NASA/DOD Aerospace Knowledge Diffusion Research Project

411 915

Paper Sixty Eight

Who is Managing Knowledge? The Implications for Knowledge Production and Management of Global Strategic Alliances in Knowledge-Dependent Industries

Paper presented at the International Studies Association's 39th Annual Convention, held 17-21 March 1998, Minneapolis, Minnesota

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WHO IS MANAGING KNOWLEDGE?
THE IMPLICATIONS FOR KNOWLEDGE PRODUCTION AND MANAGEMENT OF GLOBAL STRATEGIC ALLIANCES IN KNOWLEDGE-DEPENDENT INDUSTRIES

by

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INTRODUCTION

"Knowledge is power." Knowledge is the foundation upon which researchers build as they innovate. Innovation lies at the core of a state's or a firm's ability to survive in a competitive world. Indeed, some economic historians aver that technological innovation, not trade, is the engine to economic growth (see, e.g., Lewis, 1978; Schumpeter, 1994). Despite the centrality of knowledge to corporate success, analysts have only recently shown an interest in the "knowledge capital" or "intellectual capital" of the firm, often literally trying to assign a value to this resource. Suddenly knowledge management has become a topic *du jour* for the media (Groves, 1998; Hammonds, Jackson, DeGeorge, & Morris, 1997; Hiltzik, 1997; Plate, 1997), government agencies (Dalton & Serapio, 1995), and public and private think tanks (Arquilla & Ronfeldt, 1998), as well as serious scholarship (Pinelli, Kennedy, Barclay, & Bishop, 1997; Strange, 1988). It was even the subject of the Winter 1996 special issue of the *Strategic Management Journal* (Schendel, 1996).

Knowledge management encompasses both the creation (production) and the diffusion (transfer and use) of knowledge. The proliferation of global strategic alliances (GSAs) in a number of knowledge-dependent firms has created a new and complex dynamic interaction among technology, economics, politics, and culture, that has redefined the parameters of corporate behavior (Nelson, 1996). The need to adjust to the "relentless evolution" of the variables shaping the industry has captured the attention of at least two of the industry's leaders. Mickey Blackwell, President and Chief Operating Officer of Lockheed Martin, recently noted that only those firms which are "most adaptable to change, ... [not] the strongest, nor the most intelligent" will survive ("Transatlantic Mergers ...," 1997). Similarly, Philip Condit, Chairman of The Boeing Company, observed that "of the 12 biggest companies in the United States in 1900, only one exists today. You fail to innovate, you ... lose" ("Boeing Nears Decision ... ," 1997). The rise of GSAs has complicated and elevated the need to understand how to manage knowledge. This paper hopes to shed light on this goal by exploring two aspects of the phenomenon: first, it uses the large commercial aircraft (LCA) industry to tell the story of how and why global strategic alliances emerged, proliferated, and have become essential to knowledge-dependent firms; second, it explores the implications of GSA production structures for knowledge management, and in particular for the changing relationships within the "Golden Triangle" of knowledge creation and diffusion—academia, government, and industry. In so doing, it raises questions about who will manage knowledge in the 21st century: Who discovers knowledge? Who funds the discovery? Who decides what to look for and how it will be used? Who owns the knowledge discovered? Who controls its diffusion?

GLOBAL STRATEGIC ALLIANCES: ADAPTING TO CHANGE IN THE AIRCRAFT RD&P ENVIRONMENT

During the last 30 years, aviation, though playing an increasingly critical role in national security and economic vitality, has been transformed from a fiercely-protected, domestically-bounded industrial structure to a chaotic web of mutually dependent and globally dispersed firms. Still highly competitive, the number of primes—those manufacturers responsible for final assembly—has been reduced to two in the LCA sector: Boeing Commercial Airplane Company and Airbus Industries. However, no LCA is built using only in-house or even only domestic production structures or processes; Boeing and Airbus now "compete" to incorporate as many foreign producers as they can in an effort to capture market share into the foreseeable future. Indeed, policymakers must grapple with the imperative for foreign collaboration in the constant struggle to " ... enhance the competitiveness, production speed, and capacity of aerospace companies and suppliers ..." (*U.S.-Asian Collaboration ...*, 1997). GSAs which integrate foreign firms into the entire range of research, development, and production (RD&P) processes are potentially more fragile and vulnerable than firms bounded by national borders. Various forms of transnational coproduction arrangements in aerospace are as old as the industry itself (Bluestone, Jordan, and Sullivan, 1981; Golich, 1991; Golich, Pinelli, and Barclay, 1997; Stekler, 1965). These earlier structures were easily abrogated when countries and companies—primarily for security reasons—retrenched behind national borders for aircraft RD&P (Lorell, 1980). Genuine, globally-dispersed strategic alliances, from which retreat would be more difficult, first appeared in the 1970s and later proliferated during the 1980s (Evans, 1993; Hayward, 1986; Lorange and Roos, 1992; Mowery, 1987; Mowery and Rosenberg, 1989).

The globalization of aircraft manufacturing has created a set of intriguing problems for national industrial and trade policies, due to the complex interpenetration of the LCA sector with the innovation and technology systems considered crucial for economic competitiveness and national security. On one hand, market forces, together with foreign governments demanding production agreements as a price for market access, generate centripetal forces in the industry (Golich, 1992). On the other hand, firms and their governments continue to prize technological leadership and the strategic importance of commanding "first place" in aeronautical innovation. As Nelson (1993) observes generally about global trends in technology policy, "there is a tension caused by the attempts of national governments to form and implement national technology policies in a world where business and technology are increasingly transnational" (p.18). These tensions are particularly evident in knowledge-dependent sectors where national strategies have to co-exist with, if not globalization, then certainly regionalization of industrial and technological capabilities.

Innovation and adaptation constantly proceed through a complicated set of dynamic reciprocal interactions (Golich, 1992, p. 899; Nelson, 1996, p. 4). What changes is the relative importance of these variables as each shifts back and forth from an independent position effecting change, to a dependent position responding to change. For example, although Europeans took an early lead in technological innovation in aviation, U.S. political and economic hegemony immediately following World War II helped its firms dominate the sector; they had access to private and public finance and intellectual capital which enabled them to research, develop, produce, and sell the largest number of the most technologically sophisticated aircraft. Operating from this position of power, U.S. firms canceled several attempts at co-production arrangements with European companies, triggering a defensive "catch-up" response which eventually culminated in the creation of the Airbus Industries consortium (Golich, 1992; Hayward, 1986; Hochmuth, 1974; Lorell, 1980; Newhouse, 1982). This circumstance affected the level and style of government intervention in the industry (Hayward and Golich, 1997; Hochmuth, 1974; Shepherd, Duchene, and Saunders, 1983). Over time, as aviation firms and countries gained political and economic parity, technological change took center stage; breakthroughs in communications, computer-aided design (CAD), and transportation made transboundary, synchronous research and design work possible and decreased the transaction cost of shipping critical components long distances. Thus, Boeing can now design a paperless airplane with teams drawn from around the world, and Airbus can ferry mammoth pieces of its aircraft, built in the United Kingdom, via the Guppy to final assembly in Toulouse, France. These technological changes are now influencing politics, economics, and culture by simultaneously increasing volatility and interdependence in the global political economy and by intensifying its consequences for virtually everyone.

