Applying Technology Strategy with Enterprise Architecting: A Case Study in Transformation Planning for Integrating Unmanned Aircraft Systems into the National Airspace

by

Kristina L. Richardson

Bachelor of Science in Environmental Engineering &
Field of Study in French and Spanish
United States Military Academy, 1999

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Signature of Author ____________________
Kristina Richardson
System Design and Management Program

Certified by ____________________
Donna Rhodes
Thesis Supervisor
Engineering Systems Division
Principal Research Scientist, Systems Engineering Advancement Research Initiative (SEARI)

Certified by ____________________
Patrick Hale
Director
System Design and Management Program
President, International Council on Systems Engineering (INCOSE)

Disclaimer -- The views expressed in this thesis are those of the author and do not reflect the official policy or position of the U.S. government or the Department of Defense.

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Abstract

The research presented in this thesis combines Enterprise Architecture and Technology Strategy for analyzing, evaluating, and recommending appropriate solutions for integrating Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS). The thesis is organized into four sections. Section 1 introduces the strategic background, enterprise description, definitions of key terms, and the issues and interest surrounding UAS operations. Section 2 involves architecting the enterprise at its current state, which includes the vision, strategic objectives, enterprise layout, stakeholder analysis, and concludes with the architectural views of the current state. Section 3 discusses the vision and design for the future of the NAS enterprise, the current near-term efforts, the long-term preferred future state, and the transformation plan to achieve successful integration of UAS flight in the NAS. Finally, Section 4 concludes with the importance of leadership for success, final thoughts, recommendations, and future work. Technology Strategy coupled with Engineering Architecture emphasizes the development and application of ways of thinking that bring clarity to the complex co-evolution of technological innovation, the demand opportunity, systems architecture, business ecosystems, and decision-making and execution within the business. Architecting the current state of the NAS enterprise and then applying the technology strategy framework in an incremental systems approach to fully understand the future state of the NAS involves figuring out how to create and capture value, anticipating and deciding how to respond to the behavior of customers, complimentors and competitors, and develop and deliver technologies, platforms, and products.

Thesis Supervisor: Donna Rhodes
Title: Principal Research Scientist, Systems Engineering Advancement Research Initiative

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Acknowledgement

Attending graduate school, let alone the System Design and Management Program at the Massachusetts Institute of Technology was never a thought or aspiration of mine. I left home after graduating from high school to attend the United States Military Academy at West Point. This decision catapulted me into "Army life", which has been full of opportunities, tremendous experiences, global travel/living, and at times some steep learning curves. I have since realized the amazing possibilities available in life and that you can truly do anything that you set your mind and sights to achieve! I attribute four things to shaping me as a person: my education at a small, college-preparatory, all girls high school - Notre Dame Academy in Los Angeles, my Grandmother's constant encouragement and support, my experiences as an Army Aviator, and now my time spent in the SDM program at MIT.

Growing up in a tumultuous household in Southern California, the one constant in my life was my Grandmother. She was ahead of her time as a college educated, single mother, and professional engineer. I attribute much of my success and drive for a better life to her strength, understanding, and foresight.

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I feel extremely privileged to have embarked on this journey through the SDM program and very humbled by the extraordinary students, faculty, and staff at this great institution.

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Executive Summary

Purpose and Motivation: The current conflicts in Iraq and Afghanistan have both triggered and inspired change in the Army's tactical and strategic operations. Army Aviation has experienced an incredible amount of transformation and the large increase in demand for real-time information and the flexibility to react immediately to a threat has greatly expanded its role on the battlefield. The Unmanned Aircraft System (UAS) provides a platform to collect real-time imagery and video for intelligence, reconnaissance, and surveillance (ISR) with almost no limitations with respect to aircraft endurance, environment, and weather conditions. UASs have been used for deception operations as well as maritime missions. As the electronics systems grow in complexity, but shrink in size, new applications of use include electronic warfare and signals intelligence. As such, the emergence of UASs in the military inventory and their integration into the Aviation community has launched this technology to the forefront of the general public's interest.

Combat Commanders demand and require real-time intelligence for successful operations on the battlefield. UASs are a combat multiplier in today's conflict and their integration into the piloted military airspace demonstrates the potential for UAS integration into the National Airspace System (NAS). Similar to pilots, UAS operators return to "home station" after combat operations in support of Operation Iraqi and/or Enduring Freedom and require the use of military and civil airspace to maintain their "flight skills" in preparation for the next deployment. Accessing the National Airspace is essential for UAS operators to sustain these perishable skills and also expand military UAS operations for continuous support of the Global War on Terrorism (GWOT).

These military UAS core capabilities apply directly to many of the civil applications proposed. Wild fire suppression missions where UASs are equipped with infrared sensors to detect forests fires can notify ground stations and/or deliver fire suppression chemicals. Customs and Border Protection (CBP) are interested in UASs for border interdiction where they can be utilized to patrol land and sea boarders. Search and Rescue for ship and aircraft accidents is a direct transition from the military's use of UASs for battle damage assessment. Communications relay, high altitude/long endurance (HALE) UAS could be used as satellite surrogates during emergencies such as hurricane Katrina when most of the infrastructure has been destroyed. They can also provide aerial platforms for cameras and real-time surveillance in events such as earthquakes, disaster and emergency management. Research of environmental and atmospheric pollution is also a viable application given the appropriate payload. Industrial applications such as crop spraying, nuclear plant surveillance, and vessel escorts have also been proposed.

The introduction of UASs into the NAS is a challenging enterprise for the Federal Aviation Administration (FAA) and the aviation community as a whole. UAS proponents have a growing interest in expediting access to the NAS. There is an increase in the number and scope of UAS flights in an already busy National Airspace System (NAS). The design of many UASs makes them difficult to see, and adequate *detect, sense and avoid* technology is years away. Decisions being made about UAS airworthiness and operational requirements must fully address safety implications of UASs flying in the same airspace as piloted aircraft, and perhaps more importantly, aircraft with passengers.

Context and Scope: The System Engineering frameworks utilized in this thesis include Enterprise Architecture and Technology Strategy. Enterprise Architecture is a holistic way of thinking which is essential to modern enterprises, such as the NAS, that have highly interconnected systems. It is necessary to integrate management processes, lifecycle processes, and enable infrastructure systems. Furthermore, enterprise architecting balances the needs of multiple stakeholders working within and across boundaries and enables a full understanding of their value exchange, expectations, needs, and interactions. Technology in the UAS industry is advancing very rapidly and current military operations provide an optimal test bed for such innovation, which will assist the transition of UAS operations within the civil and commercial markets. Both Enterprise Architecture and Technology Strategy focus on a holistic approach and integrate enterprise strategic objectives, value capture and creation, in a systematic approach to achieve success in a complex, highly technical enterprise system.

This thesis is organized into four sections in order to fully examine and analyze the NAS as an enterprise in its current state, identify the future vision, and develop a transformation plan to achieve such a desired future state. Section 1 consists of the strategic background beginning with defining the NAS enterprise and the UAS, a brief historical overview of UAS development, and finally the interests and issues surrounding UAS operations. Section 2 architects the enterprise to include a discussion of the current vision of the NAS, the strategic objectives, a description of the enterprise layout, a full discussion of the multitude of stakeholders, their value exchange, prioritization, and finally concluding with the "as is' architectural view utilizing the eight views outlined in the Enterprise Architecting framework. The third section focuses on the transformation plan and begins with a discussion of the vision and design for the future enterprise, a discussion of the current near-term efforts, and the plan of action to achieve the long-term future state utilizing technology strategy as the preferred "to be" architecture. Furthermore, this section includes a detailed discussion of technology innovation, key parameters, customer segments, civil and commercial applications, building the business ecoysystem, value creation, and value capture. The final section covers the conclusions, the role of leadership in this enterprise, a discussion of the UAS industry in comparison to the emergence of the airline industry, and final thoughts.

Conclusion: Interest in UASs continues to grow worldwide. Recent advances in computer technology, software development, light weight materials, global navigation, advanced data links, sophisticated sensors, and component miniaturization are strengthening capabilities and fueling the demand for UASs. The new UAS technologies under development today will have a profound impact on the entire aviation industry. The investments and the technological advances made by military organizations have generated a growing interest in their potential use for civil government, scientific research, and commercial applications. Enabling routine access to the NAS by leveraging existing procedures for piloted flight operations, and using current guidance for unique military operations will yield a path for NAS integration and significant growth in the civil and commercial UAS market will immediately follow.

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Section 1: Strategic Background

Enterprise Description: The United States National Airspace System

Since the Wright brothers ushered in the age of powered flight and essentially launched an entire industry over 100 years ago, safety of flight has been a top priority to all involved. Pilots take seriously the responsibilities associated with operating an aircraft. As aviation evolved from a handful of experimental aircraft in the early 20th century, to more than 600,000 certified aircraft sharing the skies today, the air traffic system also advanced to maintain a high degree of safety and efficiency. From no regulations in 1903 to strict regulatory oversight under the Federal Aviation Administration (FAA) today, pilots fly in accordance with regulations that have served well, as evidenced by the fact that the United States has the safest aviation system in the world [1].

The state of the Unmanned Aircraft System (UAS) resembles the early days of aviation. During that time, creative minds, engineering talent, and entrepreneurial spirit converged to produce new technologies and designs that spawned a new market, brought aviation to the general public, and altered forever the transportation landscape. Today that same spirit permeates within the UAS industry as innovators are vying to enter and dominate in a new and potentially lucrative market [2]. However, unlike the early years of Aviation, UASs have the challenge of entering a mature civil aviation system consisting of many aircraft, controlled by complex monitoring equipment, dominated primarily by commercial sectors, interest groups, and a large regulatory structure. Integration of UASs into the National Airspace System (NAS) and their potential market success depends on a complex set of technical, economic, political, and legal factors.

The Air Commerce Act of 1926 launched the Federal government's fundamental role in regulating civil aviation. Leaders within the aviation industry believed that aircraft could not reach its full commercial potential without government action so they urged passing this legislation in order to improve and maintain safety standards. The Act charged the Secretary of Commerce with fostering air commerce, issuing and enforcing air traffic rules, licensing pilots, certifying aircraft, establishing airways, and operating and maintaining aids to air navigation [3]. The new Aeronautics Branch within the Department of Commerce initially concentrated on functions such as rules surrounding safety and the certification of pilots and aircraft. It assumed responsibility for the building and operation of the nation's system of lighted airways, a task previously conducted by the Post Office Department [4]. The Department of Commerce improved aeronautical radio communications, and introduced radio beacons as an effective aid for air navigation.

The Aeronautics Branch was renamed the Bureau of Air Commerce to reflect its enhanced status within the Department. As commercial flying increased, the Bureau expanded the ATC system and the initial air traffic controllers used maps, blackboards, and mental calculations to ensure the safe separation of aircraft traveling along designated routes between departure and arrival locations. Then in 1938, the Civil Aeronautics Act transferred the federal civil aviation responsibilities from the Commerce Department to a new independent agency, the Civil Aeronautics Authority (CAA). The legislation also expanded the government's role by giving the CAA the power to regulate airline fares and to determine the routes that air carriers would serve [4]. Soon after, President Franklin Roosevelt split the CAA into two agencies, the Civil Aeronautics Administration (CAA) and the Civil Aeronautics Board (CAB). The new CAA was responsible for air traffic control (ATC), airman and aircraft certification, safety enforcement, and airway development. The CAB was entrusted with safety regulations, accident investigation, and economic regulation of the airlines. Both organizations were components of the Department of Commerce. However, unlike the CAA, the CAB functioned completely independent of the Secretary of Commerce.

Just prior to United States' entry into World War II, the CAA began to extend its ATC responsibilities to include departure and landing operations at airports. This expanded role eventually became permanent after the war. The introduction of radar applications to ATC operations helped controllers to advance as the postwar boom in commercial air transportation increased. The approaching introduction of jet airliners and a series of midair collisions launched passage of the Federal Aviation Act of 1958. This legislation transferred the CAA's functions to a new independent organization, the Federal Aviation Agency (FAA), which had broader authority to impede aviation hazards. The Act took responsibility of making safety rules from the CAB and entrusted it to the FAA. Furthermore, it gave the FAA sole responsibility for developing and maintaining a common civil-military system of air navigation and air traffic control, a responsibility previously shared between the CAA and other interested parties.

Congress authorized the creation of a cabinet department that would combine major federal transportation responsibilities, which is known today as the Department of Transportation (DOT). The FAA gradually assumed responsibilities not originally devised by the Federal Aviation Act, to include the field of aviation security and aircraft noise standards. By the mid-1970s, the FAA achieved a semi-automated air traffic control system based on a combination of radar and computer technology. To meet the challenge of traffic growth, mainly due to the competitive market created by the Airline Deregulation Act of 1978, the FAA unveiled the National Airspace System (NAS) Plan in January 1982 [5]. The new plan required more advanced systems for enroute and terminal ATC, modernized flight service stations, and improvements in ground-to-air surveillance and communication.

The FAA's organizational structure has continually evolved to since its creation from a centralized management system under which federal government officials exercised direct control over programs in the field to a decentralization process that transferred much authority to regional organizations. In the late 1990s, a re-organization structured the FAA along its seven key lines of business in order to make better use of resources. This included the Office of Commercial Space Transportation in which the FAA was responsible for regulatory responsibilities concerning the launching of space payloads by the private sector. Following the terrorist attacks of September 11, 2001, Congress created a new Transportation Security Administration (TSA) that succeeded the FAA as the agency with primary responsibility for civil aviation security.

The FAA addressed a wide variety of technical issues as the aviation industry continued to rapidly evolve. The Aviation Safety Research Act of 1988 mandated greater emphasis on long-range research planning and on study of such issues as aging aircraft structures and human factors affecting safety [3]. In February 1991, the FAA replaced the National Airspace System Plan with the more comprehensive Capital Investment Plan (CIP). The new plan included higher levels of automation as well as new radar, communications, and weather forecasting systems.

As the modernization program evolved, problems in developing ambitious automation systems prompted a change in strategy. The FAA shifted its emphasis toward enhancing the air traffic control system through more manageable, incremental improvements. One example is the use of "Free Flight", an innovative concept aimed at providing greater flexibility to fly direct routes [3]. At the onset of the 21st Century, Free Flight's initial phase delivered benefits that added to the efficiency of air transportation. At the same time, the FAA worked to push the application of the Global Positioning System (GPS) satellite technology to civil aeronautics. Similarly, the FAA's current efforts to successfully integrate UAS into the NAS involve incremental steps with a very systematic approach as well.

Definition - What is an Unmanned Aircraft System?

Unmanned aircraft are a product of the military. Their success in Iraq and Afghanistan in support of the Global War on Terrorism (GWOT) demonstrates their worth. Militaries worldwide, are committing increasingly large funds to researching and acquiring these systems. The investments and the technological advances made by military organizations have generated a growing interest in their potential use for civil government, scientific research, and commercial applications. However, the most significant barrier to the development of these markets is the lack of access to civil airspace.

Unmanned Aircraft Systems (UASs) are sometimes called "*unmanned aerial vehicles, UASs, remotely operated aircraft, remotely piloted vehicles, or just unmanned aircraft*" [3]. UASs come in a variety of shapes, sizes, and purposes. They can have a wingspan as large as a Boeing 737 or be as small as a radio-controlled model airplane. Some are programmed to fly and navigate a substantial part of the flight autonomously or by a computer program. Other operations are flown entirely by an outside operator, referred to as the Pilot-in-Command.

Because no human pilot is actually onboard the aircraft, UASs must get information about their external environment through electronic sensors. The input from the sensors is either processed onboard, so the aircraft's computers can evaluate and monitor the flight environment and forward the data to the Pilot-in-Command controlling the aircraft, or all information can be processed on the ground normally from an operations center [6]

Generally, an Unmanned Aircraft System (UAS) is any aircraft capable of flight without a human on board. Does this include balloons, model aircraft, missiles? Civil Aviation authorities, Department of Defense, International organizations, and various working groups all have different definitions of what constitutes a UAS, yet none are universally accepted or standard.

Canadian Definition: *Section 101.01 of the Canadian Aviation Regulations (CARs) states, "Unmanned Air Vehicle" means a power driven aircraft, other than a model aircraft, that is operated without a flight crew-member on board* [7].

FAA's Definition: *Title 14 Code of Federal Regulations (CFR) (public vs. civil vs. model aircraft) states that a UAS is the unmanned aircraft (UA) and all of the associated support equipment, control station, data links, telemetry, communications and navigation equipment, etc., necessary to operate the unmanned aircraft* [6]. *An Unmanned Aircraft System is a device used or intended for flight in the air that has no onboard pilot. This includes all classes of airplanes, helicopters, airships, and translational lift aircraft that have no onboard pilot. Unmanned aircraft are understood to include only those aircraft controllable in three axes and therefore, exclude traditional balloons* [8].

Department of Defense: *A powered aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload* [9].

U.S. Army's Definition: *The acronym UAS refers to the system as a whole (unmanned aircraft [UA], payload, and all direct support equipment). Direct support equipment includes the ground control station (GCS), ground data terminal (GDT), launch and recovery (L/R) system, transport and logistics vehicles, operators and maintainers, unit leadership, and others. The acronym UA refers to the unmanned aircraft exclusively and does not include the payload unless stated otherwise* [10]. *The Army tends to use the terms UAS and UAV interchangeably when referring to systems defined previously as UAS.*

Since the scope of this thesis addresses UAS issues in the military, civil, and commercial communities, the following definition will be used to strike a balance:

> *"Unmanned aircraft operate without an on-board pilot or crew. Unmanned aircraft can either be remotely controlled from the ground by an operator or preprogrammed to conduct the entire flight without intervention. In addition to the UAS, other components, such as a control facility, data links, and any other apparatus, all combine to create an unmanned aircraft system (UAS)"* [11].

Unmanned Aircraft System Technology – A Historical Perspective

There have been several instances of UASs in past military conflicts beginning with the use of unmanned balloons in Europe in the eighteenth century. During war-time eras new developments in unmanned technology emerged, and then subsided again during peacetime often due to lack of practical application for civil use. In the 1930s and leading up to the second World War, the interest in UASs re-emerged for the purpose of target practice to train anti-aircraft gunners in both Britain and the United States [2]. However, Germany made the greatest advances in UAS development during WWII with the V-1 bomber, an aircraft capable of autonomous control. Following this success, during both the Korean and Vietnam wars, the

United States focused their UAS technological advances on surveillance capabilities, and today this is still the primary mission of the UAS.

After Vietnam, the United States went back to the peacetime trend of both reduced funding and interest for projects involving military technology and saw no value in UAS technology possibly having civil applications. Simultaneously, other countries continued to develop UAS technology with Israel in particular pioneering several new vehicles that were eventually integrated into the fleets of other countries between the late 1980s and early 1990s. During the first Gulf War, the United States utilized UAS technology again and there was a large interest in the capabilities of UAS and the expanded usage beyond just surveillance. The mass media exposure and increased interest in UAS technology catapulted the military's use of UASs into the public view during the current conflicts in Iraq and Afghanistan. As a result, some scientists recognized the success of UASs in military operations, the value of UASs, and the possibility of prospective applications in the civil and commercial sectors. However, due to limitation on the movement of UASs within the National Airspace System, these ideas were difficult to translate into reality, so the majority of progress with UAS technology has remained within the military community.

