, including the recently launched Modular Active Protection System Program.[913] In the case of the Korean aircraft-manufacturing sector, or the defense industry in general, system upgrade efforts are almost nonexistent. Korea's international bestselling weapon product, the K-9 Self-Propelled Howitzer, has not gone through a single session for system upgrade since its initial operational capability in 1989. The system upgrade programs planned for the F-4 Phantom-II and F-5 E/F Freedom Fighter were cancelled in order to divert the resources to other weapon systems programs. Consequently, the cancellation of these programs abolished the opportunity of enhancing the standing TRL and MRL (manufacturing readiness level) to higher standards. Still, the upgraded variants of the KT-1 basic trainer to the KA-1 light attacker, the T-50 advanced trainer to the FA-50 light combat aircraft, and the derivative versions of the KUH-Surion into maritime and medevac support mission platforms signifies the growth potentials in relations to the evolutionary efforts of system upgrades. Further upgrading of these systems, in a sense of extending product life cycles and improving performance in the coming days of necessary shelf life extension efforts regarding airframe reinforcements and avionics advancement works, is a matter of critical interest for relevant stakeholders.

The limits of state-led system development programs also make matters challenging for building sustained capacities in the aircraft-manufacturing sector. Vertical stovepipes and interagency bureaucracies make it difficult to initiate system upgrading efforts for programs with relatively short life cycles, such as in avionics. The quality and performance of modern aircrafts highly depends on the efficiency figures of the electronic modules integrated into the system. There is a critical linkage in avionics with commercial off the shelf technology since most of the technological sources originate from commercial information and communication technology (ICT), in which the public sector falls far behind in technological perfection compared to the private sector. Means of sensors and networks for precision strike capabilities, wireless data transmission and communication for command and control systems, integrated support systems between the battlefield engagement zones and rear area command centers in the course of sharing a common operational picture all rely on established ICT infrastructures.[914] The vibrant development pace of the commercial IT sector rapidly progresses, such

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911 Phillip Swarts, "Air Force prolongs the life of the venerable B-52," Air Force Times, February 22, 2016.
912 Gareth Jennings, "USAF Increases Scope of F-16 SLEP to Include More Aircraft and Airframe Hours," Jane's Defense Weekly, June 14, 2017.
913 Kris Osborn, "America's M1 Abrams Tanks Are Getting a Big Upgrade," The National Interest, April 6, 2017.
914 계중읍 외, IT 융합기술 기반 국방정보 기술동향 및 발전전략," 전자통신동향분석 제 28 권 제 2 호, 2013, p. 134.

that it becomes a matter of time for a novel product becoming obsolete. In order to respond to the changing market conditions, the introduction of an agile development system in the aerospace and defense sector is imperative for nurturing competitiveness and maintaining the manufacturing capacities in this domain. However, it seems to be a far achievable goal for state-led ICT development programs to obtain the expected level of agility in this regard. For instance, the Tactical Information Communication Network (TICN) shows the slow pace of public sector R&D performances, and also represents the case where regulatory restraints discourage evolutionary adaptations of advanced technologies.

International Technology Restrictions and Excessive Reliance on Foreign Sources

Restraints in international technology transfers originate from the intent of creating higher barriers for new entrants into the market while protecting the competitive advantage of the incumbent in the global market. The global aerospace and defense sector is already saturated with fluctuating market demands in the military and commercial sectors. In the extended aspects of discouraging fast followers in this field, high technological military specifications vying for attaining technological prowess in maintaining regional and global hegemony resulted in imposing stronger institutional restrictions on the flow of technology transfers and intellectual property rights.

High dependence on international sources has constantly presented constraints on indigenous efforts of capacity building for catch-up economies. As covered in earlier chapters, Korea has been overly reliant on foreign products and systems, especially in its aviation sector. Airframes, propulsion, transmissions, avionics and sensors, armaments, and so forth, all have strong dependence on the technological assistances provided by foreign partners. During the early sequentially phased developmental periods of firm capacity and national competitiveness, collaborations with international forerunners in the sector was an indispensable for later starters. In a highly complex technological domain like aerospace, international norms and regulations inhibit the entrance of new contenders in the field. Especially, the development and manufacturing technology of complex product system requires long gestation periods in learning and improvement in design and manufacturing skills, at which indispensable know-how and technology are mostly passed down tacitly in the workshop level. The technology transfer process of the KUH-Surion between the KHP design center engineers and Eurocopter technicians supports this case in a cultural sense, where Eurocopter corporate headquarters expressed strong reluctance in further transferring critical design technology during the concept development process. As a result, the KUH-Surion is generally evaluated as a physically reduced version of the Eurocopter Super Puma configuration. In a more institutional sense, however, restrictions imposed through technology security regimes also prevented the indigenous efforts of capacity building and knowledge accumulation. Technology security regimes, imposed in the U.S. export control system, have controlled the flow of proprietary rights from entity to entity when in need to share the respective technological item. All technology transfer processes had to obtain pre-approval from the U.S.