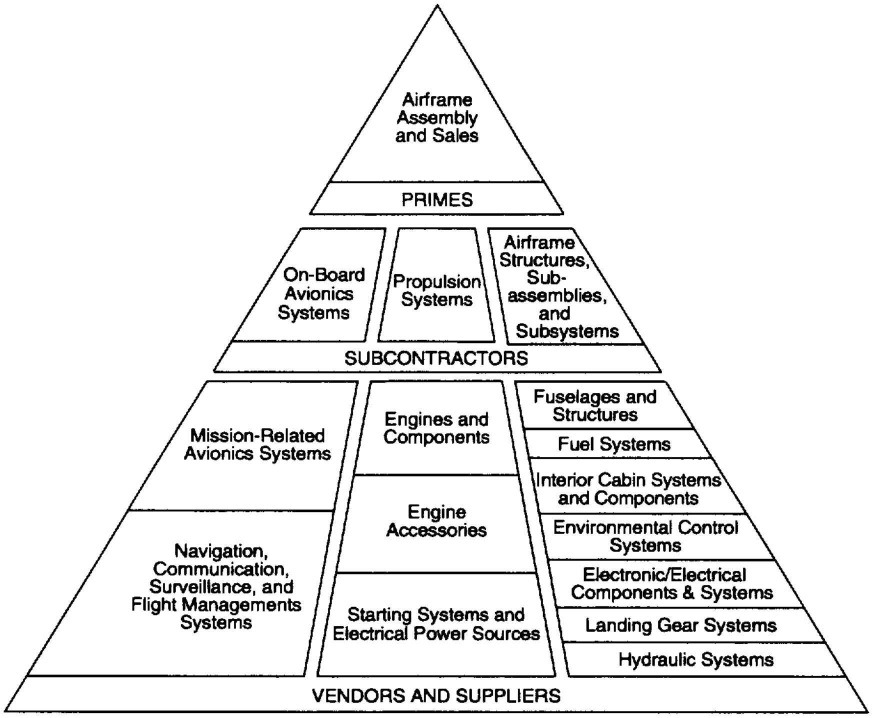
Although the dynamic reciprocity among technology, economics, politics, and culture are not easily measured in any tangible way (Nelson, 1996), a careful analysis can reveal trends, thus helping corporate and government policymakers choose appropriate strategic responses. What follows is a brief description of each of these factors, an assessment of how each has influenced and may continue to shape future structures and processes in the global political economy and aerospace, and an analysis of why they are likely to lead to a further proliferation of GSAs in one form or another.

Technology

Technological advances affect the emergence, proliferation, and permanence of GSAs in at least five ways. First, technological innovations specifically designed to enhance aircraft performance—such as lighter weight and stronger composite materials or enhanced digital displays—often have value for a wide array of both upstream and downstream industries. Aircraft manufacturing is typically a pioneer developer and user of core technologies, the early use and refinements of which help to decrease costs for other industry sectors (National Academy of Engineering, 1988; Tyson, 1988; U.S. Executive Office of the President, Office of Science and Technology Policy, 1985; van Tulder and Junne, 1988). Its role as a technology innovator and user contributes to the perception of aircraft manufacturing as strategic to maintaining a healthy economy. Second, technological innovations increase the efficiency and effectiveness of aircraft operations. They drive down labor costs; enhance the flight parameters of speed, range, and payload capacity; and expedite solutions to noise and environmental pollution. Computers, electronic components, and software—which account for over half the flyaway cost of large commercial aircraft—now navigate, control the engines, and even change the shape of an aircraft's lifting surfaces to maximize performance; in aircraft with "fly-by-wire" systems the pilot is more a systems manager than a stick-and-rudder jockey (Tomayko, 1992). By decreasing the costs of aircraft *use*, technological innovations have increased the value of air transport to governments and corporations alike. Third, technological innovations improve aircraft production and assembly. Computers direct the milling of parts to create components of greater precision and consistency than those made with traditional machine tools. Computers also facilitate the building of very large parts that are stronger, need less assembly, and are more precise than smaller units. In the assembly phase, computers employ lasers to align systems more precisely than ever before. Altogether, analysts estimate that this wave of innovation has shaved between 30 and 40 percent off the cost of airplane production, amounting to as much as a $15 million reduction in the cost of building a Boeing 747 (Kaplan, 1997; "Software Aids Crash Studies," 1997). Lower production costs, of course, yield lower prices and help to increase sales (Majumdar, 1987).

These three technological advances compel government policymakers around the world to gain or maintain a solid position in some key aspect of aircraft manufacturing. The perceived value of substantial participation intensifies national and corporate intentions to be players in the sector, and "acts as a centrifugal force impelling protectionist policies designed to avoid perceived vulnerabilities associated with mutual dependency" (Golich, 1992, p. 902). Several governments have consciously adopted intervention policies designed to promote the unilateral dominance of the sector—from the United Kingdom's "magic circle" procurement policies to France's creation of national champions rationalized by geographic region—and all have failed to achieve that goal (Cerny, 1980; Chapman, 1991; Chesnais, 1993; Cohen, 1977; Cohen, Halimi, and Zysman, 1986; Crossland, 1975; Gillispie, 1980; Gilpin, 1968; Golich, 1991; Hayward, 1983; Hochmuth, 1974; Hoffmann, *et al.*, 1963; Kolodziej, 1987; Kuisel, 1981; McCormick, 1987; Papon, 1975; Rubenstein, *et al.*, 1977; Underhill, 1997; Zysman, 1978).

They have been more successful in acquiring a participatory role as a member of a GSA, in part because of the nature of the fourth and fifth phenomena in aviation's technological innovation. Fourth, the increasing range, specialization, and sophistication of aviation technologies renders it virtually impossible for any one firm to maintain in-house RD&P of all that is required to assemble a state-of-the-art aircraft. Hence, second- and third-tier subcontractors, vendors, and suppliers are niche players in aircraft RD&P (see Figure 1). This pyramid structure of the aircraft manufacturing industry first emerged during World War II to expedite the mass production of military aircraft (Bernstein, 1995; Bright, 1978; Golich, Pinelli, and Barclay, 1997; Lilley, 1947); the arrangement facilitated and reinforced subsequent moves toward "outsourcing" for increasingly specialized components. Finally, technological innovation in research and design communications has encouraged the proliferation of GSAs. Advances in computer aided graphics and design (CAD) technologies, specifically CATIA (computer-aided, three-dimensional, interactive application), enabled Boeing to produce the 777 using its now fabled cross-functional design-build teams (DBTs) from around the world. These new computer linkages and applications facilitate greater agility in aircraft RD&P and allow the primes to integrate a larger number of foreign suppliers into their production chain. In the case of Boeing's 777, nearly 60 foreign firms—from Japan, Australia, Brazil, Canada, France, Ireland, Italy, Korea, and Singapore—supplied components. More than 238 DBTs—some with as many as 40 members—joined forces to create the 777 (Mecham, 1997b; Proctor, 1994a). During the design phase, computers can check whether two parts will fit together snugly, eliminating the need for building physical models out of plastic or clay; savings in time and money amount



Source: G. W. Bernstein

Figure 1. The Large Commercial Aircraft Production Structure in the United States.

to roughly 40 percent; computers can also conduct stress analyses and check the airflow over a plane before any parts are even ordered (Kaplan, 1997). This new production flexibility decreases the cost and price of aircraft.

Perhaps most importantly, however, this wave of technological innovation reinforces the value of global strategic alliances by making them technologically feasible and economically affordable. Without the ability to communicate effectively across vast expanses of land and sea, these relatively new corporate structures are rather fragile constructs (Evans, 1993; Lorange and Roos, 1992; Talalay, Farrands, and Tooze, 1997; van Tulder and Junne, 1988). They are vulnerable to defeat by enduring political barriers, economic competition, and cultural differences.

Economics

Just as technological advances generate equally powerful, but offsetting, motives for government and corporate behavior—pushing global players closer together through various synergies, but also pulling them apart as they seek to reap associated benefits unilaterally—the economic realities of aircraft manufacturing in today's global political economy also exert both centrifugal and centripetal forces. Aircraft manufacturing can yield extraordinary benefits—both direct and indirect—for a country with a successful sector residing within its borders. Profits from sales, arguably the most direct benefit of all, generate financial capital that can be used to support new generation production projects, and exports contribute positively to the balance of trade. Since the late 1950s, aerospace has been the leading industrial contributor to U.S. export earnings. At the dawn of the 21st century, aerospace remains the nation's leading exporter of manufactured goods, producing the largest trade surplus of any U.S. manufacturing industry. In 1997, U.S. aerospace sales recorded a trade surplus of $34 billion (Napier, 1998).