The United States Armed Forces have all embraced the usage of UAS technology in the battlefield environment with the U.S. Army taking the lead. The Army has taken bold steps in integrating UAS technology into the operational structure of daily airspace coordination. Initially, UASs were used only for reconnaissance/surveillance pictures and video feeds in advanced preparation for missions not during mission execution. A new demand has emerged which includes "providing tactical commanders near-real time, highly accurate, Reconnaissance, Surveillance and Target Acquisition. This mission is growing to include weaponization, communications relay, specialty payloads, small unmanned aircraft systems, and the linkage to manned aircraft" [12]. As a result, in December 2006 the Army Transformation plan specified that UASs would be organized and managed in Modular Combat Brigades, within the Special Troops Battalion (STB), and under the Military Intelligence Company (MICO). This proved very quickly to be an unsuccessful organizational structure for UASs. Several issues emerged as Military Intelligence Company Commanders tried to maintain command and control of their UASs, the associated maintenance and logistics requirements, and the exponential increase in demand of UAS support for combat operations dictated directly from the Division Headquarters. The UASs seemed out of place and also out of control in the MICO as the demand for real-time imagery, video, analysis, and rapid action increased. Along with an increase in demand, UAS technology advanced with varying sizes, capabilities, and associated system equipment requirements, resulting in numerous UASs invading military airspace. As a result, the Army adjusted its Transformation Plan and reorganized UASs under the Aviation Brigade. Since Aviation Brigades are self-sufficient (maintenance, logistics, etc.), not organic to the Modular Combat Brigades (ground troops), and receive all missions and directions from their immediate higher command, the Division Headquarters, the UASs fit right into the maintenance, logistical, and operational flow of the Aviation Brigade. This strategic move enabled the UAS mission to evolve rapidly and reply more effectively to the need for rapid responsiveness to today's modern threat in combat as seen in both Operation Enduring and Iraqi Freedom.

Besides the maintenance and logistical aspects of UASs aligning with the Aviation Brigades, the Aviation Brigade Commander (O6/Colonel) also provides a more efficient command and control of UAS missions. An Aviation Brigade Commander has a large staff of operational, analytical, and planning individuals, which does not exist in the MICO for a Company Commander (O3/Captain). The most recent effort to streamline the integration of UASs into the Aviation world while still maintaining the technical and analytical expertise of the Military Intelligence Community is the introduction of the newest Aviation Battalion – Task Force ODIN (Observer, Detect, Identify, Neutralize). Chartered in August 2006, first employed in February 2007 in the 25^{th} Combat Aviation Brigade (CAB) in Tikrit Iraq, Task Force (TF) ODIN is a high priority Army Vice Chief of Staff Initiative, driven by the critical requirements to "win back the roads" using Army Aviation assets to maintain a persistent stare over demonstrated at-risk areas for improvised explosive devices (IEDs) [13]. This unit consists of a network of UASs, ten modified C12 surveillance planes, ground stations, and approximately 100 soldiers all to spot and destroy IEDs and the people who plant them [14]. Integration into the 25^{th} CAB facilitated the development of the Tactics, Techniques, and Procedures (TTPs) for both piloted and unpiloted Reconnaissance, Surveillance, Targeting, and Acquisition (RSTA) assets in TF ODIN to team with the 25^{th} CAB's piloted rotary wing aircraft across the battle-space to detect, illuminate, designate, and engage valid targets with the weapon systems of the 25^{th} CAB helicopters. Tremendous synergy is created by this *manned-unmanned* teaming of Army Aviation assets in the Counter-IED flight, increasing the kinetic effects of the 25th CAB, while allowing the rotary wing aircraft to engage from standoff ranges and thereby improving aircraft survivability and reducing the threat to the pilot in the loop. These *manned-unmanned teamings* or more recently coined *Sensor-to-Shooter* TTPs will pave the way for additional aviation organizations, systems and platforms to maintain a preeminent role in counterinsurgency campaigns like the one being fought in Iraq today. General (Ret.) Richard Cody (Former Vice Chief of Staff of the Army) acknowledged the tremendous success of integrating UASs into the Aviation Brigade in Iraq:

> *"ODIN is a one-of-a-kind, proof-of-principle outfit that we built... We are moving UASs to Afghanistan to the aviation brigade to replicate the same capabilities that we have learned from ODIN"* [13].

The next step underway is to continue improving UAS, video, and bandwidth capabilities so that operators and pilots no longer have to rely on receiving data by voice, but instead can transmit the UAS video feed directly into the cockpit of Army helicopters.

The technology generated as a result of war-time development have all launched a side benefit to society as a whole. WWI yielded the biplane and aircraft carriers, which fostered significant growth in the Aviation and logistical support industries for both military and civilian sectors. WWII further expanded the Aviation realm with the advent of helicopters, jet engines, and missile technology. Korea launched the air ambulance and expanded helicopter usage within the military community, which all directly translated into the civil community adopting the use of medical evacuation (MEDEVAC) helicopters as well. Vietnam ushered in the further expansion of helicopter technology with the introduction of attack helicopters and also remarkable medical advances for trauma. The first Gulf War (Desert Storm) launched "beyond line of sight" technology and the digital command post, which began the transition into the digital-world as we now know it. Finally, with the incidents surrounding September 11, 2001 and the current ongoing conflict in the Middle East, UAS is the new focus. The military has the opportunity to fully utilize this technology and there is unlimited potential for UAS operations to merge into the civil and commercial markets in the near future.

Interest in Unmanned Aircraft Systems

Interest in UASs continues to grow worldwide. Recent advances in computer technology, software development, light weight materials, global navigation, advanced data links, sophisticated sensors, and component miniaturization are strengthening capabilities and fueling the demand for UASs. Currently, there are at least 32 countries developing UASs and the projected spending and Research and Development (R&D) continues to increase over the next decade (see Figure 1 below).

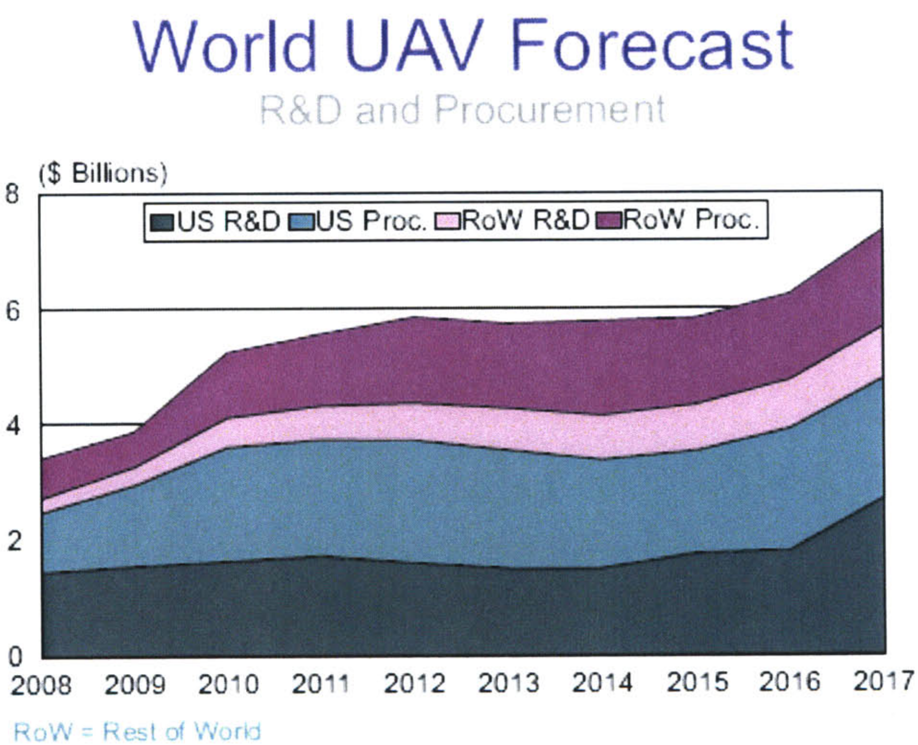

Figure 1: World UAS Forecast [15]

Of these, the United States is leading in terms of the size, variety, and sophistication of UAS systems, with Israel at a close second as they have a very strong market for its military UASs, some of which have been purchased by the United States for military and homeland security. The U.S. Army has demonstrated significant strides towards integrating UASs into full spectrum operations, to include airspace integration with piloted aircraft. This essentially paves the way for civil and commercial applications of UASs to emerge in the National Airspace System. Furthermore, the Army's integration of UASs into the Military Aviation community greatly enhanced the safety of UAS flight and also required that the UAS community comply with flight standards, processes, and procedures required for piloted aircraft. As a result, even with the rapid increase in UAS flight hours, the accident rate has decreased greatly since its integration into the Military Aviation Community and abiding by the respective safety protocols (See Figure 2 for UAS Program Summary below).

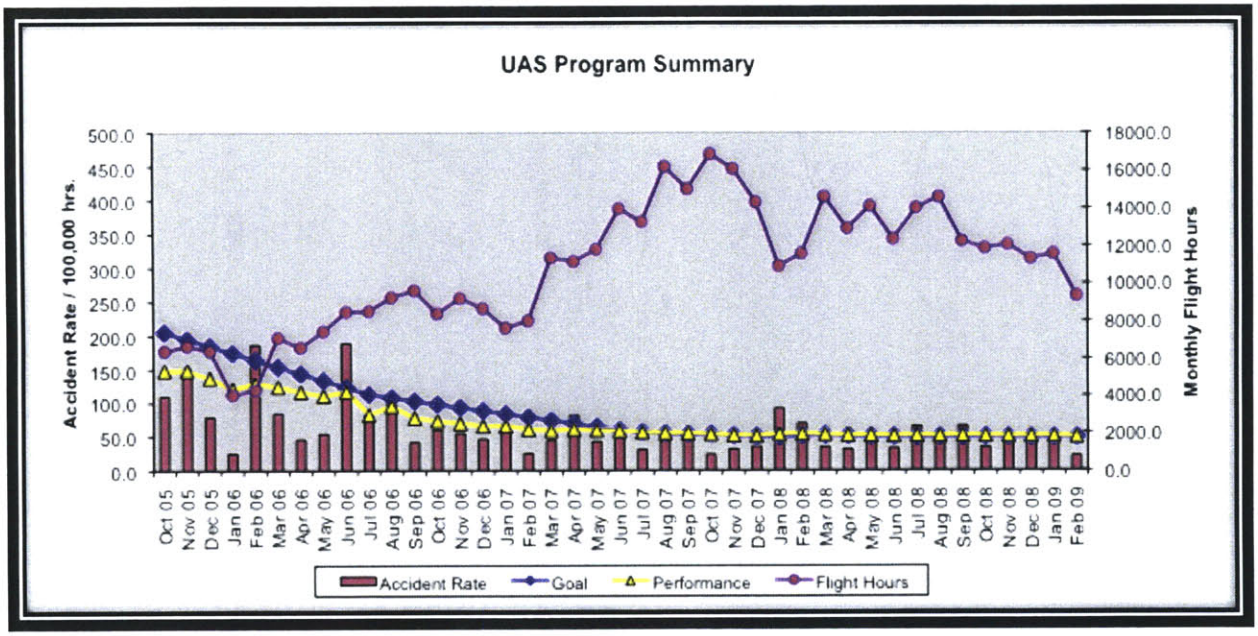

Figure 2: UAS Accident Rate & Monthly Flight Hours [16]

This demonstrates a significant step towards fully integrating UASs into the civil aviation community and the National Airspace System, rather than leaving UASs to operate as an exception. The question is whether the current state of UAS operations within the military community can successfully translate into the civilian and commercial sectors and operate safely within the National Airspace.

Issues Surrounding Unmanned Aircraft Systems

UASs are rapidly being developed and deployed and there are currently 5,331 unmanned aircraft in the U.S. Military inventory – almost double the amount of piloted military aircraft [17]. In February 2007, the FAA published a UAS policy to outline how these aircraft can be used in the National Airspace System [18]. The rules vary depending on if the UAS is operated as a public aircraft (operated by the government) or as a civil aircraft. Public aircraft operate under individual waivers or Certificates of Authorization (COAs), which are issued after an FAA review of the program and its safety protocols. The FAA issued 102 COAs in 2006, 85 in 2007, and 164 in 2008. As of February 23 2009, the agency has issued 17 COAs and has 62 applications pending [19]. Civil aircraft must operate under experimental airworthiness certificates.

At issue is the fact that there is no FAA certification or regulatory standards for operating UASs in the National Airspace System. Instead, the FAA issues COAs for each and every UAS operation. The COA establishes limitations and requirements intended to prevent accidents between UASs and piloted aircraft. However, many stakeholders within the enterprise feel that UASs need to meet the same certification and operational standards as piloted aircraft, and they must fit into the existing National Airspace System without any negative impact on general aviation operations.

With the exception of UASs, there is not an aircraft operating in the NAS today that has not complied with strict Federal Aviation Regulations (FARs) governing its certification and maintenance. And again, with the exception of UAS operators, there is not a pilot operating today that has not undergone rigorous pilot certification training and testing.

Pilots also comply with very strict FAA general operating and flight rules as outlined in the Federal Aviation Regulations (FARs), including the FAA's important *see and avoid* mandate. These regulations provide the historical foundation of the FAA regulations governing the aviation system. The three major issues that UASs fail to comply with in regard to the FAA regulation CFR91 include *See and Avoid, Command and Control, and Airworthiness:*

See and Avoid: A key requirement for routine access to the NAS is UAS compliance with CFR 91.113, *Right-of-Way Rules: Except Water Operations.* This section contains the phrase, *see and avoid*, and is the primary restriction to normal operations of UASs. The intent of *see and avoid* is for pilots to use their eyes (as sensors) and other tools to find and maintain situational awareness of other air traffic and to yield the right-of-way, in accordance with the rules, when there is a traffic conflict. Since the purpose of this regulation is to avoid mid-air collisions, this should be the focus of technological efforts to address the issue as it relates to UASs rather than trying to mimic and/or duplicate human vision. Meaningful *sense and avoid* (S&A) performance must alert the operator to local air traffic at ranges sufficient for reaction time and avoidance actions by safe margins. Furthermore, UAV operations beyond Line-of-Sight (LOS) may require an automated *sense and avoid* system due to potential communications latencies or failures.

The FAA does not provide a quantitative definition of *see and avoid*, largely due to the number of combinations of pilot vision, collision vectors, sky background, and aircraft paint schemes involved in seeing oncoming traffic. Having a sufficient field of regard (FOR) for a UAS *sense and avoid* system is fundamental to meeting the goal of assured air traffic separation. Interestingly, the FAA does provide a cockpit field of regard recommendation in its Advisory Circular 25.773-1, but the purpose of AC 25.773-1 does not specifically mention *see and avoid.*

Although an ambiguous issue, one fact is completely clear - the challenge with the *sense and avoid* requirement is based on a capability constraint, not a regulatory one. Therefore, a possible definition for *sense and avoid* systems emerges: *Sense and avoid* is the onboard, self-contained ability to:

⇒ Detect traffic that may be a conflict

⇒ Evaluate flight paths

⇒ Determine traffic right-of-way

⇒ Maneuver well clear according to the rules in CRF91.113, or

⇒ Maneuver as required in accordance with CFR91.111.

Once the *"sense"* portion of *sense and avoid* is satisfied, the UAS must use this information to execute an avoidance maneuver. The latency between seeing and avoiding for the pilot of a manned aircraft ranges from 10 to 12.5 seconds according to FAA and DoD studies [20]. If relying on a ground operator to see and avoid, the UAS incurs the same human latency, but adds the latency of the data link bringing the image to the ground for a decision and the avoidance command back to the UAS. This added latency can range from less than a second for line-of-sight links to more for satellite links.

Closely tied to *see and avoid*, is the issue of UAS reliability. This refers to UAS mishaps, which as discussed previously are much greater than manned aircraft mishaps (See Figure 2). Improving reliability is necessary for winning the confidence of various stakeholders such as the general public, the acceptance of other aviation constituencies (airlines, general aviation, business aviation, etc.), and the willingness of the FAA to accept UAS flight. Acceptance of UAS operations by the FAA also should lead to acceptance by international (ICAO) and foreign civil aviation authorities of UAS operations. Such acceptance will greatly facilitate obtaining over-flight and landing privileges when the United States military's larger, endurance UASs deploy in support of contingencies. In addition, acceptance will save time and resources within both the Department of Defense (DoD) and the FAA by providing one standardized, rapid process for granting flight clearances. Finally, acceptance will encourage the use of UASs in civil and commercial applications, resulting in potentially lower acquisition costs to military UAS procurement programs and eventually demonstrate the same trend with a UASs explosion in the civil and commercial sectors as well.

Command and Control: In general, the two main areas of concern when considering link security surrounds inadvertent or hostile interference during the uplink and downlink process. The uplink controls the activities of the UAS platform itself and the payload hardware. This command and control link requires a sufficient degree of security to ensure that only authorized agents have access to the control mechanisms of the platform, which is an imperative for flights in the NAS given the events of September 11, 2001. The return or downlink transmits critical data from the UAS platform payload to the war-fighter or analyst on the ground or in the pilot in the air. System health and status information must also be delivered to the ground control station or UAS operator without compromise.

The air navigation environment is changing partly due to the demands of the increase in aircraft activity in the NAS. In order to maintain control, ATC has reduced allowances for deviation from intended flight paths and encouraging the usage of standard departure and arrival procedures. This provides another means for increasing air traffic capacity as airways and standard departures and approaches can be constructed with less separation. As tolerances for navigational deviation decrease, the need to precisely maintain course increases. All aircraft must ensure that they have robust navigational means (i.e. GPS, VHF Omni-directional Range or VOR, Automatic Direction Finder or ADF). Historically, this robustness has been achieved by the installation of redundant navigational systems. The need for dependable, precise navigation reinforced the redundancy requirements. The *Federal Radio Navigation Plan*, signed March 2002, established the following national policies [22]:

⇒ Un-augmented, properly certified GPS is approved as a primary system for use in oceanic and remote airspace.

⇒ Properly certified GPS is approved as a supplemental system for domestic en route and terminal navigation, and for non-precision approach and landing operations.

⇒ The FAA's phase-down plan for ground-based Navigational Aids (NAVAIDS) retains at least a minimum operational network of ground-based NAVAIDS for the foreseeable future.

⇒ Sufficient ground-based NAVAIDS will be maintained to provide the FAA and the airspace users with a safe recovery and sustained operations capability in the event of a disruption in satellite navigation service.

These policies apply, as a minimum, to all aircraft flying in civil airspace. With GPS, the prospect for relief of complete redundancy requirements in piloted aircraft may be an option in the future. However, UASs have a diminished prospect for relief since, unlike piloted aircraft, a UAS cannot readily fallback on dead reckoning, contact navigation, and map reading in the same sense that a pilot can.

Airworthiness: The FAA's airworthiness regulations are meant to ensure that aircraft are built and maintained so as to minimize their hazard to aircrew, passengers, and people and property on the ground. Airworthiness is concerned with the material and construction integrity of the individual aircraft and the prevention of it coming apart in mid-air and/or causing damage to people or property on the ground.

FAA regulations do not require public aircraft (government-owned or operated) to be certified airworthy to FAA standards. Because most non-military public aircraft are versions of aircraft previously certified for commercial or private use, the only public aircraft not related to FAA certification standards in some way are almost always military aircraft. Instead, these aircraft are certified through the military's internal airworthiness certification/flight release processes.

There are five self-certifying agencies recognized in the United States – the Army, Navy, Air Force, NASA, and the FAA. Military UASs follow the well-established airworthiness certification processes. The Army requirement is defined in the Army Regulation (AR) 70-62 as "a demonstrated capability of an aircraft or aircraft subsystem or component to function satisfactorily when used and maintained within prescribed limits". As shown in Table 1, the certifying official for Army Aircraft is the Commanding General (CG) at the United States Army Aviation and Missile Command (USAAMCOM) located in Huntsville Alabama. The Aviation Engineering Directorate (AED) is an organization within USAAMCOM and is the compliance agent. The CG at USAAMCOM is the approving authority for the airworthiness of Army aircraft for which USAAMCOM has the engineering cognizance and he then delegates this responsibility to the Aviation Engineering Directorate.