Department of State and remain in constant monitoring by technology security authorities. Simple modification requirements such as cockpit reconfiguration work had to obtain U.S. Government approval. In this regard, system modification or upgrading requirements under indigenous efforts were restrained by the imposed technology security regime.

The receding government influence in the defense industrial sector was associated with diminished assistances in financial support and contract awards. The deregulation process abandoned the protective designation incentives of certain defense firms implemented by the previous Specialization and Systematization Act, which further compelled the entire defense industrial base to enter into indefinite competition against each other. As such, more responsibility and authority has been given to the corporate sector. Lesser government influence and more competition have raised doubts on the prospects of building competitiveness and effectiveness, but is still a matter for continued observation as the domestic aerospace and defense sector constantly strives to secure a position within the country's national innovation system. The 2014 selloff of Samsung Techwin and Samsung Thales from its holding company Samsung Electronics, the country's foremost chaebol firm, symbolizes the dilemma confronted by the domestic defense industrial base regarding the future hope in this sector.[915]

The upper-tiered structure of the aircraft-manufacturing system still show overlaps in functions and responsibilities. The number of aeronautical programs sponsored under the two major aerospace and defense laboratory, ADD and KARI, require some streamlining efforts to enhance effectiveness and productivity in the R&D realm. The low popularity of aeronautical engineering departments at the university level should be more closely connected with government sponsored research programs awarded by the two aerospace related research institutes. These efforts shall be further exploited by the symbiotic relationship with the domestic manufacturing sector, represented by KAI and its subcontractors. Moreover, state sponsorship and networked collaboration with key proponents in the sector still remains as an integral component in aircraft manufacturing for late entrants in the sector such as Korea.

The Korean aircraft-manufacturing sector has incrementally followed the traditional development pathway when securing a foothold in the global market. Throughout the years of building sector specific capacity, aircraft manufacturing has proven the apparent limits of state led development processes in complex product systems, which not only associate sophisticated and interconnected technology products, but also international norms and regulations that sometime facilitate knowledge sharing efforts and technology transfer mechanisms, whereas also restrains further growth opportunities. Future development projects such as the indigenous Korea Fighter Experiment and the sector's entry into commercial aircraft manufacturing will be a point of observation over the transformative aspects of innovation systems under the developmental states construct.

915 채우석, "삼성이 방위산업을 포기한 이유," 뉴스타운경제, 2017.6.12.

Concluding Remarks

The classic conundrum for sustaining a defense industrial sector relates with the pressing necessities of coping with impending national security threats. Especially, the perils of an immediate outbreak of war in the Korean Peninsula stresses the urgent need to deploy military force requirements in order to maintain the conventional balance in armaments between the two Koreas. That being said, military planners preferred short-to-midterm defense acquisition programs to rapidly introduce the required operational capabilities rather than a long-term commitment to indigenously build-up a self-reliant capacity in domestic arms production. Such inclination to expeditiously marshal military capabilities collided with the value points prevalent in the hierarchies of other bureaucratic apparatus, which prioritized industrial development and prospective commercial opportunities. Due to the high reliance on government resources in aerospace and defense, the programming and execution of defense acquisition programs constitute the impetus of sustaining and improving the corporate sector into higher competitive grounds. Whatsoever, the differing value orientation between the military and industrial forces comprised the main reason for government indecisiveness in deliberating major aircraft development initiatives. In a program management perspective, such delay in government decision making compelled program management authorities to hastily proceed with the required R&D work and recklessly enter into contract awards in order to meet the condensed program timetable outlined for field deployment. In this regard, program authorities were unable to exert full commitment into incubating foundational capacities in the technology development phases of the respective program. Indiscreet control measures over emerging developmental risk factors constrained program authorities to rely inevitably on foreign sources, not only because of falling short in engineering and manufacturing skills, but also because of the preconditions to comply with major program milestones.

As observed in the major development programs, the program authorities did not productively utilize interagency competencies in system design and development. The planning and resourcing of major fixed wing and rotor wing development programs exclusively relied on the defense industrial sector without reaching out to the accumulated experiences of other public and private entities that obtained higher performance levels in managing complex product systems. Historically, major aircraft programs in the 80s and 90s, such as the HX series helicopters and KTX series trainer programs accounted for nearly billions of dollars in program execution budgets, in which entitled each program as the '*Most Expensive National Development Program Since the Mythical Foundation of the Nation*'.[916] Despite the unprecedented resources entrusted into the aircraft-manufacturing sector, the supervising echelons over the national level S&T architecture was not adequately involved in the comprehensive process of the program. Thus, the domains of the national level innovation system were not effectively activated throughout the developmental aspects of domestic aircraft manufacturing endeavors. This is the most regretful part where the lack of a constructive coordinative mechanism,

[916] The term is frequently catch phrased in Korean as '*단군이래 최대 국책사업*'.

which adjudicates imperative competencies and resources, consequently mars the prolific effects of innovative outcomes.