Indirect benefits are significant as well. The industry's key position as a developer and first user of core technologies has already been noted. Aerospace also plays an important role in creating jobs and as a supplier to and user of upstream and downstream industries. According to a study by the Congressional Research Service, for every $1 billion of aircraft shipments by U.S. firms in 1991, nearly 35,000 jobs were created (Cantor, 1992). In 1997, U.S. aerospace firms employed nearly 870,000 persons—of which 43 percent were skilled production workers, 22 percent were engineers and scientists, and 7 percent were technicians (Napier, 1998; 1995)—thus helping to sustain a skilled workforce capable of generating the core technologies so important to successes in a wide range of other industries. The aircraft used in air transportation constitute a critical "intermediate" good; any business that depends on air transport benefits from increased efficiencies afforded by state-of-the-art equipment. In addition, aircraft production is connected in some significant way to nearly 80 percent of the economy. Directly or indirectly, about 340 sectors of the economy, out of about 429 defined sectors, produce goods and services that support aircraft RD&P; 150 of those supply outputs directly to the aircraft industry (Cantor, 1992, p. 43). "Thus the 'linkage externality' is positive—both the private returns to aerospace manufacturers and the social and private returns to upstream and downstream users are increasing" (Golich, Pinelli, and Barclay, 1997, p. 5).

Naturally, the United States hopes to continue the economic gains it has enjoyed from aerospace over the years. However, other governments have observed this largesse accruing to the U.S. and have decided they would like a share of the benefits as well. Other industrialized nations in Europe and Asia, which once had thriving aerospace industries of their own, seek to reestablish that foundation either through competition, as with Airbus Industries in Europe, or through strategic linkages, such as those between Japanese firms and Boeing (Barclay and Pinelli, 1997; Hayward, 1986; Pinelli, Barclay, and Kotler, 1997; Samuels, 1994; Samuels and Whipple, 1989a; 1989b). Industrializing nations seek to join the party through various co-production or sub-contracting arrangements (Harr, 1972; Schaufele, 1988).

Whereas aircraft manufacturing's huge potential for returning a wide range of economic benefits for domestic and regional economies explains why so many nations hope to join forces with well-established aerospace firms in some form of a global strategic alliance, it does not explain why dominant firms are willing to partner with weaker firms in foreign countries. Two economic phenomena unique to the last quarter of the 20th century combine to account for this puzzle. The first is simply that the largest market potential for aircraft lies outside the borders of either the United States or continental Europe. The Pacific Rim and Latin America have, by far, the largest demand for aircraft into the foreseeable future. This clearly gives them the ability to bargain for co-production arrangements as part of the purchasing agreement (Harr, 1972; Schaufele, 1988).

The second economic phenomenon has been the transformation of aircraft production into an extremely risky business financially, where the stakes are very high. Aircraft manufacturers make major capital investment decisions despite uncertain future payoffs. They spend several billion dollars to conceptualize, develop, and build a new generation airframe. However, the typical 10- to 15-year return on investment cycle defies accurate prediction. As a result, new aircraft may not fit market needs, as happened after the 1978 economic deregulation of the U.S. airline industry, when manufacturers were caught in the middle of producing wide body aircraft that airlines no longer wanted. Despite the high risk associated with long lead times and major capital outlay, timing has been critical to the market success of a new aircraft. Not only has it been important to get a final product to market first, it has also been critical that aircraft be delivered to airlines on time (Bluestone, Jordan, and Sullivan, 1981; Golich, 1989, 1992; Hayward, 1983, 1986; Miller and Sawers, 1968; Mowery and Rosenberg, 1982; 1989; Newhouse, 1982). Performance, training and maintenance costs, and price far outweigh other factors in today's market; nevertheless, Boeing was still concerned enough about timing that one of its articulated goals for the B-777 was to avoid the delivery delays and initial service problems that have accompanied the introduction of virtually every other new generation aircraft (Majumdar, 1987; Proctor, 1994a; 1994b).

By the 1980s, key corporate and government decision makers around the world concluded that technological advances and economic dynamics rendered transnational collaboration critical to maintaining a competitive position. Through collaboration they secured financial support for RD&P, avoided potential tariff and non-tariff barriers, sought to nullify or dilute competition from other firms, and avoided domestic antitrust restrictions. Global strategic alliances would also help prime manufacturers improve market access, increase risk sharing, lower RD&P costs, and gain financial support for sales.

Politics

Politics play an intriguing and important role in the creation and maintenance of aviation GSAs. Both domestic and foreign politics—each influenced by multiple constituencies—contribute to the number and shape of aviation GSAs. As soon as the military value of aircraft was recognized, their manufacture became a vital component of national security; thus, government policies became essential to the sector's development. Aviation remains a keystone of the military industrial base. Moreover, it is now also regarded as an economic linchpin, highly valued for its "spillover" effects, either as a powerful force pushing innovation through a cascade of "downstream" activities, or as a "first user" of novel technologies. Although harder to measure or quantify, aircraft manufacturing brings an element of prestige to countries around the world which can afford to participate in the industry; as such it contributes to a country's "international status and predominance in the future development of science and technology" (Todd and Simpson, 1985, p. 33). The drive to attain and sustain military superiority, economic competitiveness, and prestige has consistently compelled national governments to support RD&P efforts in aviation. Typically this has involved a combination of protection against foreign competition and of domestic-level promotion (Bluestone, Jordan, and Sullivan, 1981; Cohen, 1994; Council on Competitiveness, 1994; Davies, 1964; Dertouzos, Lester, and Solow, 1989; Golich, 1989; 1992; Golich, Pinelli, and Barclay, 1997; Julius, 1990; Lopez and Yager, 1987; National Academy of Engineering, 1987; Nau, 1974; Neuman, 1984; Newhouse, 1982; Rapkin and Strand, 1995; Ruggie, 1975; Servan-Schreiber, 1968; Simonson, 1968; Solberg, 1979; Strange, 1988; Tyson, 1988; 1992; van Tulder and Junne, 1988; Vander Meulen, 1991; Williams, 1984; Yoffie, 1993).

Governments can choose from a wide array of policies to promote aviation, including financial subsidies, information dissemination, government mandated technology transfer from foreign sources, technical standards, and government procurement (Golich, Pinelli, and Barclay, 1997; Mowery, 1994). Public policies—the outcomes of politics—can be directed at aircraft manufacturers. For example, in 1967, U.S. government officials were worried about the health and well-being of two then-core aerospace firms—McDonnell Aircraft and Douglas Aircraft Company. Inspired by domestic anxieties about losing competitiveness, jobs, and a key production and knowledge base, as well as by international apprehensions about continued defense-oriented production, U.S. policymakers supported the merger of McDonnell and Douglas by waiving antitrust concerns and providing a $75 million guaranteed loan; only four years later a similar set of motives inspired a $250 million loan guarantee to prevent Lockheed from declaring bankruptcy (Golich, 1989; Mowery and Rosenberg, 1982).

However, most public policies which affect aircraft manufacturers address concerns largely, if not completely, unrelated to aviation. Public policy establishes the market parameters within which economic activity takes place. A range of policies—including immigration, intellectual property rights and patent laws, currency valuation, and trade liberalization—defines critical economic, education, and legal infrastructures (Ergas, 1987, p. 92). For example, a strong dollar, which the U.S. "enjoyed" throughout the 1980s, provided financial capital for research and development as foreign *and* domestic capital sought investment opportunities in the United States. However, a strong currency can make exports noncompetitive in price, and has contributed significantly to the rise of aviation GSAs as firms have sought to counter-balance the "costs" of a strong currency with production participation by potential foreign consumers.