	Civil (14 CFR) Process	Public (OSS&E) Process
Customer	Airline	Major Command (MAJCOM)
Certification Authority	FAA	Commanding General, United States Army Aviation and Missile Command (USAAMCOM)
Compliance Agent	FAA or designee	Aviation Engineering Directorate
Maintenance/ Operational Criteria	14 CFR Parts 43, 91, 121, 135, 145	AR70-92
Certification Criteria	14 CFR Parts 23, 25, 33	Airworthiness Certification Criteria (MIL-HDBK-516A)

Table 1: Civil and Public Parallels in Certification

The Army Airworthiness Process is illustrated in Figure 3 and involves the aircraft requirements from the specific Program Manager (PM), the development of the Airworthiness Qualification Plan (AQP) and the Airworthiness Qualification Specifications (AQS), the negotiations for substantial methods and data to be used in the AQS, the testing and analysis phase, the development of aircraft and component test plans, the complete testing and addressing problems during the testing phase, the test flight release (TFR), test results delivered to AED, AED review of results, and finally issuing the Statement of Airworthiness Qualification (SAQ).

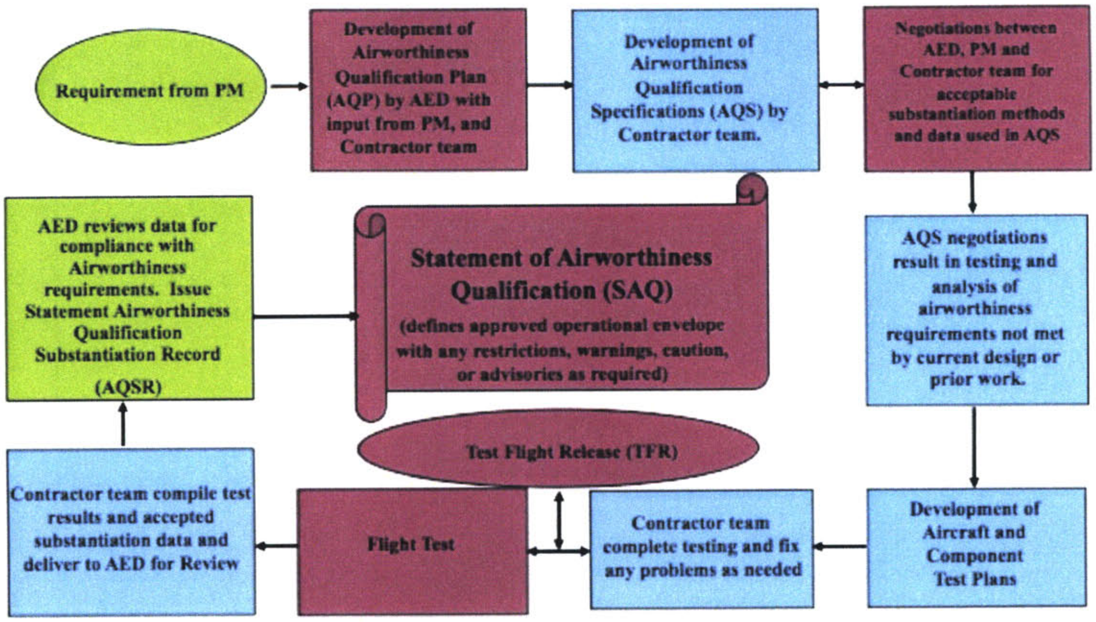

Figure 3: Army Airworthiness Process [23]

A Tri-Service memorandum of agreement describes the responsibilities and actions associated with mutual acceptance of airworthiness certifications for piloted aircraft and UAS within the same certified design configuration, performance envelope, parameters, and usage limits certified by the originating Service. Similar to piloted military aircraft, unmanned military aircraft are also subject to the airworthiness certification and flight release process. The operational requirements for UAS operations in civil airspace specify that flight over populated areas must not raise airworthiness concerns. Therefore, UAS standards cannot vary widely from those for piloted aircraft without raising public and regulatory concerns. There are three levels of authorization for UAS flight which vary from certification standards equivalent to piloted aircraft and those with a minimum acceptable level of safety for small UAS and not equivalent to aircraft, yet all require a UAS Flight Release which is obtained through the airworthiness process described previously. Level 1 certifies to standards equivalent to piloted aircraft yet tailored for UASs, so it has minimum reliability requirements equivalent to General Aviation. Level 2 authorizes standards less stringent than those for piloted systems and is the lowest level of classification for UASs with weapon systems. Level 3 authorizes to a minimum acceptable level of safety for small UASs, targets, drones, and R&D assets yet it requires AED review and appropriate risk-level approval. Army UAS platforms by type, what airspace they currently operate in, and at what level of authorization is listed in Figure.

	Army Platforms	Existing Regulatory Guidance	Max Weight (lbs)	Max Speed (kts)	Int'l Airspace	National Airspace	DoD Airspace	
					Sovereign	FAA Class A, B, C, D, E, G	Ship Controlled	Restricted Areas & Combat Zones
Med/Large Fixed Wing	ER/MP, Hunter	Part 23, 25	>1320	>200	Level 1	Level 1	Level 1	Level 2
Med/Large Rotary Wing	Fire Scout (Class-IV)	Part 27, 29	>1320	N/A	Level 1	Level 1	Level 1	Level 2
Light F/W and R/W	Shadow, Class-III	Sport Aircraft / Ultralight	Up to 1320	200	Addressed on case-by-case basis		Level 2	Level 2
Small / Mini / Micro F/W and R/W	Raven, SUAV, Class I-II	AMA	Up to 55	120			Level 2	Level 3

Figure 4: UAS Flight Authorization Levels [23]

The problem the FAA faces is that UASs challenge this historic foundation because they operate by remote control and without an onboard pilot, which is unlike any other aircraft in the airspace system. As a result, the FAA continues to grant COAs in lieu of creating new regulations for the UAS community.

Recently this has become a significant issue due to civil security agencies operating these unregulated UASs in the National Airspace System without the FAA introducing regulations to dictate UAS operations in the NAS. For example, the FAA is working with urban police departments in Houston and Miami on pilot test programs involving unmanned aircraft. The goal is to begin identifying the challenges that UASs will bring into this environment and what type of operations can safely be conducted by civil law enforcement. The FAA granted COAs to authorize the Houston Police Department to conduct one demonstration flight, which took place on November 16, 2007. Operations were limited to a radius of two nautical miles from a specific point in an unpopulated area. The agency continues to work with the Miami-Dade Police Department on their proposal for UAS demonstration flights. Most likely, a COA would permit a limited number and type of tests in an unpopulated area near the Everglades, and eventually provide a way to continue flights for training purposes [19]. Such UAS operations have resulted in large-scale flight restrictions while subverting progress toward regulations and proper integration of the UAS into the National Airspace System. Flight restrictions prohibit flights within a specific area of airspace defined by ground references and are in effect for stated dates and times. Flight restrictions for UAS operations are generally inefficient, restrict other airspace users, and a short-term approach to addressing the important operational and safety issues surrounding the integration of UASs in the NAS. Overall, the COA process is lengthy, laborious, inefficient, and does not support the Army's need for a robust UAS training program. Although the FAA is utilizing COAs for current UAS operations, it is also working with various agencies on an incremental approach to develop policies and procedures to address UAS operational issues in the NAS.

The introduction of UASs into the NAS is a challenging enterprise for the FAA and the aviation community as a whole. UAS proponents have a growing interest in expediting access to the NAS. There is an increase in the number and scope of UAS flights in an already busy NAS. The design of many UASs makes them difficult to see, and adequate *detect, sense and avoid* technology is years away. Decisions being made about UAS airworthiness and operational requirements must fully address safety implications of UASs flying in the same airspace as piloted aircraft, and perhaps more importantly, aircraft with passengers.

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Section 2: Architecting the Enterprise

Vision

The joint efforts of the Office of the Secretary of Defense and the Federal Aviation Administration (OSD-FAA) must develop policies, procedures, and an approval process to enable operations of Unmanned Aircraft Systems [24]. Their vision is to have "File and Fly" (F&F) access for appropriately equipped UASs while maintaining an equivalent level of safety (ELOS) to that of an aircraft with a pilot onboard [21]. For military operations, UASs will operate with piloted aircraft in and around airfields using concepts of operation that make on or off-board distinctions transparent to air traffic control authorities and airspace regulators. The operations tempo at mixed airfields will not be diminished by the integration of UASs. Positive aircraft control must be assured through secure communications and established procedures for UASs operating in the NAS.

The OSD-FAA has established certain guiding principles in pursuit of this vision, which include [21]:

Do no harm: "Avoid new initiatives; enacting regulations for the military user that would adversely impact.

1. The military's right to self-certify aircraft and aircrews
2. Air traffic control practices or procedures
3. Piloted aviation continuous operations (CONOPs) or tactics, techniques, and procedures (TTPs); or unnecessarily restrict civilian or commercial flights.

Where feasible, leave 'hooks' in place to facilitate the adaptation of these regulations for civil use. This also applies to recognizing that 'one size does NOT fit all' when it comes to establishing regulations for the wide range in size and performance of DoD UASs."

Conform rather than create: "Interpret the existing Title 14 Code of Federal Regulations (CFR) (formerly known as Federal Aviation Regulations, or FARs) to also cover unmanned aviation and avoid the creation of dedicated UAS regulations as much as possible. The goal is to achieve transparent flight operations in the NAS."

Establish the precedent: "Although focused on domestic use, any regulations enacted will likely lead and/or conform to similar regulations governing UAS flight in International Civil Aviation Organization (ICAO) and foreign airspace."

As a result, the joint OSD-FAA effort focuses on enabling routine access to the NAS by leveraging existing procedures for piloted flight operations and using current guidance for unique military operations as a path for NAS integration [42]. Furthermore, the OSD-FAA plans to define the standards for DoD *sense and avoid* (S&A) system and finally demonstrate the F&F process and S&A system in a serious of UAS flights among FAA regions.

Strategic Objectives

The driving forces in the external environment of the National Airspace enterprise include a very high operational tempo of the United States Army Aviation assets and subsequent aircraft maintenance. Additionally, as previously stated the demand for UAS technology as a fully integrated asset into daily combat and peacetime operations is expanding and will continue to expand long into the future. Based on current guidance, this expansion will not result in a corresponding increase in access to additional civil airspace. This represents a significant challenge to the successful expansion of UAS operations for the military as they continue to expand the usage of UASs in Iraq and Afghanistan, then require additional airspace in the NAS for sustainment and continuation training as units redeploy from the current conflict. Furthermore, as the civil and commercial demand for UAS usage increases, this is an additional group of stakeholders who will push for access to the NAS.

At the Department of the Army (DA), the DoD, and national levels, there are cycles in terms of priorities and resources. The aviation component of the Army has been resourced significantly well to support on-going operations. As experienced in the early part of the current decade, significant increases in operational and maintenance requirements for Army Aviation related equipment, to include the emergence of increased UAS usage, were not matched with adequate resources. Currently, the defense industry is generally meeting the demands for operational and logistical support of UAS activity at the strategic and tactical level in support of the current conflict in the Middle East. However, demand analysis has shown that the dynamics can have drastic effect with changes in this environment.

Strategic Objectives for the National Airspace System:

1. Increased safety
2. Greater capacity
3. International leadership
4. Organizational excellence

Enterprise Layout – U.S. National Airspace System

The National Airspace System (NAS) is the network of United States airspace, which includes air navigation facilities, equipment, services, airports or landing areas, aeronautical charts, information/services, rules, regulations, procedures, technical information, manpower, and material [25]. Included are system components shared jointly with the military. The system's present configuration is a reflection of the technological advances concerning speed and altitude capability of jet aircraft, as well as the complexity of microchip and satellite-based navigational equipment. To conform to international aviation standards, the United States adopted the primary elements of the airspace classification system developed by the International Civil Aviation Organization (ICAO) as shown in Figure 5.

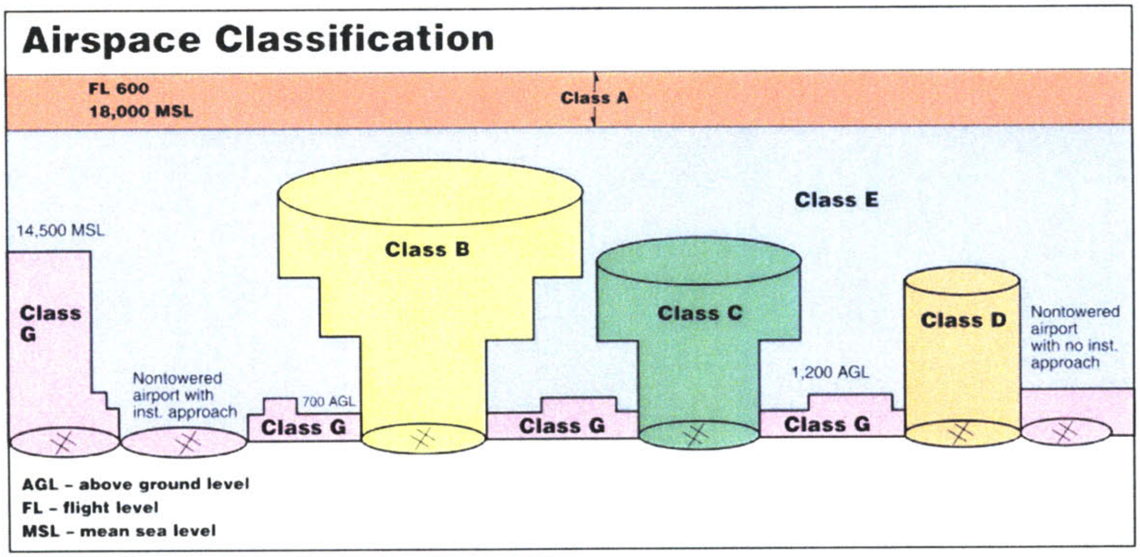

Figure 5: Airspace Classification in the NAS [25]

The NAS is one of the most complex aviation systems in the world consisting of thousands of people, procedures, facilities, and pieces of equipment that enables safe and expeditious air travel in the United States and over large portions of the world's oceans. The NAS requires 14,500 air traffic controllers, 4,500 aviation safety inspectors, and 5,800 technicians to operate and maintain services. It has more than 19,000 airports and 600 air traffic control facilities with over 41,000 NAS operational facilities. In addition, there are over 71,000 pieces of equipment, ranging from radar systems to communication relay stations and approximately 50,000 flights each day utilize the NAS (see Figure 6) [26].

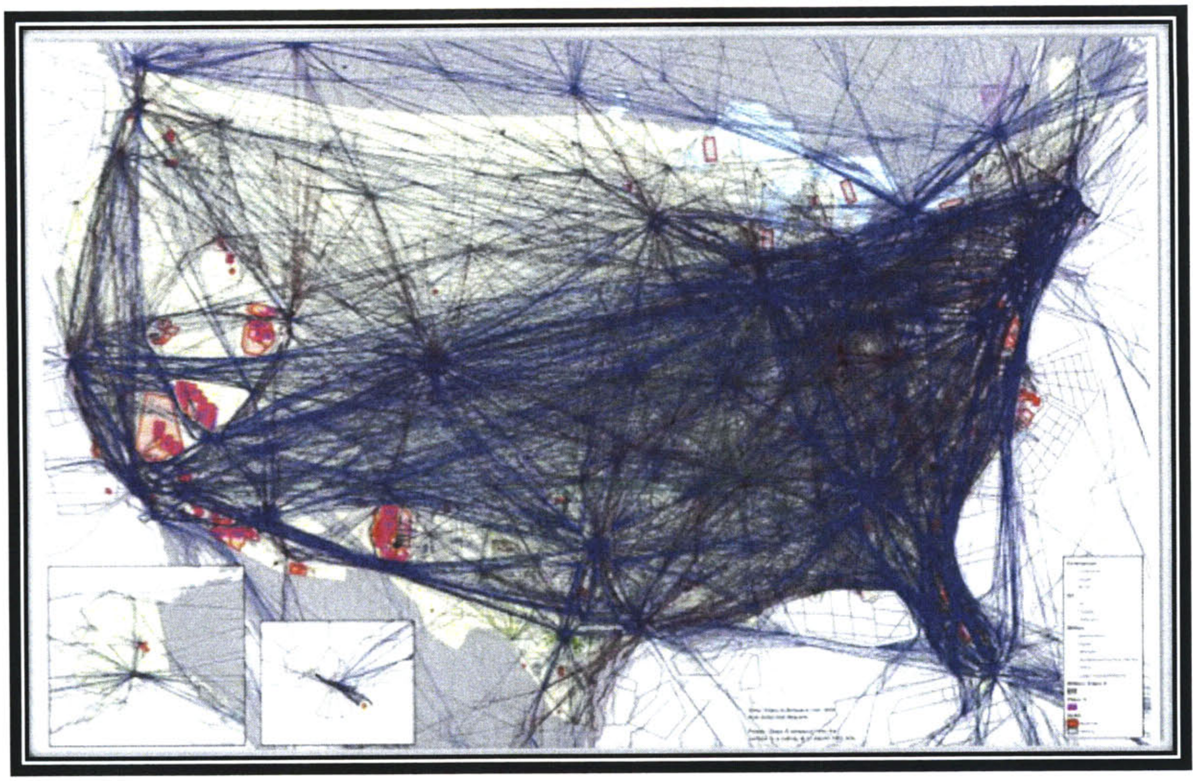

Figure 6: A Day's Worth of Traffic in the United States [27]

In today's National Airspace System, air traffic control depends on voice communications to relay a wide array of critical information between aircrews and controllers. The use of voice communication is labor intensive and limits the ability of the NAS to effectively meet future traffic demand. In order to achieve the vision and meet the strategic objectives previously discussed, Data Communications (Data Comm) will assume an ever-increasing role in controller to flight crew communication, contributing significantly to increased efficiency, capacity, and safety of the National Airspace. The evolution of Data Comm in the operational environment will be based upon the incremental implementation of advanced communication capabilities. Data Comm represents the first phase of the transition from the current analog voice system to an ICAO compliant system in which digital communication becomes an alternate and eventually predominant mode of communication. As depicted in Figure 7, the operations and services enabled by Data Comm will allow air traffic controllers to manage more traffic, increase the capacity of the NAS, increase airspace user efficiency, enhance safety, and evolve into a high performance airspace – all strategic objectives of the enterprise.