A critical linchpin considered for propelling this coordination mechanism is a professionalized workforce. Regardless of all the coordinative regimes and institutions established under the purview of government S&T initiatives with the stated purpose of revamping private-public partnership in various forms, the general performance of these venues was overall mediocre. An important strand of opinion raised by this author over such meager performance outcome extracts its roots from the poor professionalization levels of its workforce. In the days astride vast economic development and technology catch-up, simple abilities in machinery and consumer products was perhaps a requisite skill set for fast followers. Government coordination to build such capacities was comparatively accessible and easy to replicate. On the contrary, capacity building in developing complex product systems requires not only the most advanced level technology and capital support, but also extensive coordination efforts across relevant agencies and abounding pathways for accumulating knowledge and experiences. No matter how many regimes built for facilitating intra/interagency coordination processes, the catalyst for sustaining this effort is realized through a capable workforce that can adequately manage such complexities. Recent cases in international mergers and acquisition, where the principal agents strive to obtain requisite manpower in each respective areas of expertise, shows the significance of retaining a professional workforce. Recently, China has been aggressively recruiting talent around the globe in high-tech professions such as in semi-conductors, precision instruments, leading edge materials, and so forth. China has been recruiting top talent Chinese scholars in the S&T field residing overseas through the Thousand Talent Project, or The Recruitment Program of Global Experts, in order to enhance stronger technological competencies in major national innovation projects across various disciplines. China has also gained a notorious fame in snatching talented foreign engineers from competitor companies by luring high salaries and lucrative incentives. In the LCD panel business or semiconductor development, China has attracted the big wigs in major R&D projects from Korean firms with a so called 1-3-5 Deal (three times the annual salary over five years), or in some cases, offered a salary package nine times higher over a five-year period, including family support. Most of these high technology fields are those taught in university level classes and readily available through textbooks or public sources. However, it is the mastery of these technical subjects at the individual level that makes these tasks difficult to comprehend. Thus, in the high-technology field, fast followers must overcome the predicament of grasping the essentials of tacit knowledge against codified information.[917]

In the case of the aerospace and defense sector, the task becomes even more insurmountable. The vast system integration requirements of complex product systems strongly demand expert knowledge and skills in the program management side. Until the late 1980s, the U.S. defense industry constantly experienced program delays, system failures, cost increases, and so forth. A number of

[917] 남윤선 외, 반도체 전쟁: 4 차 산업혁명 시대 중국의 역습, 한국경제신문, 2017.

organizational insufficiencies and overlaps were identified in the weapon system development process. The sector turned into a large pit of cost overruns and excessive expenditures, represented by a case where a coffeepot purchase amounted $7,000 and hammer cost $400. These procedural insufficiencies were rampant across the board, which undermined key development projects of the military.[918] In order to overcome the bureaucratic and managerial hiccups throughout the weapons development process, the White House launched the Packard Commission and initiated a major reform effort to efficiently manage the defense acquisition system by carrying out a full-scale restructuring process, instituting stronger government oversight, and promoting a professional workforce. The Commission identified the absence of a fine-tuned career pathway for the acquisition workforce, which lacked adequate training curriculums and structured career development and management planning. The Commission recommended the institution of an effective interactive mechanism between curriculum development and acquisition program management field activities in order to build a healthy training program that applied practical challenges confronted in the real-world. The launching of a reasonable career management pathway through the combination of training and post-training assignments enabled the workforce to accumulate knowledge and experience in the process of handling major defense programs.[919]

Unfortunately, neither of the Chinese aggressiveness in recruiting talent nor the U.S. determination in professionalizing its workforce is projected in the reality of Korea. Efficient coordinating mechanisms do not come fully enforced without the experts, specialized in each respective sectors, fully driving the steering wheel behind these initiatives. Experts are grown, not born, and the way how to home grow expertise is to acknowledge and respect the profession with a structured mindset and tenacious patience. An organization that rotates assignments every two-three years over subject areas irrelevant to each other, without instating a work development plan connected to one's education and training endeavors, in the absence of a visionary career path considered translucent and promising, would apparently obstruct the seamless accumulation of knowledge and experiences, which serves as a prerequisite for bolstering competitiveness. Government policies always tend to capture these rhetoric in language, but it is in the detailed implementation phases where the actual execution of these initiatives requires a structured and patient approach. The Defense Acquisition Improvement Group in 2005, the preliminary commission in preparation of major structural defense acquisition reform, clearly stipulated the need to build a professional workforce in the newly legislated Defense Acquisition Program Act. However, the actual implementation of the stipulation still remains inactive even at the time of this publication.

918 David. S. Meyer, A Winter of Discontent: The Nuclear Freeze and American Politics, Praeger, 1990, p. 57.
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