Although all governments with a robust aircraft manufacturing sector have been actively and intimately involved in aviation's development, this is where the similarity ends. Governments have adopted different styles of intervention. Some of this difference is attributable to politics and some to culture; in each case the differences have influenced the number and shape of aviation GSAs. U.S. aeronautical leadership was obtained by close cooperation between state and industry, following a "mission oriented" strategy characterized by large-scale project work, centering on large firms with a heavy emphasis on areas such as defense. Extensive federal support for production, transfer, and use of aeronautical knowledge and technology began in 1917 under the auspices of the National Advisory Committee for Aeronautics (NACA). It was later strongly influenced by extensive Cold War military procurement and defense-related research and development (R&D), and managed by NACA's 1958 replacement, the National Aeronautics and Space Administration (NASA). The strategy worked, largely due to the range, scale, and overlap of early U.S. civil and military "missions," and to the flexibility of U.S. organizational structures (Ergas, 1987).

For the most part, European governments have been motivated to intervene in aviation for economic, social, and political prestige purposes; national security as a "mission" has been less of a concern. They have employed general and selective subsidies to promote both generic R&D activities and specific projects such as the creation and maintenance of Airbus Industries. European governments have encouraged collaboration and rationalization fairly aggressively among domestic firms so as to spread investment risk more widely—across society as a whole—because the benefits deriving from these activities usually diffuse quickly throughout other industry sectors, thereby benefiting society as a whole, but creating something of a disincentive for individual firms unable to profit from their work. They also hope to discourage competitive and duplicative R&D and to boost returns to scale in R&D by increasing firm size (Fölster, 1991, pp. 26–30; Eden and Molot, 1996; Golich, 1996; Kudrle, 1996; Moore, 1996; Rapkin and Strand, 1996; Rothwell and Zegveld, 1981). In addition, Europeans, concerned about their status in the global economy, especially vis-à-vis the U.S., launched an aggressive series of industrial and technology policies in 1968 designed to sustain or reinvigorate their competitiveness. Embedded in these strategies was a recognition that transnational collaboration would be necessary, and governments actively encouraged firms to cooperate across formerly impenetrable political borders (Nueno and Oosterveld, 1986; Organization for Economic Cooperation and Development, 1968; Scherer, 1992; Servan-Schreiber, 1968).

As with the United States and Europe, Japan has implemented a variety of policies—

foreign and domestic—aimed at both generic R&D activities and specific sectors, including aircraft manufacturing. Unlike the national policies of the United States and Europe, Japanese public policy appears to be more coherent and coordinated, targeting clearly articulated, though broadly based, goals. It is grounded in the assumption that technological leadership is critical to national economic performance and to Japan's ability to remain competitive in today's global political economy. Closely identified with survivability, Japan's public policy is focused, consistent, pragmatic, adaptive, and designed to increase corporate capacity to adjust to technological change across entire industry structures via the effective diffusion of imported and domestically produced knowledge and technology (Branscomb, 1993; Ergas, 1987; Frankel and Kahler, 1993; He, 1993; Imai, 1991; Komiya, Okuno, and Suzumura, 1988; Pinelli, Barclay, and Kotler, 1997). So, for example, education policy, which includes a mandatory six years of pre-college English training, dovetails with industrial policy because it ensures that Japanese adults can learn from and diffuse the explicit or codified knowledge contained in books, journals, and drawings, as well as from the experiential or tacit (learn-by-doing/learn-by-using) knowledge gained by working with engineers, scientists, and technicians trained in the U.S. and by studying abroad (Arrison, Bergsten, Graham, and Harris, 1992; Imai, 1991; Mowery and Rosenberg, 1985b; Odagiri and Goto, 1993; Okimoto, 1986; Peck and Goto, 1981).

The Ministry of International Trade and Industry (MITI) is the principal state player in the Japanese economy (Johnson, 1982; Samuels, 1994). MITI nurtures the development of industries such as aircraft manufacturing as sources of knowledge that can be "spun on" to other industries. It fosters research collaborations, alliances, and linkages—among domestic firms, such as the Japanese Aircraft Development Corporation (JADC), as well as with foreign firms, such as the JADC/Boeing "program partnership," the 777 project—as one way to access and import external knowledge and technology (Cheney and Grimes, 1991; Pinelli, Barclay, and Kotler, 1997).

Japan has targeted aircraft manufacturing as one of three key technologies for the 21st Century (Todd and Simpson, 1986, p. 209). Aircraft production complements Japan's strengths in such areas as materials, microeletronics, and computer-aided design and manufacturing (CAD/CAM) (Council on Competitiveness, 1996; Mowery and Rosenberg, 1985a; National Research Council, 1994; Sabbagh, 1996; Samuels and Whipple, 1989a; 1989b; Todd and Simpson, 1986; U.S. Congress, Office of Technology Assessment, 1991; Yoshino, 1986). However, for Japan to be a "player" in the sector, policymakers have recognized they must form strategic partnerships with firms in the U.S. or in Europe. Four key reasons underlie this conclusion:

> First, the market, both domestic and foreign, for military aircraft was relatively small, cyclic, and well established. Second, the small size of the domestic (Japanese) market (coupled with the lack of a mechanism for international sales and a launch customer) was insufficient to support commercial aircraft production. Third, the RD&P costs are so great that no one firm (or consortium of Japanese firms) can assume the risk associated with launching a new LCA. Fourth, Japanese industrial policies, industry sortia combine to make Japan ideally structure, and airframe and engine con-

> suited to participate in joint ventures as subcontractors and risk-sharing partners with established LCA producers (e.g., Boeing). (Pinelli, Barclay, and Kotler, 1997, p. 857)

As with technology and economics, political concerns, at both the domestic and the international levels, send government officials mixed signals regarding the wisdom of supporting global strategic alliances. Whereas technological, economic, and political gains associated with aerospace suggest policymakers should do all they can to protect an independent, self-sufficient, domestic industry, global technological, economic, and political realities, such as greater parity and competitiveness across the board, compel policymakers to embrace GSAs. As Gibbons, *et al.* (1996) note however, the specialized knowledge firms need to create competitive advantage is difficult for all firms to acquire or imitate; it is particularly difficult for those "firms whose national culture does not yet support a well articulated science and technology infrastructure" (p. 13). This is borne out by Figure 2, which reveals the U.S. technology position relative to Japan and Europe. Those firms have done well whose governments have been proactively involved in the economy—in particular, those nations where education, science and technology, and competition policy are integrated into "a comprehensive innovation policy that is sensitive to the fact that knowledge production is socially distributed" (p. 16). (For more on some of the issues confronting knowledge diffusion "policy" in the United States, see Chapman, 1995; Dye, 1996a; 1996b; Rosenbloom and Spencer, 1996.)

Culture

The impact of culture as a variable affecting something as technical as the engineering and science associated with commercial class aircraft manufacturing surprises only those who have not been involved in trying to merge corporate cultures or to negotiate outsourcing arrangements with foreign companies, much less the terms and conditions associated with a global strategic alliance. Culture influences the shape and number of GSAs at both the firm and the national (or society) level.

At the most fundamental level, culture shapes a society's economic ideology. Culture helps to define the acceptable and appropriate relationships between the state and the market (Strange, 1988). For example, United States policymakers often confuse economic liberalism with an assumption that the government should never intervene in the economy. This defies a very long tradition in the U.S., dating back to the very beginnings of our nation, of significant government involvement in the economy (Golich, Pinelli, and Barclay, 1997). In some countries, e.g., France, policymakers choose to directly involve themselves in the economy. (For more on the effect of history, ideology, and culture on national approaches to innovation policy, see Brander, 1987; Cerny, 1980; Chandler, 1977; Chandler and Daems, 1980; Chapman, 1991; Chesnais, 1993; Gillispie, 1980; Gilpin 1968; Golich, 1992; Hoffmann, *et al.*, 1963; Keck, 1993; Markovits, 1986; McCormick, 1987;

Sector	Parity		Lead			
			Slight		Substantial	
Energy						
Energy efficiency		△	■			
Storage, conditioning, distribution, & transmission		▨	■			
Improved generation		▨	■			
Environmental quality						
Monitoring & assessment			▼	▽		
Pollution control	■	▨				
Remediation & restoration		▽	▼			
Information & communication						
Components	▲			▨		
Communications				▨	■	
Computing Systems				▨	■	
Information management					▲	
Intelligent complex adaptive systems	■			▽		
Sensors	▲	△				
Software				▨	▲	
Living systems						
Biotechnology			■	△		
Medical technologies			▲	▨		
Agricultural & food technologies			▼	△		
Human systems				△	▲	
Manufacturing						
Discrete product manufacturing			■	▨		
Continuous materials processing	■	▨				
Micro/manofabrication and machining	▲			▨		
Materials						
Materials			▼	▨	▼	
Structures				▨		
Transportation						
Aerodynamics				▨	▼	
Avionics & controls				▽	▼	
Propulsion & power			▼	▨		
Systems integration				▨	■	
Human interface					■	△

Source: European Commission (1996) *National Critical Technologies Review Groups*

Japan	Europe
▲ Improved	△ Improved
■ Maintained	▨ Maintained
▼ Declined	▽ Declined

Figure 2. US Technology Position Relative to Japan & Europe.