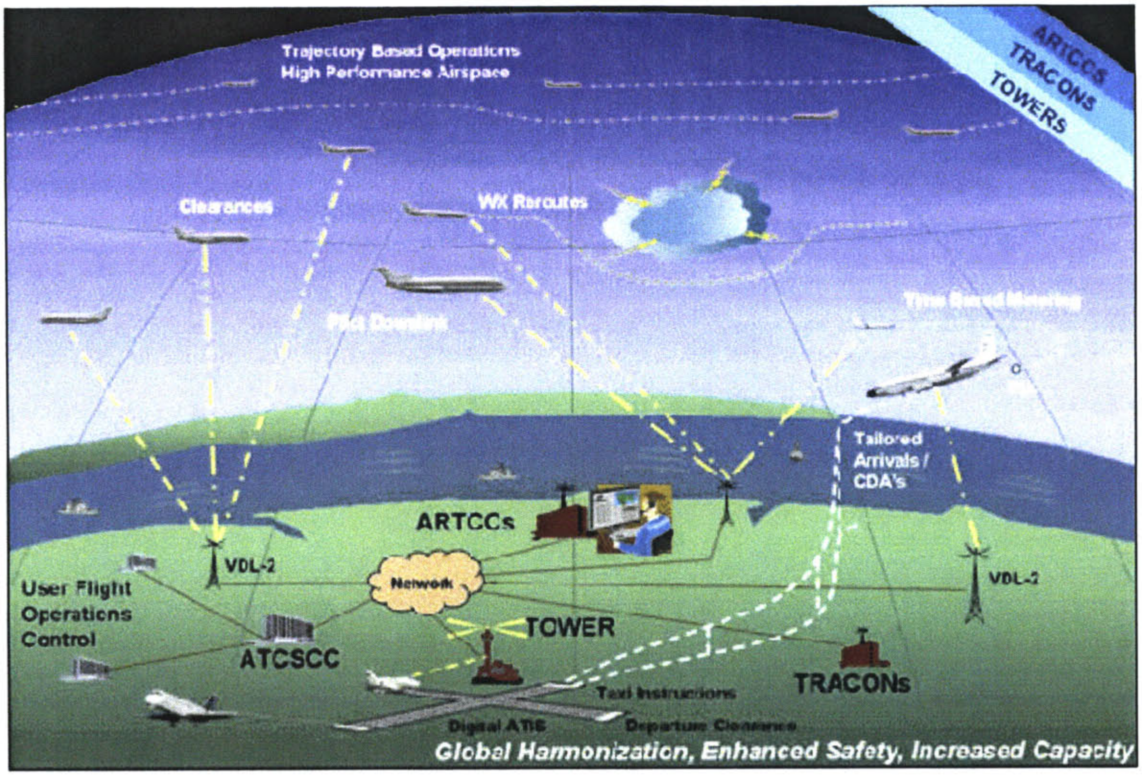

Figure 7: Vision of a High Performance Airspace [28]

External: When examining the National Airspace System, there are several external entities that must be considered and should be satisfied. These are stakeholders who have a significant influence on the internal participants, can impose constraints, or request services but do not have direct control. The following comprises a list of those external to the enterprise:

Applicant: The issue at hand is integration of UAS into the NAS and the applicant consists of someone who is applying for a Certificate of Authorization (COA) for a new UAS in order to access the NAS. The applicant remains external to the enterprise layout. Once they are granted a COA and access the NAS with a UAS, they then become *end users* and are internal to the enterprise.

Federal Aviation Administration (FAA): The FAA's primary mission is the safety, security, and efficiency of the National Airspace System. It is a highly complex and large organization and there are a few specific offices within the organizational structure that are directly involved in the integration of UAS into the NAS as external players. See the organizational chart in Figure 8 for an overview of the FAA's structure.

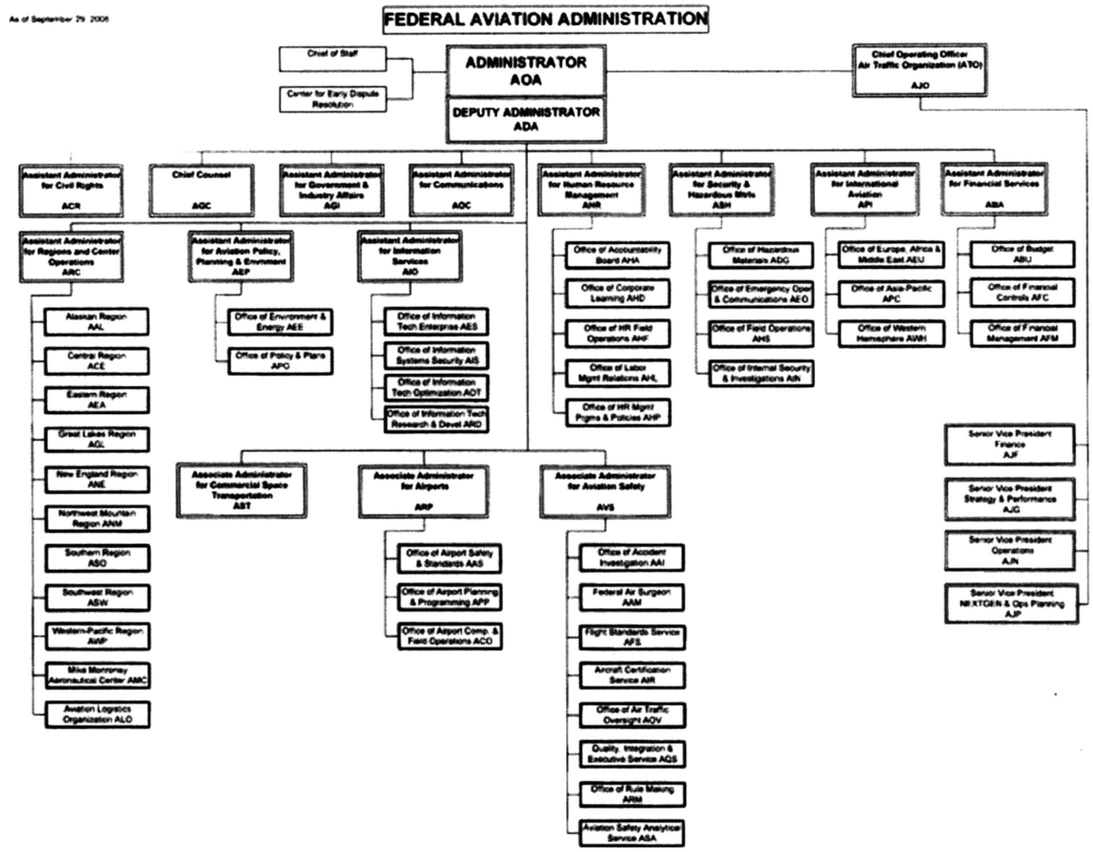

Figure 8: FAA's Organizational Structure [29]

The *Air Traffic Airspace (ATA) Unmanned Aircraft Systems Office (UAS)* is the primary group within the FAA that deals with reviewing proposed UAS applications and works with the Unmanned Aircraft Program Office (UAPO) on actually approving applicants seeking a Certificate of Authorization (COA). Since the ATA UAS coordinates with applicants and is involved in the review and granting of COAs, they remain as an external component of the enterprise.

Internal: Those stakeholders who must be considered and satisfied and represent those who are internal to the specified enterprise primary boundary. Internal entities are normally primary participants in the NAS and they have some ability to control aspects of the enterprise design and operation.

NAS users are mainly military, civil, commercial, and private pilots who access the airspace whether controlled or uncontrolled.

UAS end users are mainly DoD associated organizations, such as the Army, Air Force, and the Navy who all have various types of UASs. There are a select few civil organizations that are also considered end users on a very limited basis, such as the National Aeronautics and Space Administration (NASA), the Department of Homeland Security (DHS), and various local police organizations who have been granted limited COAs to fly UAS in the NAS.

FAA Offices that deal with the end users once they receive an approved COA regarding certification and integration of their UAS into the NAS. These organizations within the FAA include the *Aviation Safety Division (AVS),* the *Aircraft Certification Service* (AIR), and the *Unmanned Aircraft Program office (UAPO).*

Extended network: This portion of the enterprise consists of those stakeholders who should be considered and might be satisfied. Furthermore, it is an area when discussing the enterprise for those with an identified interest and who may, under specific conditions, influence one or more of the internal stakeholders.

International Civil Aviation Organization (ICAO) is an organization that falls under the United Nations agency concerned with civil Aviation issues. ICAO works to achieve its vision of safe, secure, and sustainable development of civil aviation through cooperation amongst its member States.

General Public Interest represents anyone living within the National Airspace boundaries whether participants or non-participants, who are concerned with achieving the full benefits of UAS operations while still preserving safety through effective mitigation of risks with the least possible restrictions.

Various NAS User Associations: Aircraft Owners and Pilots Association (AOPA), Airline Pilots Association, Association of Unmanned Vehicle Systems International (AUVSI)

Potential Civil and Commercial Market End Users: such as the Department of Homeland Security (DHS), Department of Transportation (DOT), Customs and Border Patrol (CBP), United Parcel Service (UPS), etc.

Figure 9 is an illustration to summarize the enterprise network and each component.

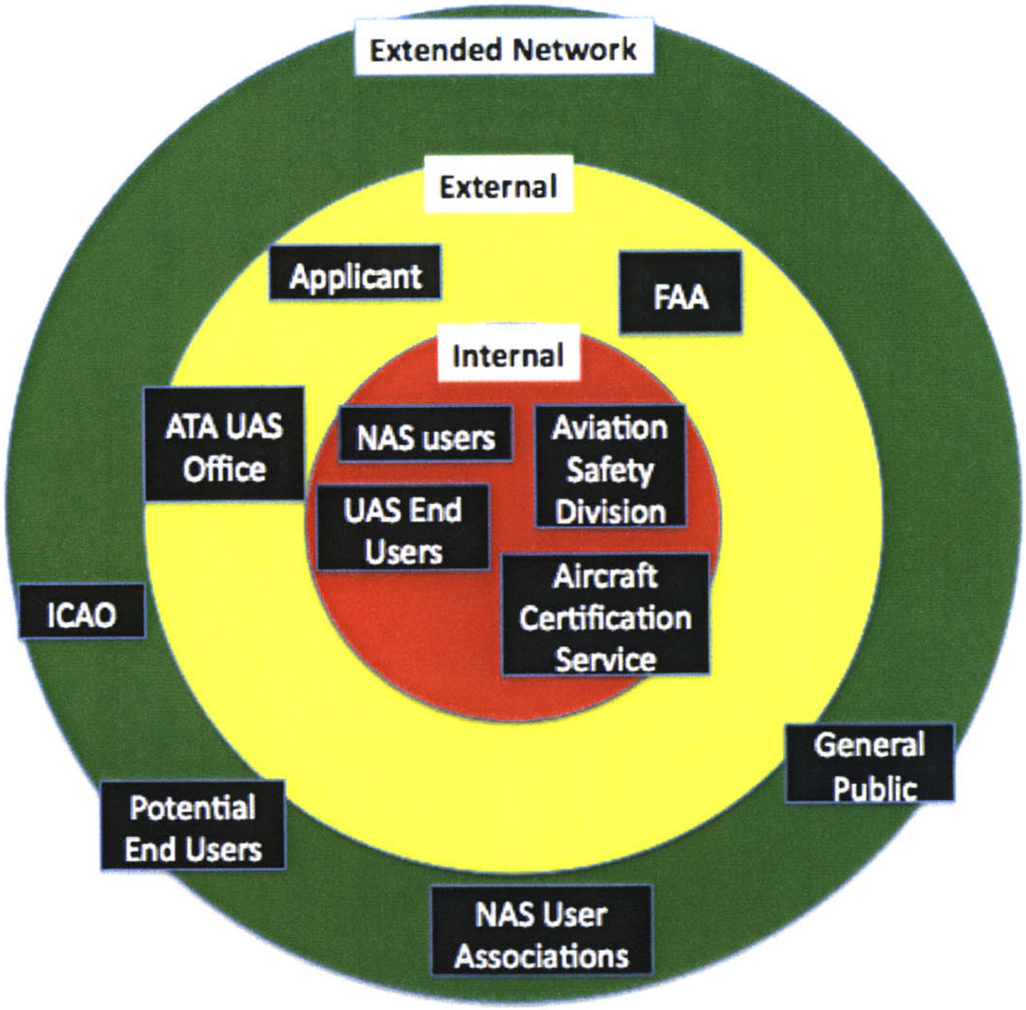

Figure 9: Enterprise Network

Enterprise system issues

When discussing UAS technology, it is important to first address the notion that replacing a human pilot with technology increases the risk involved. The general public perception that a UAS is more dangerous than a piloted aircraft can be mitigated by recognizing that a UAS possesses the following inherent advantages, which contribute to flying safety:

⇒ Many piloted aircraft mishaps occur during the take-off and landing phases of flight, when human decisions and control inputs are substantial factors. Robotic aircraft are not programmed to take chances; either preprogrammed conditions are met to land, or the system goes around.

⇒ Since human support systems are not carried, mishaps from failed life support systems (oxygen, pressure, temperature, etc.) will not occur.

⇒ Smoke from malfunctioning, but non-vital, onboard systems do not pose the same threat of loss. Smoke in the cockpit of a piloted aircraft can distract operators and lead to obscured vision or breathing difficulties.

⇒ Automated take-offs and landings eliminate the need for pattern work, resulting in reduced exposure to mishaps, particularly in the area surrounding main operating bases.

The preceding points are useful to keep in mind when considering the various technology issues surrounding airspace integration of UASs. It is also important to remember that 14 CFR Part 91 does not directly prohibit military UASs from flying as long as they can comply with existing regulations [21]. This makes such compliance a technical rather than exclusively a regulatory issue.

Allowing routine and safe access of UASs to the National Airspace involves numerous issues that touch on nearly every aspect of the Enterprise. These issues are organized into five major groupings: safety, security, regulations/standardizations, air traffic/integration, socio-economic, and leadership. An expanded discussion on the issues of safety and security is detailed below as they most directly pertain to the scope of this thesis

Safety

In the past, UASs were treated like ground vehicles with all safety measures maintained on the ground side of the FAA's Safety Center. Therefore, there was little to no Aviation culture within the small UAS community, as they were treated more like a radio controlled model rather than performing functions that the human would normally do – fly [30]. Humans still perform control and visual tasks, but no longer actually fly or pilot the aircraft with the exception of those UASs that require manual departures and landings. Successful integration of UASs in the National Airspace will require assurances that they can safely operate within the constructs of a commonly shared aviation system and environment. As such, UASs must demonstrate that they do not pose an undue hazard to other aircraft or personnel on the ground. They must provide for an equivalent level of safety to piloted aircraft. But defining this equivalency in terms of requirements is difficult. UASs operate differently from piloted aircraft. And because the pilot is no longer at risk in a UAS accident, the question arises as whether UAS systems can or should be held to the same safety standard as piloted aircraft.

Safety risks are pervasive in the design and operations of any complex system and UASs are no exception. Identifying, organizing, and defining the numerous individual safety risk factors and their interrelationships is a difficult task. However safety is the most important issue surrounding UASs flying in the National Airspace and this section will focus on the high-level safety issues such as collision avoidance, system reliability, human factors, and weather. Collision avoidance is chosen for its potential to result in catastrophic accidents, while system reliability, human factors, and weather hazards are existing weak links [2].

The FAA's main concern about UAS operations in civil airspace is safety. It is critical that these vehicles do not come too close to aircraft carrying people or compromise the safety of anyone on the ground. Many in the aviation community have expressed concern over the safety of UASs operating routinely in civil airspace. This concern is not completely unfounded. Based on the military's experience, UASs initially had a poor safety record. However, as shown previously in

Figure 2, examining the number of accidents per 100,000 flight hours monthly over each year, UAS accident rates have recently decreased as flight hours increased. This demonstrates that as technology matures, safety measures increase and less malfunctions occur. Compared to a piloted aircraft, such as the Army's AH64D Longbow Apache, the Army's tactical UASs have a greater rate of accidents. This can be attributed to the fact that the Apache helicopter is already a mature technology in which pilot training, tactics, and maintenance standards are well established. In contrast, the UAS is a relatively immature technology and such a rate is expected at this technological level. However, UAS accident rates have demonstrated a downward trend in the last couple of years (again reference Figure 2) since its integration into Army Aviation and all flight standards associated with piloted aircraft.

The UAS community is aware of the safety concerns and has moved aggressively to improve this record. They understand that any public trust and political support for UASs that exists today will rapidly erode should a UAS be involved in a fatal accident in the air or on the ground, regardless of fault. Therefore, safety remains foremost on the minds of manufacturers, operators, airspace users, and regulators.

While much attention focuses on safety risks posed by UASs, considerably less attention is given to potential safety benefits. Many of the new technologies and procedures being researched for UASs have the potential to improve safety for both piloted aircraft and unmanned aircraft. Advances in UAS automation, sensor detection systems, communications, data exchange networks, and monitoring systems will have direct and positive influences on all aircraft. Much of this is outlined in the DoD's UAS Roadmap [31].

While reliability, human factors, and weather, are all concerns, the most pressing safety concern is collision avoidance, which is the problem of detecting and avoiding aircraft and other objects. UASs must have a *see and avoid* capability, which is often referred to as *sense and avoid* or *detect and avoid.* This ability to detect and safely steer clear of aircraft and other obstructions is outlined for pilots in the FAA advisory circular 90-48C *Pilot's role in collision avoidance*. A similar directive for UASs, outlined in FAA Directive 7610.4J, called *Special Military Operations* states that UAS operations require the "*comparable see and avoid requirements for manned aircraft*". Furthermore, FAR Part 91.113 *Right of way rules* states that regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to *see and avoid* other aircraft [32]. To satisfy the requirements, all UASs must be able to reliably avoid collisions with all aircraft both cooperative and non-cooperative at all times. This capability will fall to sensors that can effectively detect aircraft that do not explicitly or actively make their presence known.

Interestingly, most of today's mid-air collisions occur during clear daylight and typically near uncontrolled airports, which points to the human failings of the *see and avoid* requirements [33]. *See and avoid* is a challenge due to differences in human skills, abilities, and habits. Not all pilots have the same visual acuity or depth perception, nor do they spend equal time looking out the window and following consistent scanning techniques. Furthermore, the FAA indicates that most mid-air collisions that occur in the conditions described previously are a result of an aircraft overtaken by a faster aircraft. Such incidents account for less than one percent of all aviation accidents, so out of approximately sixty million flights per year in the United States, there are on average thirty mid-air collisions per year [34]. Although pilots have limited to no visibility to the rear of their aircraft, a UAS can have a 360 degree viewing range depending on sensor type and placement, which quite possibly gives the UAS a better collision avoidance system then a piloted aircraft.

Work on *sense and avoid* standards is underway but beyond the difficulty of developing a standard is the challenge of finding a sensor that could meet that standard. Most UAS optical systems in use today require good weather, are susceptible to obscurants such as smog and smoke, and the search rates are often slow and may not be sufficient for traffic detection. UASs must also have a cooperative surveillance system such as a transponder, Traffic Collision Avoidance System (TCAS), or Automated Dependent Surveillance-Broadcast (ADS-B). There are numerous technology solutions being explored for *sense and avoid* systems. Some researchers continue to work with existing sensors and surveillance technologies to see how they may work in a UAS context. Others possibilities for smaller UASs hold promise due to advances being made in miniaturization and subsystem capability improvements. With the advent of high performing digital processors, field programmable gate-arrays, and radio frequency and baseband analog electronics; small, low-cost, low-power radars may are also a possibility [35]. Finally, there are others seeking novel ways to fuse information from these sensors as well as to develop new sensor/surveillance technologies specifically designed for UASs. The Air Force Research Lab (AFRL) and the Defense Research Associates developed a model that calculates the detection range required to avoid a collision for both piloted aircraft and unmanned aircraft to meet the FAA *see and avoid* requirement. The model allows variation in sensor and target velocities; initial separation and look angle; latencies associated with communications, decisions, and maneuvers; a safety factor (final miss distance); and specific UAS maneuvering capabilities (flight speeds, climb rates, and turn rates as a function of altitude). Directorate engineers applied this model to the Air Force's Global Hawk and Army's Predator UAS to determine the detection requirements for a *see and avoid* system placed on each of these platforms. After completing the requirements definition phase and flight demonstration of an aircraft detection system, directorate engineers compared the results of both. The UAS air traffic detection system performance exceeded that of a trained human pilot [36]. Recently, AFRL and Northrop Grumman teamed to study attributes of a *see and avoid* sensing architecture to define the way data is collected from various sensors and how such data could be fused to create an integrated view of the airborne environment. They are also working collaboratively with various government, associations, and industry organizations to address civil sensing requirements under a newly formed Autonomous Flight Control Sensing Technology program. This initiative will examine past mid-air accidents and compare them to airspace tasks for UAS operations in the NAS.