Porter, 1990; Talalay, Farrands, and Tooze, 1997; Underhill, 1997.)

Culture also affects styles of communication and negotiation that can facilitate or complicate problem solving (Gray and Wood, 1991). Comfort levels with the time it takes to find the common ground which might lead more easily to dispute-resolution vary across cultures. This becomes absolutely critical when the time comes to negotiate strategic alliances that transcend political borders. By their very nature strategic alliances are intentionally created to last, otherwise firms could pursue the far simpler task of negotiating a time-certain contracting arrangement. Strategic alliances, however, involve the sharing of key factors of production, including financial, human, and intellectual capital, and therefore can only endure if a long-term horizon is considered. During the course of a strategic alliance, partners will contribute to and withdraw from the various resource pools unevenly at any given point of time, but in a balanced fashion over the long haul. Therefore, significant trust that the benefits will, in fact, accrue equitably must be in place for the alliance to be successful. Cultural differences regarding what is fair or appropriate to give and to take can, therefore, play very important roles in negotiating the final structures and processes involved in GSAs (Gray, 89; Gray and Wood, 1991; Harris and Mowery, 1990; Hoffman and Kaplinsky, 1988; Imai, 1991; Katzenstein, 1976; Koenig and van Wijk, 1992; Kohn, 1992; Lawler, 1985; Money and Haufler, 1992; Mytelka, 1987; Perlmutter and Heenan, 1986; Pravitt, 1990; Rorlich, 1987; Spekman and Wilson, 1992).

At the level of the firm, corporate culture defines how the work of the firm gets done (Gray, 1989; Kohn, 1992) and affects attitudes toward corporate rivalry and collaboration (including between domestic and international corporations), international copyright and patent law, and the priority of task orientation and hierarchy versus process orientation and consensus. Management of key resources, e.g., financial, human, and intellectual capital, is also embedded in corporate culture. For example, though economists have long cited "labor" as a critical production factor, the value of educated, highly skilled, easily trained, mobile, and flexible employees, capable of working across functional boundaries, has only recently gained attention. Since neither knowledge nor technology has value without application, the availability of a workforce that is capable of taking advantage of discovery and innovation in either arena is critical to continued economic success. How firms value human and intellectual capital are extremely important in high-technology industries that are dependent on continuous innovation for their very survival.

Finally, yet another culture resides *within* the firm: the culture of innovation: " ... the time-honored traditions and well-entrenched cultures that drive the research establishment" (Berghel, 1996, p. 16). This includes an element of "enormous inertia" (Berghel, 1996, p. 16) as well as a social network of innovation, the formal and informal communications networks that link the people and institutions involved in research and production. The social network of innovation influences both the speed and the nature of a corporation's reception to and utilization of external knowledge and technology, e.g., the perceived value and consequences of technology transfer (Morris-Suzuki, 1994). The culture of innovation affects the style or process of research and development within a country or society; it helps to define access to and availability of the tools of innovation.

National culture—the body of customary beliefs, social forms, and material traits embedded in the traditions of a country—helps define corporate structures and processes. These then affect the shape of global strategic alliances. For example, in the United States, early concerns about the consequences of monopoly led to antitrust legislation that encouraged corporations to be self-sufficient and autonomous; treated as individuals legally, corporations avoided partnerships with other firms for fear of the punitive consequences of "collusion." In contrast, the French government actively encouraged and directed the outcome of industry rationalization, creating the *groupement* business structure, a configuration that provided individual companies autonomy within umbrella organizations that served essentially as marketing cartels. Member firms could preserve their "own fixed capital, production facilities, research laboratories, and administrative services. Each group created a central bureau to parcel out orders to member firms, negotiate contracts, and search for foreign clients" (Chapman, 1991, p. 37). Thus, the stage was set for collaboration in Airbus Industries—initially organized as a *groupement*—which provided perceived guarantees with respect to national sovereignty as well (Cerny, 1980; Cohen, 1977; Gilpin, 1968; Kreiger, 1987; Kuisel, 1981; Stoffaes, 1986; Thornton, 1995; Zysman, 1978). And, in Japan, *keiretsu*—a group of cooperative, and often subcontracting, firms (Johnson, 1982; Samuels, 1994) and a descendant of similar, but much more tightly connected groups of firms, known as *zaibatsu*—have a well-established tradition of long-term, semi-fixed relationships between users and suppliers and among affiliated firms, subcontractors, vendors, and others (Yoshimura and Anderson, 1997). The *groupement* and the *keiretsu* industrial organizations are beginning to replace the previously dominant "multinational corporation" structure. This structure derived from the United States' early dominance of international investment—a dominance in which a large business enterprise, headquartered in one country, participated in wholly-owned, direct foreign investment in other countries. *Groupement* and *keiretsu* are replacing the traditional multinational corporation precisely because of the increased national and corporate protections which accrue to *all* participants as a result.

National culture can also influence the structural and procedural outcomes of GSAs. Whereas economics, technological innovation, and politics all have elements which promote the creation of GSAs, culture is likely to be the factor most resistant to GSAs. In the end, however, the first three factors clearly have overwhelmed the latter. As a result, culture's role in affecting GSAs lies primarily in its capacity to define styles of interaction and communication.

THE RISKY BUSINESS OF PREDICTION

The business of predicting change is risky at best, particularly in the case of aircraft manufacturing. Manufacturers understand that it is important to bring a differentiated product—with the performance parameters and costs airlines both need and can afford—to the market in a timely fashion. The extraordinary costs of RD&P, as well as the incredibly long cycles associated with both product gestation and return on investment, combine to make it very difficult to predict future market demand beyond a one- to two-year period (National Academy of Sciences, 1998). Effective forecasters must not only be cognizant of the complicated set of factors described above; they must also realize that these factors do not trigger change in a linear, unidirectional, or independent fashion. Rather, they converge in a dynamic and reciprocal relationship such that changes in each mold changes—both predictable and unpredictable—in others in a never ending process of intersection and adaptation (*Basic Research White Paper*, 1997; Golich, 1992; Nelson, 1996; Port and Carey, 1997). So it is with some fear and trepidation that the authors assert that, in the foreseeable future, these factors will continue to make a case for global strategic alliances.

Global Strategic Alliances—Part *Un*

To date, the emergence and proliferation of global strategic alliances in aircraft manufacturing represent responses to two distinct change phases. During the first phase—roughly 1950 to 1990—strategic alliances were a response to the need for critical mass in aircraft RD&P.[1] Technological advances in aircraft were relentless, and as they increased the potential rewards to be derived from aviation, they also increased costs and risks. Larger and more complicated aircraft required longer lead times between gestation, production, and revenue earning. Attempting to incorporate increasingly sophisticated technology—e.g., the jet engine—into aircraft design and production precipitated a dramatic rise in RD&P costs which simultaneously increased uncertainty about future payoffs and decreased the ability of a single manufacturer to finance an aircraft development program (Golich, 1989; 1992; Hayward, 1983; 1986; Majumdar, 1987; Miller and Sawers, 1968; Mowery and Rosenberg, 1982). New industry dynamics made it "more difficult, and certainly more expensive for a firm missing out on one generation of aircraft to challenge for success in the next" (Hayward, 1983, p. 1). Once Boeing launched the B-707, followed within a year by the Douglas DC-8, other American manufacturers lost so much market share that they virtually vanished from the scene. As Boeing dominance grew, the weakening position of Douglas Aircraft Company triggered its 1967 merger with McDonnell Aircraft discussed above (Mowery and Rosenberg, 1982, p. 111).