Assuming that conflicts can be detected, whether by optical or electronic means, there remains the issue of how the ground operator or vehicle itself reacts to avoid that conflict. Should the UAS act autonomously or should the ground operator (or even the air traffic controller) redirect the vehicle? Latencies associated with the air/ground communications link may also present a problem. Despite the statistical rationale indicating low probabilities, numbers mean little when it comes to public perception and political acceptance. One of the first necessary steps is to develop a sensible baseline measure for a *see and avoid* requirement that can be translated into a Minimum Performance Standard (MPS). This MPS should be sensitive to and flexible enough to account for the range of UAS types, missions, and operating environments. Any requirement evolving from an MPS should not be technology specific, nor should the requirement expect a near-perfect system where none exists today. And because future UAS operations will involve international boundary crossings, the requirement should be internationally adopted in ICAO Standards and Recommended Practices (SARPs) and manuals. Encounter scenarios should be detailed to validate the requirement, and costs and complexity must be factored in. The key issue preventing acceptance of any collision avoidance requirement will probably not be technical in nature, but rather involve issues of cost and implementation feasibility.

Another major challenge in developing a reasonable *see and avoid* requirement will be to address the unique issues associated with small UASs. Because pilots flying aircraft will have a greater difficulty in seeing these small vehicles, there may be an argument for the development of a cooperative sensor/surveillance system that can assist both piloted aircraft and UAS vehicles/operators in identifying and avoiding proximate traffic. Such a solution must be sensitive to cost, weight, and power consumption so as to be acceptable to small-piloted aircraft and small-unmanned aircraft. There is reason for optimism that *see and avoid* solutions will be found for all UAS types. Research conducted and advances in existing technologies indicate that detection devices will continue to diminish both in size and power requirements while concurrently increasing in capability and affordability. New technologies being explored will not only benefit the UAS community, but will migrate to piloted aircraft and may eventually reduce the risk of collisions for all aircraft.

Security

The wide variation in flight environments, missions, and vehicle sizes makes the secure control of UAS flights a unique challenge. Security requirements of the ground control station, data link infrastructure, vehicle and even the data must be a fundamental consideration in system design and operational policies and procedures of UASs. In addition to being vulnerable to security breaches, UASs themselves are also a potential security threat. And as the cost of UAS systems decrease and the capabilities improve, the wide availability of highly capable UASs could further exacerbate security concerns.

The operation of UASs is generally conducted from ground-based facilities, which can vary in size from small mobile units such as the U.S. Army's Raven to elaborate interconnected global systems such as the U.S. Air Force's Global Hawk. This has prompted the development of security requirements for these controlling facilities and becomes quite complex when ground operations are distributed over various locations worldwide. The amount of security depends on the size of the UAS, the airspace utilized, and the mission at hand. Large centralized operations are obviously easier to secure and control than small, mobile facilities but the communication infrastructure must also have built in redundancy to ensure that alternate paths exist as well.

UASs are dependent on ground-based links, which are often times widely distributed geographically. These links are used for vehicle control, monitoring, and air traffic communications and can be vulnerable to jamming and interference or attempts to usurp control. To prevent this, a system of high-integrity, secure data links between the aircraft, the ground control stations, and air traffic facilities is fundamental to UAS operation in the NAS. Modern encryption and authentication technology tools, including augmented versions, may mitigate the issue. However, high power jamming will also pose a hazard even with modern encryption and authentication technologies.

Communications security depends on the frequency used, the communications media, the encryption technology employed, and the associative properties of the communication link. Typically, encryption with a lower frequency and low bandwidth poses more of an issue than with higher frequencies and high bandwidths. There is also a tradeoff concerning security, performance, and cost - the higher the security, the less the performance, and the greater the cost.

The military has established technologies to ensure adequate encryption of Satellite Communications (SATCOM) data links for its larger UASs. These systems tend to be expensive and may not be available for civil use. It is possible, however, that some civil variant of the military systems will be made available for UASs. Beyond the military systems, there are number of encryption technologies available in the civil environment to enhance data-link security, but many of these may not be available, effective, or practical for all the communication links currently being explored for UASs. The security requirements of the communication system and the components that it links should be considered at the beginning. This should entail the production of a security policy that contains an evaluation of the threat to the system, security level of the communication data, an assessment of the vulnerability of the system, and requirements as to how the system should be protected.

The Department of Defense has a critical growing dependence on information systems that are part of its network-centric environment. To address data security concerns, the DoD is developing a suite of technologies and programs to prevent cyber attacks, while providing managers of the information system an ability to see, counter, tolerate, and survive such attacks. The Aviation community can adopt these programs from the military to protect data that will be vital to future aviation operations to include UAS operations.

Data management initiatives are being designed to address data security and integrity issues. The issue of data security and control is already being addressed as it affects modern piloted aircraft. There is an increased reliance on navigational data for onboard systems, as well as other data used for mission planning and dynamic updates. Controlling the data input process, where good data may be intentionally altered prior to downloading into a UAS flight management system, may be the greatest challenge.

UASs, especially the small UASs, are varied in the type of take-off and landing environments and systems they use. Some UASs are capable of taking off vertically like a helicopter, launched from building tops, projected from vehicles, or even hand launched. This versatility gives UASs the opportunity to operate within virtually any environment, including urban areas. While this operational flexibility is a plus, it also creates a security risk as surreptitious flights may be made easier and UAS uses expand to include a platform for weapons systems. This threat poses issues concerning the control of UAS operations and technologies and how this can be done without imposing unnecessary restrictions on the market. There is a growing concern that advanced technologies, specifically those pertaining to miniature sensors, advanced data links, and micro-miniature guidance and navigation components, will be used for nefarious activities [37]. The use of UASs as weapons by terrorist or others may influence tighter controls that may result in reduced or inhibited UAS capabilities and civil/commercial activities.

The issue of operational security and technology controls is, therefore, a law enforcement issue. Restricting the use of UAS activities, or trying to regulate security, will do nothing to address the issue. A person determined to use UASs for terrorism or other criminal activities will not seek permission or obey any restrictions imposed by the government. The effect of such security controls has a greater impact on hindering market expansion possibilities than on preventing criminal acts. The issue to the UAS community is therefore one of supporting law enforcement in developing plans to assist in identifying potentially nefarious activities. The government can and should continue to prevent the proliferation of technologies that could be easily configured for terrorist use, but this will becoming increasingly difficult as many of these technologies, or close variants of them, become pervasive in the commercial markets.

Regulations and standardization applies across products, technology, & information management. The absence of certification standards and regulations addressing UAS systems, operations, and operator qualifications is also a significant issue that prevents progress in the integration of UAS into the NAS. Finally, the lack of an effective and affordable collision avoidance system capable of detecting non-transponder equipped aircraft is an essential step to the future state of the NAS and UAS integration [2]. Much of this has been discussed previously, but the main issue is the lack of consensus among stakeholders within the enterprise on operational concepts, definitions, and classifications of UASs. A thorough understanding and analysis of the enterprise stakeholders, their values, prioritization, and their interactions is essential to a successful enterprise transformation.

Stakeholders and Value

Stakeholders

In any complex enterprise, there are numerous stakeholders representing a wide variety of needs and values. Focusing on the enterprise level emphasizes the importance of being oriented towards recognizing that all stakeholders are essential in the orientation of activities within a given enterprise [38]. Similar to aerospace enterprises, the NAS enterprise is characterized by the complexity of their stakeholders that often exhibit a high degree of interdependence, as well as a complicated set of relationships that bind them together. Understanding the needs of all stakeholders associated with the enterprise, their values, prioritization, and their influence or control of enterprise activities is essential to the transformation process.

A stakeholder is "*any group or individual who directly or indirectly affects or is affected by the level of achievement of an enterprise's value creation processes*" [39]. The process of identifying those relevant stakeholders within the enterprise for the creation of value and clear boundaries is the first step. In his 2003 thesis *Stakeholder Analysis in the Context of the Lean Enterprise*, Ignacio Grossi presents a stakeholder identification model that involves the identification of potential stakeholders and determining the salience of those stakeholders to evaluate whether it is reasonable to consider them for the analysis [40]. Furthermore, this methodology identifies enterprise system level value, focal organization, and potential groups through an iterative process.

This is a highly complex enterprise with numerous stakeholders involved. Not only are there several stakeholders, but there are also such a wide variety of stakeholders - from the UAS operator to the members of Congress. However due to the scope of this thesis, I will limit the stakeholder discussion and analysis to those with the most significant impact on Army UAS and their integration into the NAS. The following is a list of stakeholders identified using Grossi's identification model, then scoped to include only those stakeholders within the boundary of those involved in the Army UAS integration into the NAS effort:

Applicant: includes all product design and development teams as well as support personnel and resources; not necessarily the "end user"; examples include AAI, Aurora Flight Services, Cyber Defense Systems, Raytheon, Telford, Northrop Grumman, Boeing, DoD [41].

Federal Aviation Administration (FAA) (See Figure 8 for Organizational Chart): is a regulatory organization that acts as a gatekeeper for all Aviation Operations.

> UAS program office (UAPO): is an office within the FAA responsible to safely integrate Unmanned Aircraft Systems into the U.S. National Airspace System. This organization is essentially a study group or research group tasked with devising a plan to integrate UAS into the NAS.
>
> Unmanned Aircraft Systems Group: is the principal element within the Air Traffic Airspace Management Program within the FAA responsible for authorizing unmanned aircraft (UA) operations in the National Airspace System (NAS). This office works in close coordination with Aviation Safety's Unmanned Aircraft Program Office (UAPO) to review proposed applications and ensure that approvals to fly unmanned aircraft, regardless of size, do not compromise the high level of safety for other aviation, the public, and property on the ground.

OSD-FAA: the joint OSD-FAA Airspace Integration Initiative is intended to facilitate military UAV operations within the National Airspace System. The effort began in 2001 and focuses on the technology concerning sense-and-avoid requirements, regulatory issues surrounding "file and fly" procedures, and the implementation of UAS integration into the NAS for military, civil, and commercial applications while maintaining the current level of safety. The OSD-FAA is working through the DoD Policy Board on Federal Aviation (PBFA) and is engaged in establishing the air traffic regulatory infrastructure for integrating military UAS into the NAS [21]. By limiting this effort's focus to traffic management of domestic flight operations by military UASs, they hope to establish a solid precedent that can be translated into public and civil UAS in the domestic and international airspace. The PBFA outlines the DoD organizational structure for interface with the Department of Transportation, the FAA, and other agencies on air traffic control and airspace management. In this capacity, the PBFA provides policy and planning guidance for comprehensive airspace planning in order to ensure that the Military Departments have sufficient airspace to fulfill military, training, and test and evaluation requirements; cooperate with the FAA for the effective and efficient management of the NAS; and ensure operational interoperability between the DoD and the FAA [43].

U.S. Army: primary end user of UAS (Shadow, Predator, Hunter)

US Army Aviation and Missile Command (USAAMCOM or AMCOM): a major command element within the Army structure that encompasses the missions and organizations of the Missile Command and Army Aviation and Troop Command, in a joint effort to develop certain airborne missile systems to support the soldier in the field.

Project Manager UAS (PM UAS): is within the USAAMCOM organization and is responsible for management of the entire fleet of Army UASs.

Aviation Engineering Directorate (AED): an organization within USAAMCOM responsible for ensuring that Army aircraft comply with airworthiness requirements.

Training and Doctrine Command (TRADOC): a major command within the Army structure that develops the Army's Soldier and Civilian leaders and designs, develops and integrates capabilities, concepts and doctrine in order to build a campaign-capable expeditionary Army in support of joint war-fighting commanders through Army Force Generation (ARFORGEN).

Air Force: primary end user of UAS (RQ-4 Global Hawk)

Navy/Marines: primary end user of UAS

Office of the Under Secretary of Defense (OSD) Acquisition, Technology, and Logistics (AT&L) Task Force: OSD is the principal staff element of the Secretary of Defense in the exercise of policy development, planning, resource management, fiscal, and program evaluation responsibilities [44].

Joint Unmanned Aircraft System Center for Excellence (JUAS COE): works towards standardization, integration and training for UAS and UAS products. This organization focuses on joint UAS employment and training standards, providing support to the joint operator, the services and combatant commands across all military services [45].

General Public Interest: represents anyone living within the National Airspace boundaries whether participants or non-participants, who are concerned with achieving the full benefits of UAS operations while still preserving safety through effective mitigation of risks with the least possible restrictions.

Piloted Aircraft: any active aircraft with on-board pilots within the National Airspace. This includes commercial, military, private, and recreational aircraft.

Aircraft Owners and Pilots Association (AOPA) is a not-for-profit organization individual membership association dedicated to general aviation. It is the largest most influential aviation association in the world with over 415,000 members and proving member services that range from representation at all government levels, legal services, and advice [46]

Airline Pilots Association (ALPA) is the largest airline pilot union in the world and represents nearly 52,250 pilots at 35 U.S. and Canadian airlines. It provides three critical services to its members – airline safety and security, representation, and advocacy [47]

UAS Operators

Association of Unmanned Vehicle Systems International (AUVSI) is the world's largest non-profit organization devoted exclusively to advancing the unmanned systems community. AUVSI has over 1400 member companies consisting of government organizations, industry and academia, and is committed to fostering, developing, and promoting unmanned systems and related technologies [48].

UAS Training/Flight Schools

Department of Homeland Security (DHS)

Customs and Border Patrol (CBP)

Air Marine Operations Center

Federal Emergency management Agency (FEMA)

Exxon, Mobile, BP, Shell, UPS

International Civil Aviation Organization (ICAO): is a UN Specialized Agency that provides a global forum for civil aviation. ICAO works to achieve its vision of safe, secure and sustainable development of civil aviation through cooperation amongst its member States [49].

Radio Technical Commission for Aeronautics (RTCA SC-203): is a private, not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance, and air traffic management (CNS/ATM) system issues. RTCA functions as a Federal Advisory Committee. Its recommendations are used by the Federal Aviation Administration (FAA) as the basis for policy, program, and regulatory decisions and by the private sector as the basis for development, investment and other business decisions [50].

Prioritize and Group the Stakeholders

The National Airspace System is a complex enterprise with an extensive number of stakeholders. An extension of the model presented by Mitchell, Agle, and Wood, Grossi's stakeholder salience methodology will be used to assess the relative ordering and ranking of stakeholders as they relate to the integration of UASs into the National Airspace System [51]. Grossi's methodology allows for a complete understanding of each stakeholder's influence and priority along with a consistent categorization and treatment of various kinds of stakeholders while taking into consideration their ability to influence or control enterprise activities. As discussed previously, there are over 300 possible stakeholders involved in the integration of UASs into the National Airspace but for the scope of this thesis, the focus is on those that directly affect the integration of Army UAS into the NAS (See Appendix 1 for a full list of stakeholders). Table 2 below summarizes those identified stakeholders, the rationale, importance to the enterprise, and the six groups that emerged during the identification process previously discussed:

Code	Stakeholder	Rationale	Group
S01	Applicant	includes all product design and development teams as well as support personnel and resources; not necessarily the "end user"	Applicant
S02	Federal Aviation Administration - FAA	a regulatory organization that acts as a gatekeeper for all Aviation Operations	FAA
S03	FAA UAS Program Office (UAPO)	To safely integrate Unmanned Aircraft Systems into the U.S. National Airspace System.	FAA
S04	FAA Unmanned Aircraft Systems Group (UAPO)	the principal element within the Air Traffic Airspace Management Program responsible for authorizing unmanned aircraft (UA) operations in the National Airspace System (NAS)	FAA
S05	Office of the Secretary of Defense - Federal Aviation Administration (OSD-FAA)	the joint OSD-FAA Airspace Integration Initiative is intended to facilitate military UAV operations within the National Airspace System and works through the DoD Policy Board on Federal Aviation (PBFA)	FAA/Leadership
S06	U.S. Army	currently the lead end user of UASs	UAS End User
S07	Army UAS Project Manager (PM UAS)	responsible for management of the entire fleet of Army UASs	UAS End User
S08	Army Training and Doctrine Command (TRADOC)	providing the right people, with the right skills, right capabilities, at the right time and right place for today and tomorrow.	UAS End User
S09	ArmyAviation Engineering Directorate (AED)	determines airworthiness of Army aircraft	UAS End User
S10	U.S. Air Force	a significant end user of UAS	UAS End User
S11	U.S. Navy/Marines	a significant end user of UAS	UAS End User
S12	OSD Acquisition, Technology & Logistics Task Force (OSD AT&L)	is the principal staff element of the Secretary of Defense in the exercise of policy development, planning, resource management, fiscal, and program evaluation responsibilities	Leadership
S13	Joint Unmanned Aircraft System Center for Excellence (JUAS COE)	works towards standardization, integration and training for UAS and UAS products	Leadership
S14	Association of Unmnanned Vehicle Systems International (AUVSI)	the world's largest non-profit organization devoted exclusively to advancing the unmanned systems community.	Leadership
S15	International Civil Aivation Organization (ICAO)	is a UN Specialized Agency that provides a global forum for civil aviation.	Leadership
S16	Radio Technical Commission for Aeronautics (RTCA SC-203)	is a private, not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance, and air traffic management (CNS/ATM) system issues.	Leadership
S17	Association of Unmnanned Vehicle Systems International (AUVSI)	the world's largest non-profit organization devoted exclusively to advancing the unmanned systems community.	Leadership
S18	General Public Interest	often represented through the various organization and in members of Congress	NAS User
S19	Piloted Aircraft	any certified pilot flying in the NAS (mlitary, civilian, commercial, private, etc.)	NAS User
S20	Aircraft Owners and Pilots Association (AOPA)	not-for-profit organization individual membership association dedicated to general aviation	NAS User
S21	Airline Pilots Association (ALPA)	the largest airline pilot union in the world	NAS User
S22	DoD UAS Operators	currently military operators of UAS	NAS User
S23	DoD UAS Training/Flight Schools	currently military operators of UAS	NAS User
S24	Department of Homeland Security (DHS)	potential applications for maritime, border control, etc.	Potential End Users
S25	Customs & Border Patrol (CBP)	a subordinate organization within DHS	Potential End Users
S26	Air Marine Operations Center	Provide funding, training requirements, and maintenance requirements	Potential End Users
S27	Federal Emergency Management Agency (FEMA)	Provide funding, training requirements, and maintenance requirements	Potential End Users
S28	Commercial Companies: Exxon, Mobil, BP, UPS	Provide funding, training requirements, and maintenance requirements	Potential End Users

Table 2: Stakeholders and Stakeholder Groups

It was difficult to identify the importance of each stakeholder compared to the rest because several appeared to have equal importance to the enterprise, and as expected each stakeholder feels that they are the most important to the enterprise. In order to differentiate between stakeholders, the concept of Stakeholder Salience is utilized. Furthermore, the relevance or saliency of each stakeholder is accomplished using Grossi's detailed set of considerations to help quantify each stakeholder's score on the power, legitimacy and urgency scale. A stakeholder demonstrates power in its relationship with the enterprise when it gains access to or can gain access to coercive, utilitarian or symbolic means to impose its will in the relationship [52]. Coercive power refers to the use of physical resources of force, violence, or restraint. Utilitarian power is based on the exchange of material or a financial transaction, while symbolic power is such things as prestige, esteem, love, or acceptance. Legitimacy is defined as general perception or assumption that the actions of a stakeholder are desirable and appropriate based on social norms and values. Urgency exists when a relationship or claim is time-sensitive and when that relationship or claim is important or critical to the stakeholder operations and strategies [52].

In order to identify the relative importance of the stakeholder to the enterprise and prioritize the stakeholders, the stakeholders were asked to evaluate all identified enterprise stakeholders in a qualitative manner. Instead of utilizing the ranking system (1-10) for power, legitimacy, and urgency, qualitative descriptors were used as listed below to equate to the values of stakeholder salience when polling the stakeholder. Also, Grossi provides different subtypes for each attribute with associated qualitative descriptions for each point range (See Appendix 2). This prevented the stakeholders from biasing the results and they were more comfortable using the qualitative assessment en lieu of assigning specific values. Then the scale in Table 3 was used to arrive at an ordinal scale.

Descriptor	*Point Range*
Excellent	*8-10*
Above average	*6-8*
Average	*4-6*
Below Average	*2-4*
Poor	*0-2*

Table 3: Stakeholder Salience Scoring

Once the stakeholders identified their relative importance to the enterprise based on power, legitimacy, and urgency using the above classifications, the information was analyzed, reconciled where necessary, and translated to the numerical method in the stakeholder salience chart. With this method, stakeholder importance was better identified to the enterprise, but also several groupings of stakeholders holding the same salience level emerged. Overall this method provides a clear picture as to the actual importance of each stakeholder to the enterprise.

Code	Stakeholder	Rationale	Group	Power	Legitimacy	Urgency	NSSI	Rank
S01	Applicant	includes all product design and development teams as well as support personnel and resources; not necessarily the "end user"	Applicant	3	3	3	9.0	24
S02	**Federal Aviation Administration - FAA**	a regulatory organization that acts as a gatekeeper for all Aviation Operations	FAA	10	10	9	93.3	1
S03	**FAA UAS Program Office (UAPO)**	To safely integrate Unmanned Aircraft Systems into the U.S. National Airspace System.	FAA	8	10	8	74.7	2
S04	**FAA Unmanned Aircraft Systems Group**	the principal element within the Air Traffic Airspace Management Program responsible for authorizing unmanned aircraft (UA) operations in the National Airspace System (NAS)	FAA	8	9	8	69.3	3
S05	**Office of the Secretary of Defense - Federal Aviation Administration (OSD-FAA)**	the joint OSD-FAA Airspace Integration Initiative is intended to facilitate military UAV operations within the National Airspace System and works through the DoD Policy Board on Federal Aviation (PBFA)	FAA/Leadership	7	8	8	58.7	4
S06	U.S. Army	currently the lead end user of UASs	UAS End User	3	7	7	30.3	11
S07	Army UAS Project Manager (PM UAS)	responsible for management of the entire fleet of Army UASs	UAS End User	4	7	5	27.7	14
S08	Army Training and Doctrine Command (TRADOC)	providing the right people, with the right skills, right capabilities, at the right time and right place for today and tomorrow.	UAS End User	2	6	3	12.0	22
S09	ArmyAviation Engineering Directorate (AED)	determines airworthiness of Army aircraft	UAS End User	5	5	2	15.0	21
S10	U.S. Air Force	a significant end user of UAS	UAS End User	3	7	7	30.3	12
S11	U.S. Navy/Marines	a significant end user of UAS	UAS End User	2	7	7	25.7	15
S12	**OSD Acquisition, Technology & Logistics Task Force (OSD AT&L)**	is the principal staff element of the Secretary of Defense in the exercise of policy development, planning, resource management, fiscal, and program evaluation responsibilities	Leadership	4	8	8	42.7	6
S13	Joint Unmanned Aircraft System Center for Excellence (JUAS COE)	works towards standardization, integration and training for UAS and UAS products	Leadership	3	8	6	30.0	13
S14	**Association of Unmnanned Vehicle Systems International (AUVSI)**	the world's largest non-profit organization devoted exclusively to advancing the unmanned systems community.	Leadership	4	8	9	46.7	5
S15	International Civil Aviation Organization (ICAO)	is a UN Specialized Agency that provides a global forum for civil aviation.	Leadership	2	2	8	12.0	20
S16	Radio Technical Commission for Aeronautics (RTCA SC-203)	is a private, not-for-profit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance, and air traffic management (CNS/ATM) system issues.	Leadership	5	8	5	35.0	10
S17	General Public Interest	often represented through the various organization and in members of Congress	NAS User	2	7	4	16.7	19
S18	**Piloted Aircraft**	any certified pilot flying in the NAS (military, civilian, commercial, private, etc.)	NAS User	3	9	8	41.0	7
S19	Aircraft Owners and Pilots Association (AOPA)	not-for-profit organization individual membership association dedicated to general aviation	NAS User	1	5	4	9.7	23
S20	Airline Pilots Association (ALPA)	the largest airline pilot union in the world	NAS User	1	5	7	15.7	20
S21	**DoD UAS Operators**	currently military operators of UAS	NAS User	3	8	8	37.3	8
S22	**DoD UAS Training/Flight Schools**	currently military operators of UAS	NAS User	3	8	8	37.3	9
S23	Department of Homeland Security (DHS)	potential applications for maritime, border control, etc.	Potential End Users	5	5	5	25.0	16
S24	Customs & Border Patrol (CBP)	a subordinate organization within DHS	Potential End Users	5	5	5	25.0	17
S25	Air Marine Operations Center	Provide funding, training requirements, and maintenance requirements	Potential End Users	4	5	5	21.7	18
S26	Federal Emergency Management Agency (FEMA)	Provide funding, training requirements, and maintenance requirements	Potential End Users	0	3	5	5.0	25
S27	Commercial Companies: Exxon, Mobil, BP, UPS	Provide funding, training requirements, and maintenance requirements	Potential End Users	0	3	3	3.0	26

Table 4: Stakeholder Saliency

The enterprise stakeholders are categorized and ranked based on their saliency index. As shown in Table 4 above the most important stakeholders include the organizations within the FAA, DoD, and NAS users. This framework provides a powerful tool for rigorously identifying which stakeholders are the most important within an enterprise context. Furthermore, it also provides a way to interface a large pool of enterprise stakeholders.

Further assessment of the saliency index provides for a straightforward method to categorize the relative importance of each stakeholder. Logical groupings of the stakeholders into categories help to assess the value received and delivered between the stakeholder group and the enterprise. The stakeholder analysis results shown previously in Table 2 suggest that enterprise stakeholders fall into one or many of the following general groups: Applicant, FAA, UAS End User, NAS User, Leadership, and Potential End User. Listed in Table 5 shows each stakeholder group, a description, and the value exchange between the groups and the enterprise:

Stakeholder	Description	Value Received From System	Value Delivered To System
Applicant (DoD, NASA, CBP)	The issue at hand is integration of UAS into the NAS and the applicant consists of someone who is applying for a Certificate of Authorization (COA) for a new UAS in order to access the NAS. The applicant remains external to the enterprise layout. Once they are granted a COA and access the NAS with a UAS, they then become end users and are internal to the enterprise.	• Airspace access • Command & control • Flexibility for training and operations • Approval & standardization	• Ability to transition controlled airspace to mission space while maintaining status quo • Maximize resources (cost and duration of flight) • Technology innovation
FAA (UAPO, UA Group, OSD-FAA)	The FAA's primary mission is the safety, security, and efficiency of the National Airspace System. It is a highly complex and large organization and there are a few specific offices within the organizational structure that are involved in the integration of UAS into the NAS as external players.	• Maintain status quo – safety • Command & control • Maximize resources	• Maintain status quo – safety • Gatekeeper for airspace operations • Procedures, policies, & regulations • Approval & Standardization
UAS End User (Army, AF, Navy)	UAS end users are mainly DoD associated organizations, such as the Army, Air Force, and the Navy who all have various types of UASs. There are a select few civil organizations that are also considered end users on a very limited basis, such as the National Aeronautics and Space Administration (NASA), the Department of Homeland Security (DHS), and various local police organizations who have been granted limited COAs to fly UAS in the NAS.	• Airspace access for training & operations • Command & Control • Flexibility for training and operations • Procedures, policies, & regulations	• Technology innovation, testing and implementation • Ability to transition controlled airspace to mission space • Recognition/best practices
NAS Users (General Public, Piloted A/C, UAS Flt Tng, ALPA)	Encompasses a wide range of interests and objectives. NAS users are qualified as either participating traffic or non-participating traffic. They are mainly military, civil, commercial, and private pilots who access the airspace whether controlled or uncontrolled.	• Maintain status quo – safety • Procedures, policies, & regulations • Approval & Standardization	• Technology Innovation • Maximize resources • Recognition/best practices • Societal Preferences
Leadership (OSD-FAA, JUAS COE, AUVSI)	Those organizations leading the efforts on promoting UAS operations in the NAS through their efforts on policy creation, product innovation, training, and resource support.	• Airspace Access • Flexibility • Maintain status quo – Safety • Established procedures, policies, & regulations	• Maximize resources • Recognition/best practices • Established procedures, policies, & regulations • Technology Innovation
Potential End Users (FEMA, DHS, UPS)	Independent review of safety and efficacy. Facilitate diffusion by establishing standards. But FDA very under-resourced relative to mandate, no single "system owner" agency	• Access to airspace • Approval & standardization	• Maximize resources • Technology innovation

Table 5: NAS Enterprise - Stakeholder Value Exchange [39]

Taking the stakeholder value exchange a step further, it is important to analyze each stakeholder group's importance to value creation and their current performance within the enterprise. Understanding this value exchange between the stakeholder groups demonstrates the strong correlation between the enterprise objectives and the current performance of value delivery. A summary of this analysis is shown in Table 6:

Stakeholder	Value Received	Value Delivered	Importance to Value Creation	Current Performance
Applicant (DoD, NASA, CBP)	• Airspace access • Command & control • Flexibility for training and operations • Approval & standardization	• Ability to transition controlled airspace to mission space while maintaining status quo • Maximize resources (cost and duration of flight) • Technology innovation	**Medium** – Until the FAA approves an applicant and issues a COA, the applicant doe not greatly affect the enterprise. However power is in numbers – the more applicants pushing, then the FAA will be forced to evaluate currently policies and regulations.	**Low** – Besides DoD applicants, there are not many civil or commercial applicants due to the hesitancy to invest in UAS operations until the FAA established clearer policies and standards.
FAA (UAPO, UA Group, OSD-FAA)	• Maintain status quo – safety • Command & control • Maximize resources	• Maintain status quo – safety • Gatekeeper for airspace operations • Procedures, policies, & regulations • Approval & Standardization	**High** – The FAA is the gatekeeper to the National Airspace System. Establishing policies, procedures, and standards for UAS access to the NAS is essential.	**Medium** –The FAA is moving forward with research groups, relationships with DoD, and the creation of offices within the FAA organization to specialize in the issues of airworthiness and integration of UAS into the NAS.
UAS End User (Army, AF, Navy)	• Airspace access for training & operations • Command & Control • Flexibility for training and operations • Procedures, policies, & regulations	• Technology innovation, testing and implementation • Ability to transition controlled airspace to mission space • Recognition/best practices	**High** – DoD is making rapid advances with UAS technology but also with integration into military airspace. Much of this could be transferred to the FAA policies and also to civil, and commercial applications.	**High** - due to the GWOT, DoD is heavily funded and invested long-term in UAS technology. No other agencies have power to drive change or the current demand.
NAS Users (General Public, Piloted A/C, UAS Flt Tng, ALPA)	• Maintain status quo – safety • Procedures, policies, & regulations • Approval & Standardization	• Technology Innovation • Maximize resources • Recognition/best practices • Societal Preferences	**Low/Medium** – Although the current users are important, they do not have the power or influence to prevent or alter the possible integration of UAS into the NAS. They can simply provide their view and are represented through the various organizations but are not an integral part of the initial value creation.	**Low** – normal NAS operations continue and UASs are granted COAs for flight in the NAS and TFRs are normally established. NAS participants must follow those regulations and operate safely in the NAS. However, NAS participants and non-participants have extensive experience and ideas that may help mold future policies and successful integration of UAS into the NAS.
Leadership (OSD-FAA, JUAS COE, AUVSI)	• Airspace Access • Flexibility • Maintain status quo – Safety • Established procedures, policies, & regulations	• Maximize resources • Recognition/best practices • Established procedures, policies, & regulations • Technology Innovation	**High** – the current efforts from the various organizations involved in UAS integration into the NAS have made great strides to provide access and yet still maintain the safety of the airspace	**High** – The current efforts are excellent (especially between the FAA and OSD) but the focus must continue to be policy and strategy issues and no so much on the product or technology.
Potential End Users (FEMA, DHS, UPS)	• Access to airspace • Approval & standardization	• Maximize resources • Technology innovation	**Low** – Potential end users do not have the marketing or financial backing to push forward as applicants. They are waiting to see what progress DoD, the FAA, and other government agencies make on moving forward with airworthiness and policy procedures for UAS in the NAS.	**Low** - – The civil and commercial applications are quite a ways off in the future. Process, policy, and strategy must first be addressed using public aircraft and then the success can translate to the potential end users.

Table 6: Stakeholder Importance & Performance

"As is" Architectural View

In order to analyze the enterprise in its current state, the National Airspace System enterprise is individually evaluated based on the eight views of the enterprise: strategy, process, knowledge, product, service, IT, information, and policy. Through the consideration of issues from these respective *lenses*, one can best envision the enterprise from perspectives generally not considered from an individual stakeholder's analysis or even that from a group of stakeholders when together considering the issues at hand. The motivation behind utilizing enterprise architecting is the need for a sufficiently robust approach that can address the full-spectrum issues surrounding the National Airspace and the integration of UAS into this system. Enterprise architecture is a holistic approach capable of addressing the complexities inherent in the Aviation Community in a systematic manner. So what is enterprise architecture? As defined by Deborah Nightingale and Donna Rhodes:

> *"Applying holistic thinking to design, evaluation, and select a preferred structure for a future state enterprise to realize its value proposition and desired behavior"*[39]

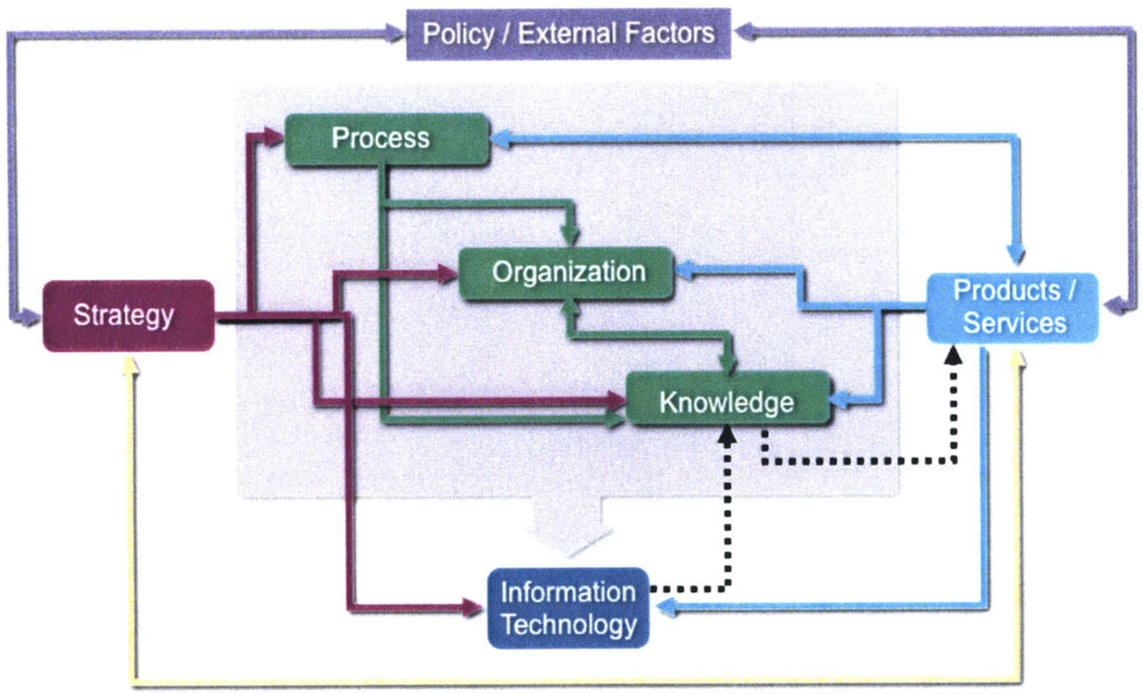

Figure 10: Enterprise Architecture Views – Interrelationships [53]

This holistic approach fits within the broader value-creation framework and enables value capture of the structure, value, and behavior within the enterprise.

In order to develop a systematic method for analyzing the "as-is" state, the general approach for identifying the interrelationships seen in the enterprise architecting framework (Figure 10) surrounds primarily the views of Policy, Strategy, Product, and Process Views. In the current state of the NAS enterprise, Policy greatly influences the Product, Process, and Strategy views, which ultimately drives the rest of the enterprise views and aligns other interrelationships. However, Policy seems to be the one view that remains unchanged in the current state. As a result, in order to comply with the current FAA Policies, one must view the entire enterprise from the perspective of the Product view in order to evolve into the Future State. This will then directly impact the Strategy and Process views and the rest of the views will follow suit. Since Policy is not changing and will most likely not change in the near future, the focus is on Strategy, Process, and Product views, their value exchange, and their affect the remaining views, in order to develop a transformation plan for the future state (summarized in Table 7). The effect of applying this methodology is to understand what the enterprise should look like when viewing it from the Product view (followed by the rest of the Views), rather than how the Product is viewed from the enterprise.

Policy/External Factors: This view represents the external regulatory, political, and societal environments in which the enterprise operations [54]. Much of this view has been discuss in the previous sections and the overall theme surrounding the Policy View is that it remains unchanged in the current state and will not change in the near future. As outline in the Strategic Objectives Section, the FAA prefers to "Conform rather than create" new policies to dedicated to UAS operations in the NAS. Furthermore, the FAA prefers to avoid new initiatives just for the DoD UAS training and operations in the NAS and have continued to utilize COAs for such activity. As a result, Policy will not change in the immediate future, if at all to assist in the integration of UAS in the NAS, rather process and products will influence the strategy view as well.

Product/Services: This view represents the products produced or the services provided by the enterprise [54]. The National Airspace is an enterprise that provides controlled and uncontrolled operational airspace. The issue for UAS operation in the NAS surrounds equipage – the see/sense and avoid functionality in order to comply with exisiting regulations. There are various technologies available and many with the DoD community experimenting with products to support the sense and avoid capability. Military UAS operations are significantly different from UAS operations in the NAS. Military air operations do not change very much if UAS plan to operate in the airspace with piloted military aircraft. However, UAS operations in the NAS cause a degradation in the overall performance of the system due to the numerous "exceptions" in the form of TFRs that cause other NAS participating traffic to maneuver around and adversely affect normal day-to-day operations.

Strategy: This view represents goals, vision, and direction of the enterprise and includes the business model and competitive environment. Since policy will not change and standards will remain as they currently are, the focus for interested stakeholders is to develop a strategy to enter the airspace with UAS operations utilizing the appropriate product and/or process. Furthermore, addressing the proper strategy for achieving the goals of the enterprise described previously under "Strategic Objectives" leads to the Process and Product views aligning, and the rest of the views following suit. Ultimately, the strategy is to enable UAS operations in the NAS and develop an appropriate business model to do so. Technology in the UAS community is advancing rapidly so the interaction between strategy, product, and process will greatly propel the enterprise forward. As a result, Technology Strategy is the business model that will be discussed in a subsequent section that has the potential to transform the enterprise into the future vision.