During this time period, several other key factors altered the market for aircraft RD&P. Governmental budget cuts, the spiraling cost of raising capital, sharp increases in the price of jet fuel, and increasing demands for environmental and noise regulations added significant costs to an already expensive RD&P cycle, while reducing access to financial capital. Subcontracting for components and systems was adopted as a strategy to reduce the cost and risks associated with introducing new generation aircraft. Initially limited to domestic sources, subcontracting was eventually extended to foreign firms (Hochmuth, 1974; Mowery and Rosenberg, 1982, p. 116; Rae, 1968, p. 83).

These changes were reinforced by systemic transformation of the LCA sector: Greater perceived (and real) interdependencies among trading and production partners, increased importance of aviation markets outside the U.S., surplus capacity of aircraft, and growing subcontractor and vendor demands for more extensive participation in RD&P proliferated early in the decade. The potential value of aircraft manufacturing triggered competition in a global market with a shrinking customer base—25 major air carriers accounted for more than 70 percent of the world travel market, with approximately 67 percent of the large commercial aircraft market located outside the U.S. (Clarkson, 1992; Taneja, 1994). This competition was intensified by the existence of surplus capacity in all commercial aircraft market segments (Kelly, Oneal, DeGeorge, and Vogel, 1991, pp. 84–85; Lopez and Yager, 1987, p. 5), a phenomenon aggravated, perhaps ironically, by technological progress that increased the potential life span of aircraft from 25 to 50 years and lengthened the replacement cycle.

By 1980, policymakers were concerned that denying market access might propel potential partners to become future competitors (National Academy of Engineering, 1985, pp. 63–64). In the end, corporate executives

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[1] This section relies heavily on Golich, Pinelli, and Barclay, 1997, especially pp. 13–22.

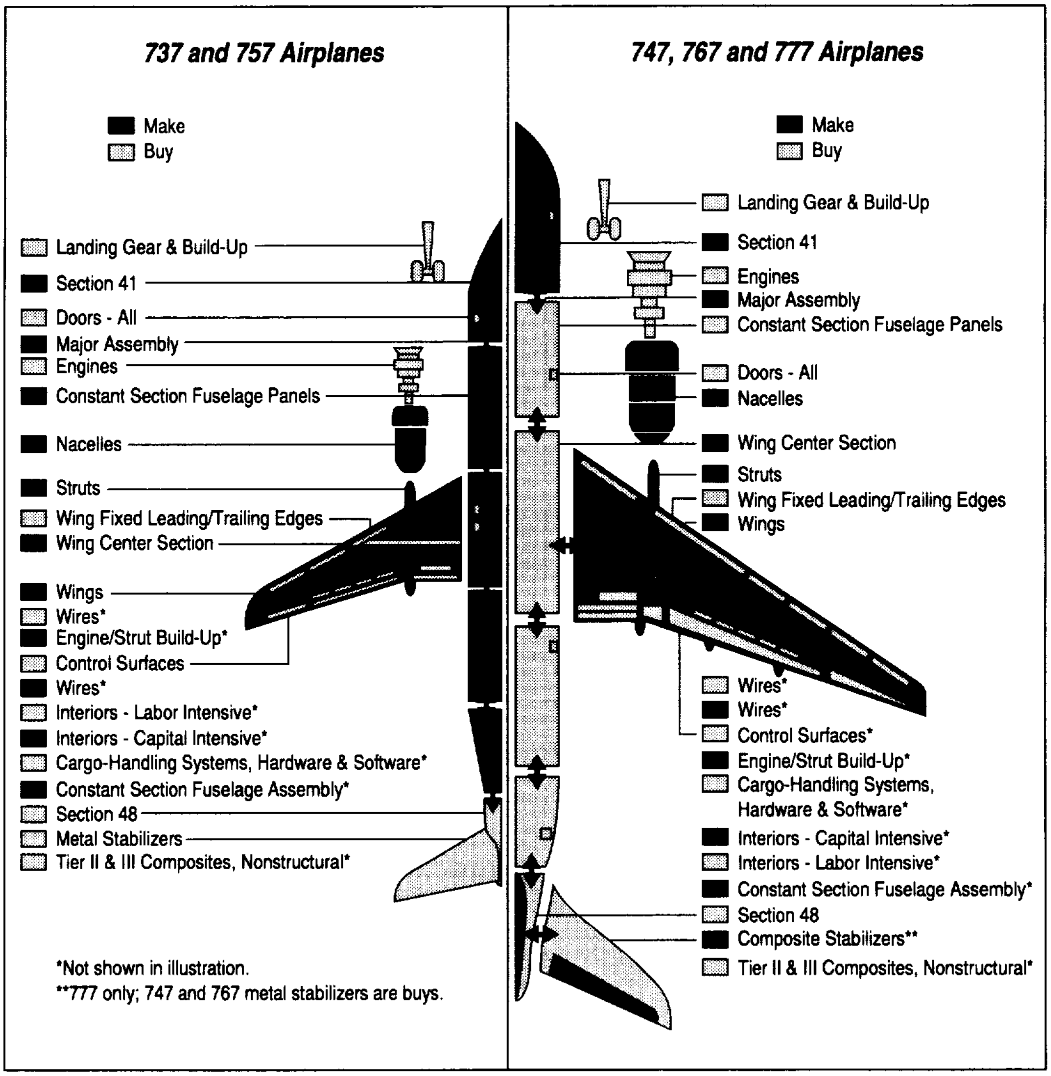
decided that collaboration with foreign partners was critical to maintaining a competitive position in aircraft manufacturing. They did so to secure financial capital, avoid potential tariff barriers, neutralize competitors, and circumvent legal restrictions. Manufacturers also sought expanded market access; greater levels of risk sharing; reduced research, development, and production costs; and sales support. Collaboration was also encouraged by the fact that so many aircraft purchases were now linked to industrial offsets (Hayward, 1986, pp. 31, 94–95; see also Bluestone, Jordan, and Sullivan, 1981, pp. 159–160; Harr, 1972; Schaufele, 1988).

Global Strategic Alliances—Part *Deux*

During the second cycle—beginning in the 1990s and extending into the 21st century—GSAs are likely to reflect a response to more recently acknowledged characteristics of the global market. Advances in communications and transportation systems have dramatically increased the tendencies toward interdependence. Advances in production and design technologies—e.g., CAD/CAM capabilities—render global RD&P economically and technologically feasible, though still vulnerable to political and cultural obstacles. The combination of economic and technological imperatives seems to be more compelling than the political and cultural impediments in place.

As we move into the next millennium, GSAs are likely to intensify further. Already, no large commercial aircraft is launched without careful attention to choosing production partners from around the world. The global arrangements include direct investment, co-production, licensing arrangements, and collaborative efforts in the research, development, production, and marketing of the aircraft. U.S. firms build Airbus aircraft components; firms from Australia, Belgium, Brazil, Canada, France, Germany, Greece, Ireland, Israel, Italy, Japan, Korea, The Netherlands, Singapore, Spain, the United Kingdom, and the former Yugoslavia help build Boeing aircraft.