Process: This view represents the core processes by which the enterprise creates value for its stakeholders. For the NAS enterprise, there exists many complex processes that are all tied to the ever-constant Policy view. As discussed previously, such policies surround airspace operations, airworthiness, and of course UAS integration procedures.

VIEW	CHARACTERISTIC	EXAMPLE VIEW INTERACTIONS
Strategy	Maintain the current level of safety with the integration of UAS into the NAS; enable increased capacity in the NAS.	Highly dependent on the Policy and Product views.
Policy	Conform rather than create; avoid separate policies for UAS.	Unchanged in the present and will most likely remain the same in the near term; Result: Strategy, Process, and Product highly coupled with Product most directly having to conform to the Policy view.
Process	Must link the process to the strategic goals and product specifications, eliminate communication gap and encourage cross-talk among and across organizations.	Strong relationship to Policy and Product architecture; complex processes exist for airworthiness, airspace operations, and integration of UAS in to the NAS.
Organization	Numerous interested organizations, research groups, and collaborative team members with holistic perspective.	Determines knowledge requirements and must be aligned with process architecture.
Knowledge	Requires a robust method for processing, accepting, verifying, and validating submitted data	Strong relationship with both product and org. arch.; both influences and is supported by IT arch.
Info Tech	Command and Control and security issues are highly important as the NAS continues to progress digitally	Highly coupled with Knowledge and supports relevant product/process information shared seamlessly across the enterprise
Product	Sense and Avoid equipage requirements: Modular vs. integral design; Need an integrative design with a large number of entrants to the market.	Strategy, Product, and Process views have high interaction; driving metric for all views
Service	Maintain safe airspace; increase capacity	Heavily drives product arch.; support requirements inherent in knowledge employed by teams in Process and Org. architectures

Table 7: Enterprise Architecture - View Interactions

A number of recent and current efforts to integrate UAS into the national airspace provide the context for the current enterprise activity. These efforts yield a significant degree of insight into the difficulties associated with creating a sustained effort for solving this issue. The primary views of concern include Policy, Strategy, Product, and Process. However, as demonstrated previous, Policy remains stagnant in the current state of the enterprise with existing standards in effect and no plan for creating separate regulations for UAS operations in the NAS. As a result, the three most significant views of concern include Product and Process, which influence the Strategic View. The remaining views are heavily influenced by the aforementioned views and it is important to analyze the enterprise through all views because some are necessary for functionality while others are important for optimization. Enterprise architecture requires a collaborative effort especially among Strategy, Policy, Process, and Product views in order to experience a successful transformation to the future vision of UAS flight in the NAS.

UASs are the technology of choice in numerous government agencies and departments and there is a growing interest among commercial companies for UAS usage. They are used more frequently in the GWOT effort both at home and abroad. The DoD and Homeland Security are developing plans to use UASs domestically. Unless these aircraft meet FAA certification standards established, large airspace restrictions will be necessary to segregate piloted aircraft from UASs.

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Section 3: Transforming the Enterprise

Vision & Design for the Future Enterprise

At the core of delivering value is the need to move the enterprise from its current architecture to the desired future state. An enterprise transformation plan describes in detail the actions and results to be achieved in order to move the enterprise from its current position to the one envisioned by the future enterprise architecture. So what does the future state look like for this enterprise?

As discussed previously, the strategic objectives for the National Airspace System consist of:

1. Increased safety
2. Greater capacity
3. International leadership
4. Organizational excellence

After a thorough analysis of these strategic objectives, the current enterprise architecture, stakeholder values, and an assessment of the constraints, the following characteristics of the future integration of UASs into the NAS emerge [55]:

1. Safety; conform to existing policy
2. Provide flexible airspace operations that enable mission execution and minimizes the impact on airspace capacity
3. Implement and remain within resource constraints
4. Integrate policy, procedures, and technology for all airspace operations
5. Reduce cost and training/operational overhead

The future vision of success ultimately reflects routine UAS flights within the National Airspace that seamlessly operate without hindering safety or airspace capacity (see Figure 12 below). However, it is a long road to reaching this vision and will require an incremental systematic approach to transition from the current "by exception" method of flight, to UAS fully integrated and compliant with airspace regulations UAS operations.

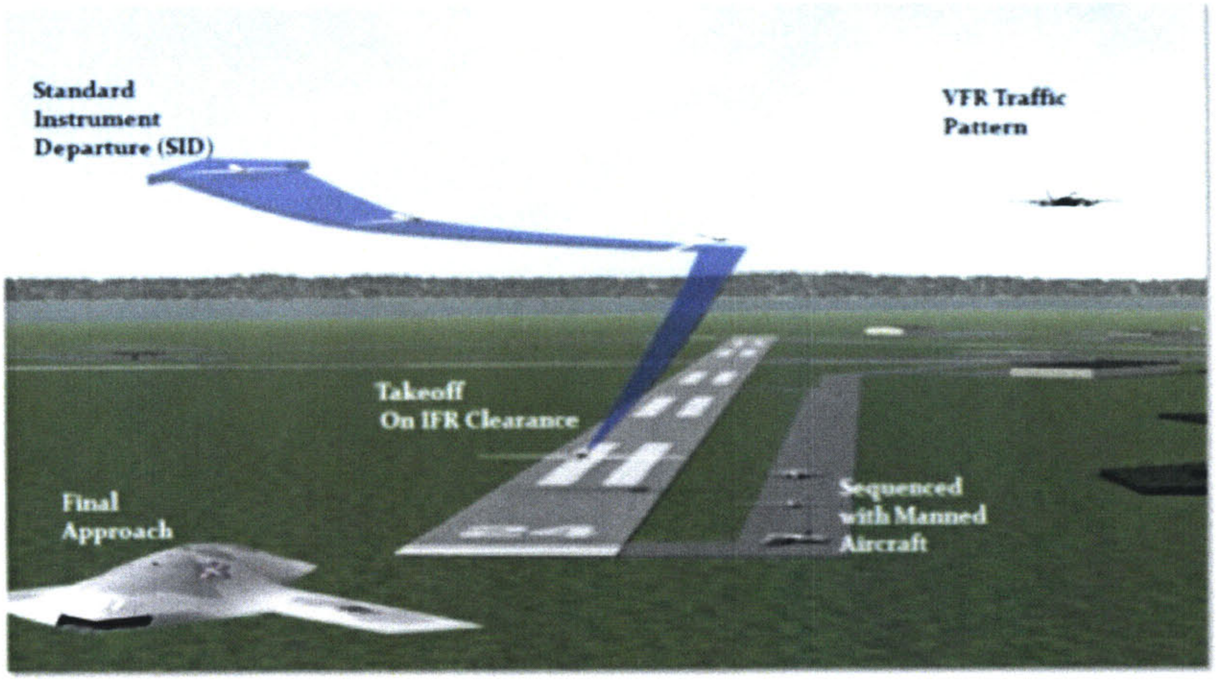

Figure 11: Future Vision of Success [56]

A simple, incremental systems approach is essential to fulfilling the previously mentioned objectives and will drive rapid performance improvement with relatively minor changes. A UAS collision-avoidance system must cover many different types of operations. It is one thing for a remotely piloted Global Hawk to climb in restricted military airspace to altitudes above Flight Level 180, where all air traffic is under positive ATC control, and then climb above FL500, where there are very few aircraft. But it is more challenging to also support a wide range of UAS sizes when the aircraft are below 18,000 ft. Here, piloted aircraft will often be flying under visual flight rules (VFR) in a *see and avoid* environment.

Current Near-Term Efforts

The Office of the Secretary of Defense (OSD) and the FAA (a joint working group often referred to as OSD-FAA) are working toward establishing UAS performance requirements, to include equipment such as a *detect, sense, and avoid* collision-avoidance system that would allow UASs to fly with a safety level equivalent to piloted aircraft. This was formerly an effort between the FAA and the Joint Integrated Product Team (JIPT) until JIPT dissolved due to lack of funding. However, JIPT made great strides to integrate UAS into the NAS and now the OSD-FAA organization continues JIPT efforts. Developing an approach to collision avoidance that would work with UASs flying near piloted aircraft is considered the intractable part of the problem for gaining better access to civil airspace. But until the FAA specifies the requirements for such a system, engineers cannot start designing an avionics box to fly on the aircraft.

The limitations on DoD UAS Operations within the National Airspace System drastically affect DoD's ability to meet operational needs. As deployed Army units with UASs return from combat operations, they need access to the NAS in order to maintain operator proficiency and prepare for their next combat deployment. As a result, the combined efforts of the FAA and OSD can establish and initiate an effective and safe method for UAS operations to *see/sense and avoid* other traffic. The immediate objective is to employ a system that safely and non-intrusively allows for access to specific areas of the NAS to meet specific operational objectives. Next, build on initial capabilities to further expand access to night operations, no observers/chase aircraft, and expanded airspace. Finally, the long-term objective is a fully integrated solution that allows for unfettered access to the NAS so that DoD can meet all operational needs to support combat and peacetime operations [30]. This integrated life cycle solution (shown in Figure 12) includes a collision avoidance algorithm and sensor development and integration. Furthermore, it enables a coordinated assessment of the policy, operational, procedural, and acquisition related factors that weigh into the ability to achieve full airspace access.

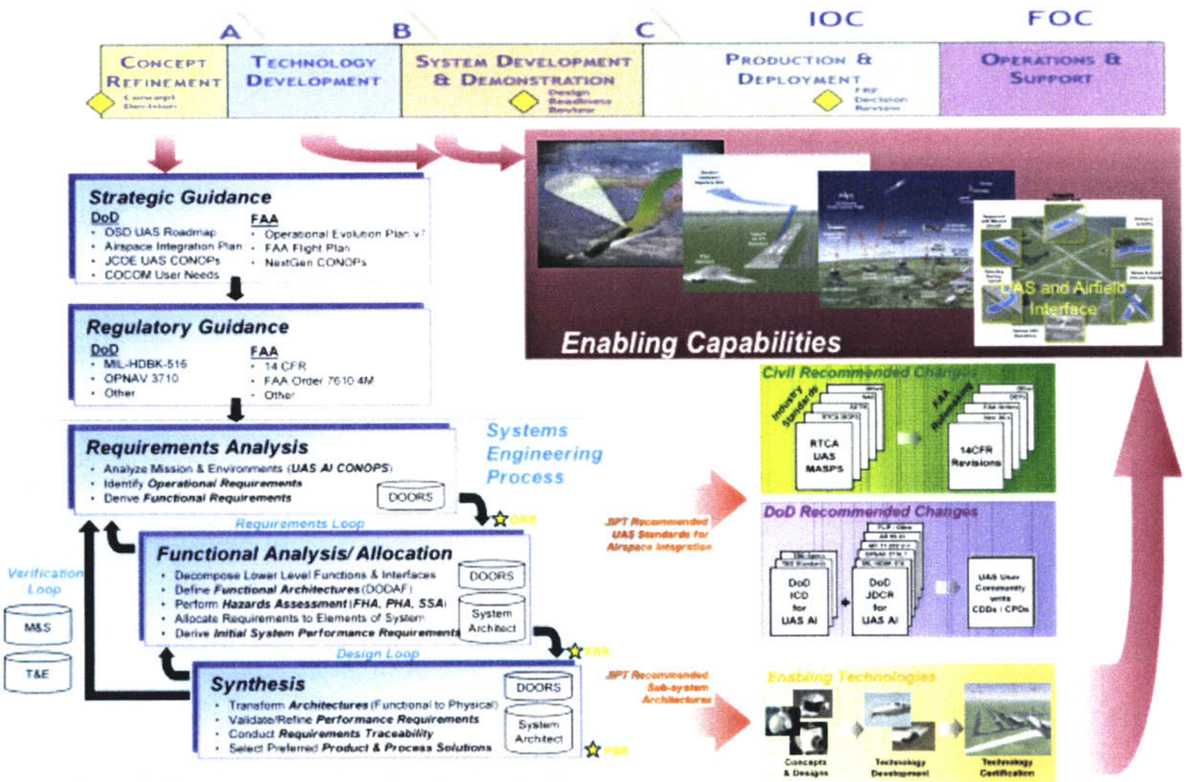

Figure 12: Integrated Life Cycle Approach [30]

In 2006, the Project Manager for Project Manager Unmanned Aircraft Systems (PM UAS) described a potential early sensing system that integrated and fused radar data to provide accurate, real-time situational awareness to a UAS operator. The operator would make decisions to safely avoid other aircraft based on the sensor data being displayed in the ground control station. The Army is working with the FAA and Joint Unmanned Aircraft System Center for Excellence (JUASCOE) to identify the technical and operational needs, and capabilities for the development of standards and specifications for a *sense and avoid* system. As a result of efforts from the now dissolved JIPT, the FAA, and PM UAS this plan has now evolved into a solution called Ground Based Sense and Avoid (GBSAA) led by the Project Manager Air Traffic Control (PM ATC) [57]. PM ATC has formed a full-time GBSAA team to demonstrate a *system-of-systems* solution that can be tailored to various installations and missions to include deployable applications to serve the needs of all Military branches of Service.

GBSAA is a "ground based means of detecting an airborne intruder and declaring a threat, in time to allow the UAS to adopt a safe state" [30]. It provides situational awareness information to UAS operators on the ground *(sense)* to enable them to maintain separation by maneuvering the unmanned aircraft away from the traffic *(avoid)*. GBSAA functional evolution consists of using existing sensors to create airways, supplemented with fixed based air traffic control and military radars dispersed across the flight areas, and provides a fused and integrated picture of the airspace (See Figure 13 below). Creating these airways and integrating GBSAA with existing aircraft sensors may expand airspace operations, reduce restrictions, and assist in the development of requirements for future onboard *sense and avoid* sensors.

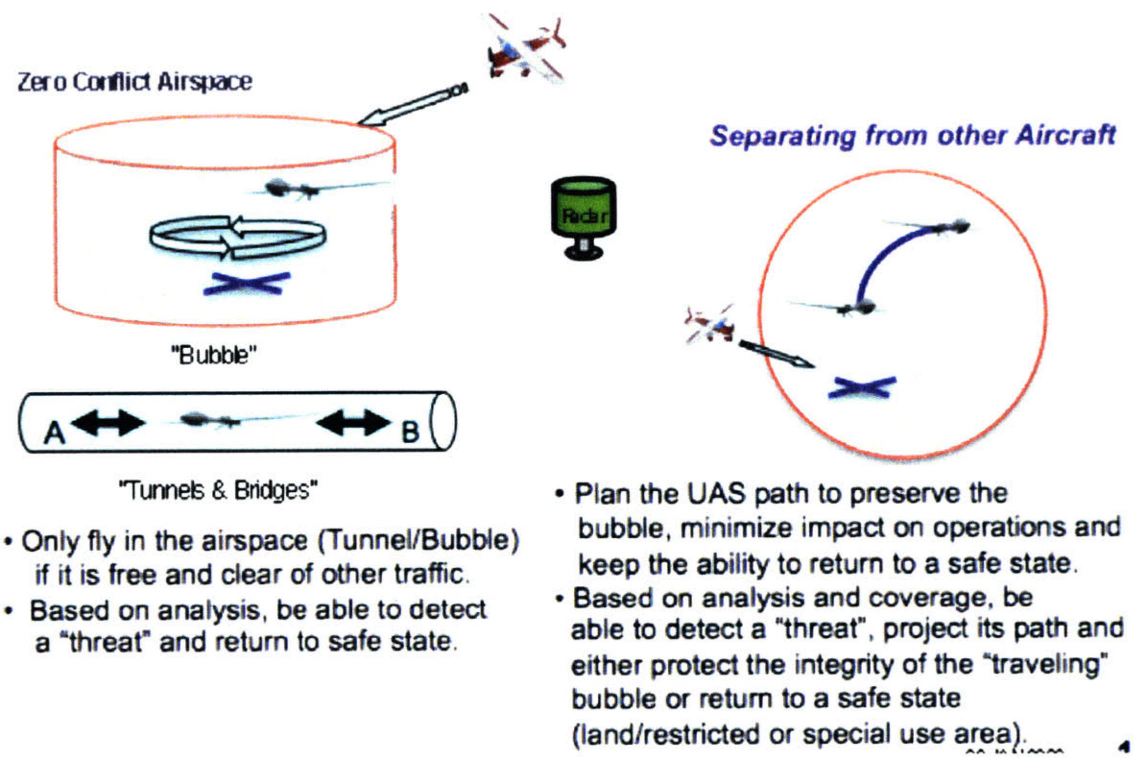

Figure 13: GBSAA Functional Evolution [30]

GBSAA provides a protected airspace for UAS operations by monitoring a volume of airspace to determine aircraft traffic and activity operating within the specified UAS operational area. This volume of airspace is within the radius of the sensors and if no aircraft are operating within this protected airspace, a UAS can be cleared for departure and begin its mission mode. If another aircraft penetrates the UAS operational area, the UAS operator is alerted and can react to avoid a conflict with another aircraft as necessary. To provide lateral and vertical safe separation between aircraft, the ground-based sensors are combined with a complex traffic display to allow conflict detection and alerting algorithms. Finally, combining an advanced traffic filtering scheme to the ground sensors and complex traffic display provides collision avoidance logic such as detection, tracking, threat declaration, prioritization, and maneuvering guidance to the UAS operator. The illustration in Figure 14 depicts several ground-based radars observing multiple targets with the radar feeds processed on the sensor fusion node. This process yields the consolidated air picture, which provides the UAS operator with situational awareness to avoid other air traffic in accordance with the FAA regulations.

Figure 14: GBSAA Concept for Safe UAS Operations [57]

Currently the U.S. Army is developing the GBSAA concept to provide a system of radars and other sensor technologies, sensor processing, and a command and control display to show a three-dimensional picture of all air traffic and protected airspace around the UAS. This provides the UAS operator visual and audio alarms to warn of impending conflicts with the UAS. The GBSAA mitigates some of the risks associated with flying UAS in the NAS and efforts are underway to prove that it meets a satisfactory level of safety. GBSAA is currently in use at El Mirage California and Fort Huachuca Arizona, with near term expansion to Fort Benning Georgia, Fort Bragg North Carolina, Fort Campbell Kentucky, Fort Hood Texas, and Fort Leonard Wood Missouri [57].

GBSAA addresses the minimum DoD specification for what is required in a sensor. The U.S. Army plans to accelerate the *sense and avoid* capability through GBSAA and will most likely integrate the Airborne Sense and Avoid (ABSAA) by 2012 using the Shadow UAS to execute this integration [30]. Since the U.S. Army has a critical need for UAS flight within the NAS from the surface to 18,000ft, they will refine ABSAA and/or a dynamic near term solution by 2014. This will propel the civil and commercial UAS industry to fully invest in this final solution and propagate the viral growth of the UAS industry across all markets. Furthermore, the FAA is beginning to create regulations for small UASs to fly in the airspace. An Aviation Rulemaking Committee (ARC) comprised of industry, associations, and other government agencies has been formed. This ARC will recommend defining and developing necessary interim policy guidance with corresponding training material for operating a small size category UAS within the National Airspace System.