For example, the Boeing Company has cautiously expanded its conventional subcontracting arrangements with foreign firms. Boeing first increased its purchases of parts made by outside suppliers with the aim of reducing the in-house content of its transports from 52 percent to 48 percent ("Boeing to increase ... ," 1995, p. 33). Figure 3 depicts this shift in contracting strategy. Then, Boeing expanded the number of its international suppliers and created tighter linkages among some program participants. With the B-767, Boeing inaugurated its first program with non-U.S. risk-sharing participants—Japan's Commercial Airplane Company, a consortium of Mitsubishi Heavy Industries, Kawasaki Heavy Industries, and Fuji Heavy Industries, furnished about 15 percent of the airframe, while Italy's Aeritalia contributed another 15 percent. Japanese representatives held membership status on the executive council and program committee and were referred to as "Program committee and were referred to as "Program Participants"—a transitional



737 and 757 Airplanes

747, 767 and 777 Airplanes

*Not shown in illustration.
**777 only; 747 and 767 metal stabilizers are buys.

Figure 3. A Comparative View of Components Made or Bought for Boeing Large Commercial Aircraft.

arrangement between a conventional subcontract and a full partner role. With the RD&P of the B-777, Boeing moved further in the direction of institutionalizing its GSAs. Although program management and control resides with Boeing, the degree of communication and integration in the "working together" teams is unprecedented, as exemplified by the data system designed to integrate engine, airframe, and airline maintenance needs; it is so interconnected that airlines can "access the enginemaker's blueprints" (Proctor, 1994b, p. 54; Cole, 1995). The Japanese, who contributed 20 percent to the program, were able to review its status, progress, and outlook and to influence some design and development decisions early in the process. In return, they accepted significant risk participation, assuming responsibility for both the nonrecurring and recurring costs of the hardware items they produced (Benke, 1987).

Two other trends are likely to prevail through the next several decades. First, consolidation among the second- and third-tier vendors will accelerate as they seek to conclude long-term supplier agreements with the two remaining primes, while also trying to cut costs and to specialize (Morrocco, 1997, p. 24; Rossant, 1997, p. 64). Second, the primes will further rationalize production, by spinning off non-core sectors while seeking new applications for the core technologies in which they excel, e.g., information technologies. "Managing data to work cheaper and more efficiently has become a prerequisite to winning contracts" (Mecham, 1997a, p. 46). Aircraft manufacturing is rapidly becoming an information processing industry, which depends on computers to show engineers how to organize production lines and build aircraft, and on artificial intelligence to improve line maintenance of aircraft fleets, to enhance flight simulation and debriefing systems, and to reconstruct and analyze accidents (Mecham, 1997a; 1997b; Lavitt, 1997; Proctor, 1997).

IMPLICATIONS FOR KNOWLEDGE MANAGEMENT

The radical changes, which have impelled governments and firms to negotiate GSAs to produce goods and services, have also affected the way knowledge is produced and used. Once the purview of university scholarship, knowledge creation has spread to a variety of public and private institutions. Knowledge, however, is only a necessary but not sufficient condition for market success. Only when it leads to a marketable technological innovation does knowledge have value for the firm. Increasingly, firms depend on specialized knowledge to provide a continuously replenishable source of created comparative advantage. However, it is becoming more and more difficult for firms to acquire the specialized knowledge they need; at the same time, it is frequently too expensive for individual firms to support the requisite R&D entirely in-house. Therefore, "firms have become involved in a complex array of collaborative arrangements involving universities, governments, and other firms, sometimes from within the same sector" (Gibbons, *et al.*, 1996, p. 13). Knowledge has been transformed into a commodity; as such it has value—as if it were a tangible asset—and its acquisition and use must be managed.

As firms and countries move toward consolidating and rationalizing their corporate connections, one key indicator of the potential for GSAs to be a long term trend is the fact that these relationships increasingly include shared work at the most fundamental levels of science, research, and development. Because innovation and discovery—areas where advances can give early users significant competitive advantage—most frequently occur at the R&D stages, the willingness to share is noteworthy (Gross, Carey, and Weber, 1994; Pinelli, Barclay, and Kotler, 1997). In what might be considered an ironic twist, the pursuit of knowledge may actually contribute to the longevity of GSAs. Before companies move into the realm of collaborative R&D they will most likely have been partnered for some time in the manufacture of a product and will have negotiated many of the pre-existing corporate cultural differences. With mutual benefits of collaboration proven, joint R&D becomes a logical extension and the knowledge created becomes jointly proprietary. Each partner recognizes that the firms benefit most—jointly and individually—from continued collaboration; this dictates against abuse of the innovations discovered (Berghel, 1996).

Moreover, as we enter the 21st century, firms are increasingly dependent on ever more specialized knowledge as they seek to create comparative advantage by producing goods which are qualitatively discreet and superior to others on the market. However, the most valuable knowledge is difficult to imitate or use because it is *tacit*, rather than *explicit*, in nature. Explicit knowledge is transmittable in formal, systematic language; it can be expressed in words and numbers but represents only the tip of the iceberg of the entire body of possible knowledge (Nonaka, 1994). Explicit knowledge is captured and maintained in libraries, archives, and databases. By contrast, tacit knowledge resides within the individual (Ambrosini, 1995; Collins, 1982; Sobol and Lei, 1994; Spender, 1993; Teece, 1986; 1981; von Hippel, 1994; 1987; Wagner, 1987). It is this personal quality that makes tacit knowledge extremely difficult to formalize and communicate. Tacit knowledge is often embodied in " ... a set of rules which are not known as such to the person following them" (Polanyi, 1962, p. 49). Since the person does not "know" the rules s/he employs to accomplish a task, s/he could not provide a useful explanation of the rules. Tacit skills may be teachable, but only through demonstration, observation, and practice (Stiglitz, 1987; Winter, 1987). Therefore, the specialized knowledge which firms need is seldom "readily available to be bought or sold off the shelf, like other commodities" (Gibbons, *et al.*, 1996, p. 13). (See Alic *et. al.*, 1992; Branscomb, 1993; Nelson and Winter, 1982; Pinelli, Kennedy, Barclay, and Bishop, 1997; and Polanyi, 1962; 1976, for additional discussion of the role and significance of tacit knowledge.)

The increasing demand for knowledge has been at least partially responsible for the proliferation of knowledge suppliers. Researchers in industry and government laboratories, think-tanks, research institutions, and consultancies partake in the business of knowledge creation and application through technological innovation. As the number of knowledge suppliers has increased, universities have come under increasing public pressure for greater accountability and suffered significant cuts in public financial support. In addition, the academic technical/science community confronts a funding crisis that it has not experienced since 1967–1975 (Brooks and Randazzese, 1998). Thus, universities—much like corporations—must form strategic alliances with government, industry, and other institutions of higher education; frequently, these alliances transcend national borders. According to Gibbons, *et al.* (1996),

> ... the parallel expansion in the number of potential knowledge producers on the supply side and the expansion of the requirement of specialist knowledge on the demand side are creating the conditions for the emergence of a new mode of knowledge production. (p. 13)

This new mode of knowledge production does not *replace* the more traditional mode. Instead, the new mode complements, or operates parallel to, the older model. The traditional mode of knowledge production is governed largely by academia and tends to generate knowledge for its own sake within narrowly defined disciplinary borders (Gibbons, *et al.* 1996); perhaps more importantly, the traditional mode of knowledge production has included a commitment to the open disclosure of research results and equal access to the derivative knowledge base for all qualified scholars. The new mode of knowledge production is transdisciplinary, carried out in a context of application, and heterogeneous in creation. But potentially most disconcerting is that it includes closer and more formal university-industry relationships. Brooks and Randazzese (1998) note at least two serious concerns for knowledge production related to this situation. First, those observing this transformation of knowledge production and supply worry that an increasingly "purposeful" pursuit of knowledge, which is inevitably linked to proven commercial relevance, may undermine the well-established tradition of open disclosure and equal access to what is essentially a public good—knowledge. Second, given the proven success of the traditional approach to open and unfettered knowledge creation under the "old" university research system, observers worry that this transformation may undermine the long-term ability of university researchers to discover purposeful knowledge.

Pursuing "Purposeful" Knowledge

The scholarly pursuit of "purposeful" knowledge is disquieting for four reasons (Brooks & Randazzese, 1998, pp. 361–385). First, though closer university-industry linkages hold promise in some arenas, greater dependency on these ties (e.g., for desperately needed research revenues) carries with it a more intense emphasis on commercially relevant research. Fundamental (basic) research, which has long been the purview of university researchers and for which they are uniquely qualified, may suffer as a result (Dasgupta & David, 1994; Geiger, 1993; Rosenberg and Nelson, 1994). Empirical evidence supports the otherwise intuitive concern that university-industry research arrangements lead to more applied research being conducted by faculty (Blumenthal, Causino, Campbell, and Louis, 1996; Cohen, Florida, and Goe, 1994; Morgan, Strickland, Kannankutty, and Grillon, 1994; Rahm, 1995).

Second, though the tighter linkages between industry and university researchers may open up some very important research opportunities which otherwise might have been too expensive to pursue, there is the very real potential that universities might compromise their commitment to open disclosure and equal access to the scholarship of discovery (Chapman, 1995; Dasgupta & David, 1994; Dye, 1996a; 1996b; Etzkowitz, 1989; Mowery and Rosenberg, 1989; Rosenbloom and Spencer, 1996; U.S. Congress, House of Representatives, 1992). Again, empirical studies support what otherwise might be merely intuitive or anecdotal evidence. Industry views knowledge as proprietary, and is therefore interested in limiting the disclosure of the results deriving from the university research it supports. Concerned researchers have queried this possibility from a number of directions. Their discoveries include the following: (a) some 47 percent of the companies supporting life science research within universities "occasionally require academic institutions to protect confidential proprietary information resulting from sponsored research for longer than is strictly necessary to file a patent application" or place other communication and publication restrictions as a condition of financial support; (b) perhaps even more disturbing, 19.8 percent of the life science faculty had *themselves* delayed the publication of their work, and 8.9 percent had refused to share research results or materials with colleagues at least once in the previous three years (Brooks and Randazzese, 1998, p. 378; see also Blumenthal, *et al.*, 1996; Rahm, 1995).

Third, the constraints placed on knowledge diffusion may also originate with the university. In their efforts to generate revenue through the aggressive assertion of intellectual property rights, university administrators may restrict the communication or publication of research results (Abelson, 1994; Brooks and Randazzese, 1998; Etzkowitz, 1989; Mowery and Rosenberg, 1989; U.S. Congress, House of Representatives, 1992). Even though relatively few patentable inventions are anticipated (except in the fields of molecular biology and computer science), universities want to have the option of exploiting profits from patents; most firms are willing to comply with a request for licensing the useful knowledge.

Finally, university researchers may find themselves compromising the traditional values of open research and discovery, and in so doing, more willingly accept short-term, restrictive research tasks and projects. Studies have revealed that, indeed, the traditional model of disinterested pursuit of knowledge within the university is being undermined by potentially lucrative research ventures which carry with them dissemination restrictions (Blumenthal, *et al.*, 1986; 1996; Brooks and Randazzese, 1998; Morgan, *et al.*, 1993; 1994; Cohen, Florida, and Goe, 1994; Krimsky, 1997; Krimsky, *et al.*, 1996).

These four concerns are further complicated when overlaid with the globalization of higher education in general, research efforts in particular, and increasingly tighter linkages between universities around the world with "stateless" corporations. Here the concern is less with parochial interests regarding the potential negative influence of foreign corporate research requests. Not only is it unrealistic and unwise to attempt to nationalize science as an economic activity, it is also the case that relatively little research is funded by foreign firms. Moreover, in those cases where research is externally funded, that research is typically more long-term in focus. Rather the questions that arise here are those asked at the beginning of the paper. What are the implications for international relations of this new set of constraints and ownership placed on knowledge?

Preventing the Erosion of the University Knowledge Base

To the extent that we continue down the path of more narrowly defined, corporate-sponsored, purposeful research, we must ask what effect this transition may have on the "old" university research system. Some see little or no threat (Gibbons, *et al.*, 1996). Rather they see the new research path operating next to the older, more traditional one. Others fear that the new path may overwhelm the older one, eventually undermining the fundamental knowledge base thought to be a core component of continuous innovation and advances (Brooks and Randazzese, 1998). This is particularly troublesome as funding for higher education continues to shrink in relative and absolute terms (Astin, 1985; Bok, 1993; Bowen, 1981; Chapman, 1995; Dye, 1996a; 1996b; Rosenbloom and Spencer, 1996; "Shared Responsibility … ," 1996). A number of policy options—with relevance to a wide array of GSAs across any number of industry sectors—might be implemented to facilitate GSA formation and maintenance, while protecting national constituencies.

First, governments could assume more proactive roles in promoting the development of human and intellectual capital in order to accelerate private sector-based innovation (Nelson, 1996; see also *Basic Research White Paper*, 1997; Carey, 1997, p. 170; Flanigan, 1996, p. D2). Complementary roles for government would be (a) to encourage companies to collaborate (Carey, 1997), (b) to provide stable and predictable funding sufficient to reduce the need for universities to submit to potentially damaging constraints on knowledge diffusion (Bok, 1993; Brooks and Randazzese, 1998; "Shared Responsibility ... ," 1996), and (c) to encourage "strategic research," that is, research which focuses on the needs of the corporate sponsor but has sufficient technical and scientific depth to warrant the interest of the professional researcher in both the university and the private sector (Berghel, 1996, p. 18).

Second, governments can promote knowledge diffusion and enhance intellectual capital by creating or supporting networks of institutions, associations, corporations, research centers, academics, and other scholars and professionals to enhance the discovery and application of knowledge and technology. Governments could also encourage the creation of "buffer institutions" to help bridge the cultural gaps between the academic and corporate worlds (Brooks and Randazzese, 1998). Such institutions are fairly common in Europe and Japan, though less so in the United States. The *Max Planck Institute*, the Japanese Aircraft Development Corporation, and the NASA Jet Propulsion Laboratory (operated by the California Institute of Technology) are examples of this kind of institution. They share the following characteristics; (a) they have both operational and research responsibilities, which translate knowledge into application; (b) they are closely connected to universities but are independently organized and managed; and (c) they have their own permanent core staff but benefit from the participation of faculty and students in problem solving (Brooks, 1970; Brooks and Randazzese, 1998; Rosenbloom and Spencer, 1996).

Third, stakeholders need to clarify the parameters of intellectual property rights protections. Law generally reflects culture and codifies extant norms and principles that guide behavior. Broad patents tend to be exclusionary and to discourage "outsiders" from participating in subsequent rounds of innovation and may, thereby, slow the processes of innovation; however, overly narrow patents may not provide enough incentive to the private sector to engage in the very expensive research and development required to apply technology to a useful product. Here, moving toward a multilateral agreement regarding intellectual property rights is a logical, though evolving, goal. Recognizing that the international community of scholars, corporate managers, and policymakers will be fortunate to *approach* agreement on what constitutes protectable, proprietary knowledge and what belongs on the "open market," codifying a goal is likely better than allowing practice to lead us down a path where the extant norms and principles provide ownership rights to publicly valuable knowledge (U.S. Congress, General Accounting Office, 1992; U.S. Congress, House of Representatives, 1992).

In their work on creating a research and innovation policy that works, Brooks and Randazzese (1998) remind us of Vannevar Bush's admonition: Science can be effective in the national welfare only as a member of a team, whether the conditions be peace or war (p. 389). It would be wise to remember that academic science represents only a small fraction of the science and technology needed to achieve economic competitiveness and prosperity. However, it is academic science that has the greatest potential to provide the conceptual foundations upon which other members of the team—in the corporate and governmental worlds—can build. The heightened need for basic science and basic technology research, combined with the simultaneous squeeze on university budgets, calls for a reconceptualization of the place of the university in the knowledge diffusion equation. We must identify new roles for academia and academic researchers that will allow them to deploy their creativity in ways that help industry innovate without compromising the academic values which have served society so well to date.

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