So what will the UAS use as a sensor to mimic the human eye? No one knows yet, and therein lies the challenge, but it does seem that a combination of ground and air sensors can provide situational awareness to UAS operators and allow them to maneuver as necessary to maintain the appropriate level of separation from other aircraft. UAS sensors will have to replicate the performance and functions of the human eye to allow unmanned aircraft to operate in a visual flight rules (VFR) environment. Seeing and avoiding non-cooperative traffic (aircraft with no transponders) will require a real feat of engineering. Developing a UAS collision-avoidance system will most likely be a more complex task than the development of TCAS, which took the aviation community more than a decade and about $400 million to develop [58]. As Andrew Lacher, UAS program lead at Missile Test and Readiness Equipment (MITRE) Corp, points out:

> *"Perhaps most significantly, UAS collision avoidance is likely to need to function in an autonomous mode (i.e., directly linked to flight controls without a pilot being in the loop). This will complicate verification and certification. As a community, we don't have good mechanisms for evaluating, verifying and certifying software-intensive and nondeterministic systems"* [2].

In comparison if the U.S. Army succeeds at implementing and refining GBSAA technology with military UAS operations, the total cost by 2014 will be approximately $44 million [30]. GBSAA technology will yield additional supplemental technology systems such as Combat Airspace Integration, Aircraft Survivability, and Missile Defense. The U.S. Army expects that the cost of these complimentary systems along the cost of GBSAA will amount to approximately $78 million [30].

Until engineers can imbed sensors into UAS design, GBSAA allows UAS operations without sensors on the actual aircraft and with existing technology, this reduces weight, drag, and fuel consumption and complies with FAA guidance. Integrating GBSAA with existing aircraft sensors will expand UAS operations and propagate the development of future on-board *sense and avoid* technology. Such technology combined with integrated flight and mission computers may yield a semi-autonomous UAS system, which enables a UAS to respond to hazards without human input. Although many efforts are underway, the U.S. Army is leading in the integration of UAS operations into the NAS with its efforts surrounding GBSAA. The U.S. Army's initiatives with *sense and avoid* ventures and research with autonomy, airborne sensor packages, and other payloads will help create a new horizon for UASs operations in the NAS in both the near term and sustainable long-term future beyond the military sector and into the civil and commercial markets.

Long Term Future State: Technology Strategy as the Preferred "to be" Architecture

Technology Strategy is a framework that enables the understanding of the structure and dynamics of high-tech businesses, combined with an approach for their effective strategic management. As such, the integration of UASs into the NAS is a highly complex issue and involves a domain in which systems are important. UASs and the NAS are both part of larger and more complex systems and are comprised of systems themselves.

Technology Strategy coupled with Engineering Architecture emphasizes the development and application of ways of thinking that bring clarity to the complex co-evolution of technological innovation, the demand opportunity, systems architecture, business ecosystems, and decision-making and execution within the business. Architecting the current state of the NAS enterprise and then applying the technology strategy framework in an incremental systems approach to fully understand the future state of the NAS involves figuring out how to create and capture value, anticipating and deciding how to respond to the behavior of customers, complimentors and competitors, and develop and deliver technologies, platforms, and products.

Technology Innovation

The emerging use of unmanned aircraft systems (UAS) by the Department of Defense (DoD) for an ever-expanding number of roles and missions makes their use and successful integration a topic of growing importance to the DoD, the Federal Aviation Administration (FAA), and Industry. Figure 15 depicts how the focus in DoD missions has shifted from defeating a known enemy in conventional battle (Finish) to locating an unknown enemy in an asymmetric engagement (Find).

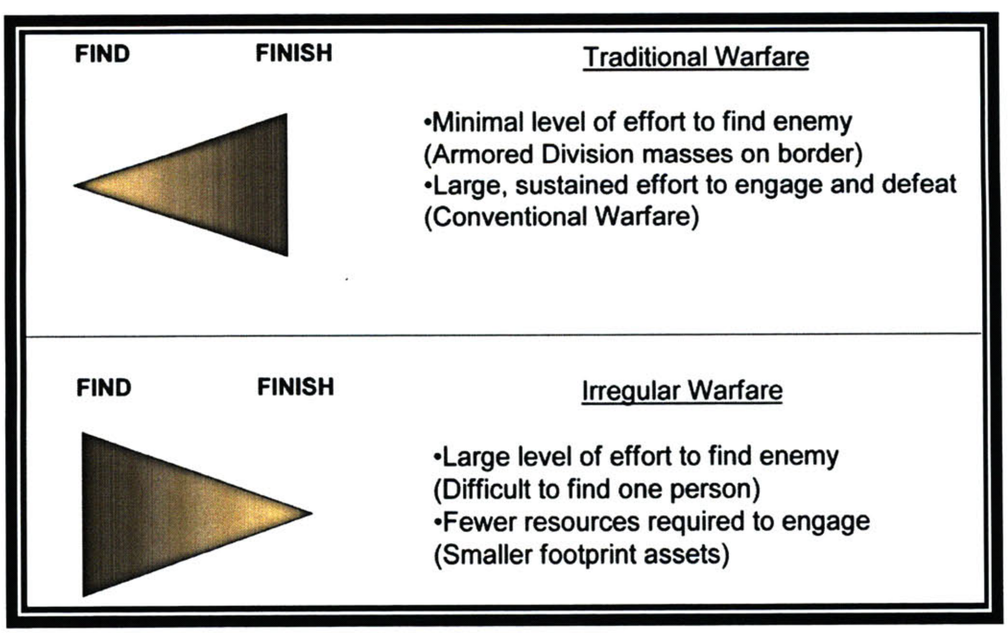

Figure 15: Traditional versus Irregular Warfare [60]

With the shift in emphasis as a result of the current Global War on Terrorism (GWOT), a new premium on intelligence, surveillance, and reconnaissance (ISR) capabilities has emerged. A recent survey of war-fighting commanders on the battlefield has demonstrated an overwhelming need for this type of capability. Figure 16 demonstrates this need through a comparative assessment of the various types of intelligence that military commanders are requesting and the amount of products available for these demands. The practical effect of these combined forces is the rapid escalation of additional ISR capabilities. It is in this capacity that UAS have seen the most dramatic rise in usage over the past five years. Figure 17 demonstrates the increase in both the flying hours and the budget allocated by DoD for the procurement and use of UAS platforms.

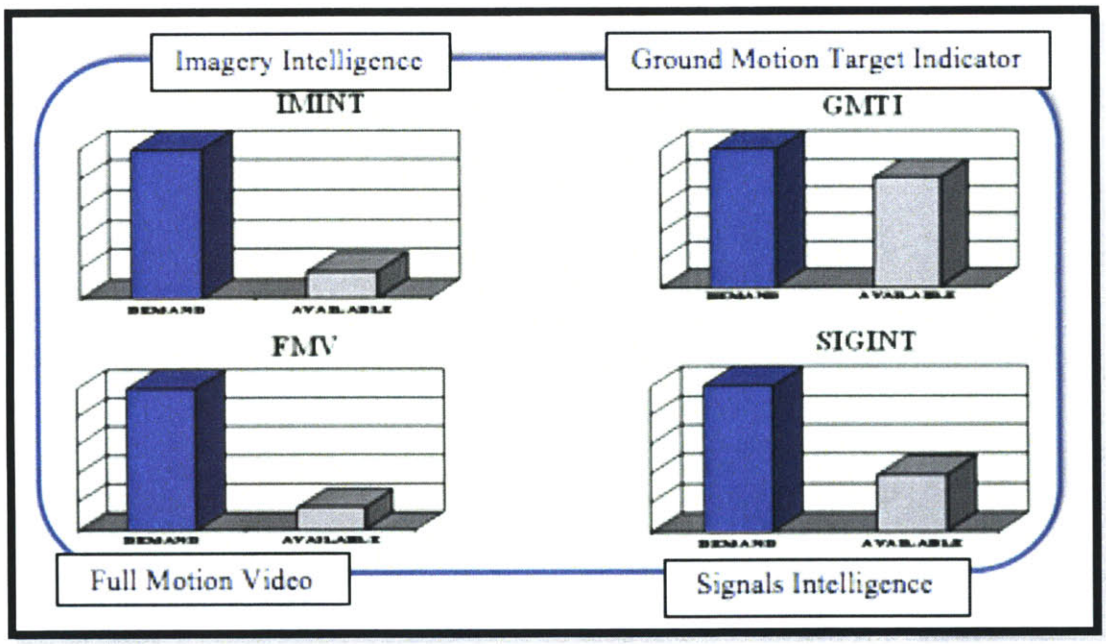

Figure 16: ISR Demand versus Capability [61]

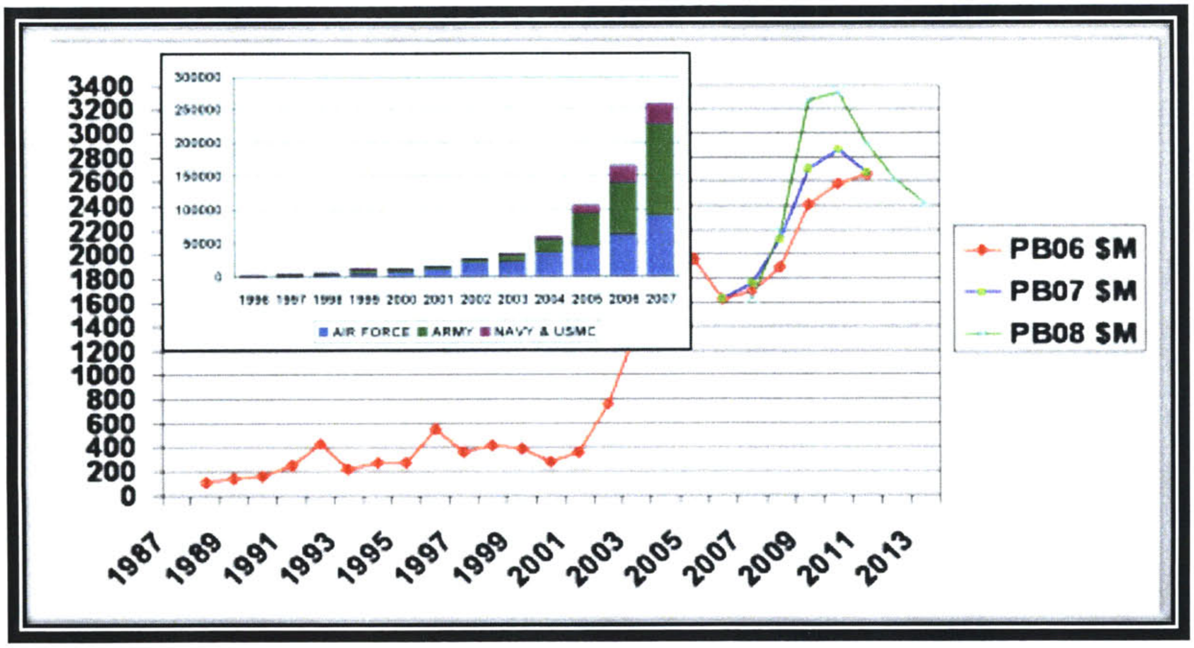

Figure 17: UAS Budget and Flight Hours Growth [60]

As the number of UAS assets grows, and they become increasingly integrated into the military infrastructure and operational picture, their importance to the conduct of successful missions becomes paramount. Often times, war-fighting commanders will postpone or even cancel entire missions if the capabilities provided by UAS ISR assets are not available [59]. Of particular interest in the current investigation is the issue of how UAS assets are integrated into the overall air traffic management structure and the technology development required to realize fully integrated manned/unmanned operations.

Key Parameters, Trade-Offs and Performance Envelopes

The UAS is an unpiloted aircraft that can be remote controlled or fly autonomously. The key performance parameters are safety, cost, payload capacity, degree of autonomy, flight time and speed. The most important of these issues is currently safety. With respect to integrating UAS into the existing airspace structure, the strategic performance parameters devolve into the ability of the UAS to meet equipage requirements (especially for sensing and avoiding other aircraft), respond to air traffic control (ATC) direction, and conform to the established "rules-of-the-road" behaviors in accordance with existing FAA regulations. In the case of equipage requirements, this can be measured largely in terms of safety, typically expressed in the number of accidents or near mid-air collisions (NMACs) per flight hour. In other words, does the UAS have the required equipage to maintain the needed separation between itself and other aircraft, can it see and avoid other airborne objects that may pose mid-air collision hazards, can positive command and control of the aircraft be maintained throughout its mission, and are there appropriate emergency procedures in place should any of the above capabilities fail? The specified intent in all of these actions is to ensure that the UAS does not collide with another aircraft or object, or in the case of a UAS malfunction, it executes the appropriate procedures to prevent creating undue hazard to those on the ground similar to piloted aircraft procedures.

The ability to respond to ATC direction is measured in terms of the UAS transparency to air traffic controllers that are directing the aircraft in their section of airspace. The kind of things that are typically assessed include the need to provide the UAS with special handling or priority routings because of aircraft performance limitations, increased separation standards between the UAS and other aircraft due to the UAS' inability to *see and avoid* other air traffic, the ability of the UAS to follow and maintain air traffic controller instructions for altitude, airspeed, and heading directions, and the overall impact on the capacity of the controller and the airspace structure for accommodating higher levels of airspace activity.

The ability of the UAS to behave in a consistent manner with the established airspace procedures goes directly to the issue of how predictable the UAS behavior is when compared to the piloted aircraft standard procedures associated with flying. This parameter is typically assessed through the overall "comfort factor" that both air traffic controllers and other aircraft pilots have that the UAS will operate in a way that is highly predictable and stable within a prescribed set of circumstances. A good example is the operational behavior of a UAS when it goes into a "lost link" mode in which the unmanned aircraft component is fully functional, but it has lost the command and control link that connects it to the ground station controlling its altitude, direction, and airspeed. In this case, knowing exactly what the unmanned aircraft will do in this situation is critical, and the more the behavior models a piloted aircraft equivalent situation, the better the system can handle these exceptions to normal operations.

The key tradeoffs involved in the technology for these platforms is the decision about how much of the performance deficit must be accounted for with additional equipage requirements versus how much can be mitigated through procedural and policy "work arounds" that treat UAS as special case aircraft rather than platforms that are required to meet existing piloted aircraft regulatory guidance. The resulting performance envelope will have significant ramifications for the operational flexibility of the system once it is in use. The better the equipage on the system, the more capable the platform will be in terms of integrating with the existing airspace management structure, and the greater the degree of flexibility allowed in the way it can be operated. The more the system relies on special procedures and handling from air traffic controllers, the more restricted the operations, and the greater the procedural limitations will be in how it can be used in order to ensure the appropriate degree of safety is maintained in the airspace.

Innovation Trajectory and Key Technologies

The progression of UAS can be characterized as predominantly an intermediating trajectory, especially when considered in the light of piloted aircraft technology. In this case, the advances made in avionics for such things as autopilots, inertial navigation systems, global positioning systems, and command & control all represent assets from the piloted aircraft community that are directly applicable in the UAS arena. However, the rudimentary manner in which these assets are employed (i.e. the activity base) is fundamentally altered with the introduction of UAS into the scene. In this case, the assets are relatively stable, but the activities themselves must be reconsidered in light of new information. Anita McGahan characterizes this type of situation as an intermediating change [62].

The key parameters are still in their infancy, and they have yet to be quantified in any systematic fashion; however, there are several key factors that appear to be emerging from the field. The first is the overall UAS reliability with respect to the number of mechanical failures that occur per flight hour resulting in damage or loss of an unmanned aircraft (See Figure 18). The other clear trend is the increasing insistence by those regulating the airspace structure that UAS platforms must become better equipped to comply with existing regulatory requirements. As the number of UAS platforms continue to increase, it becomes harder and harder to accommodate their operations on a "by exception" basis.

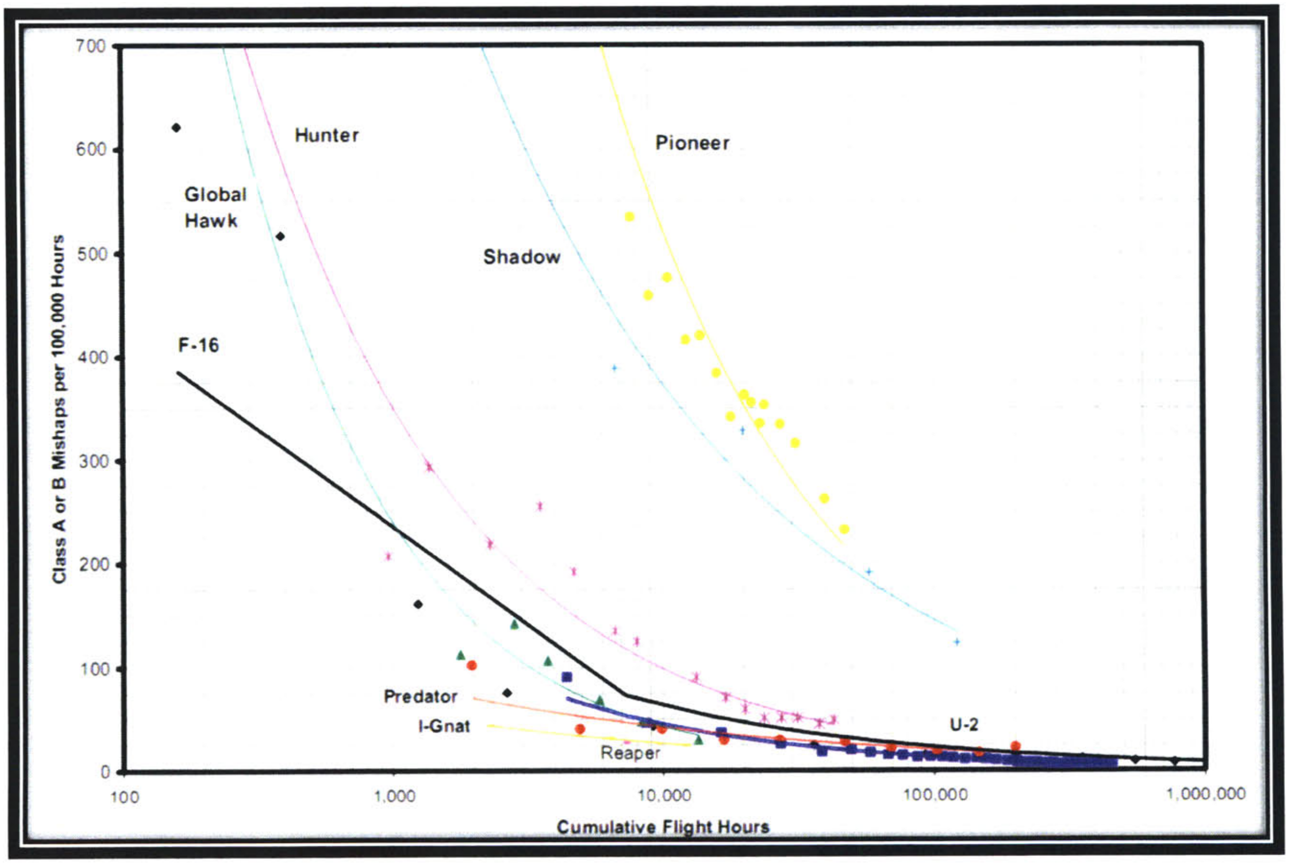

Figure 18: Military Aircraft and UAS Class A Mishap Rates (Lifetime), 1986-2006 [31]

The UAS itself competes directly with piloted aircraft missions designed to provide similar capabilities. It also competes with satellite systems for certain applications. In the case of their primary competition, piloted aircraft, the UAS is competing on three primary factors: mission capability, cost, and degree of operational flexibly. The advantage the UAS has over the equivalent piloted aircraft is that it can remain on station (or in flight) for longer durations of time because it is not limited by pilot flight duty restrictions. The UAS can also be built to much lower safety factors because a flight failure does not result in the potential loss of a human life, which means that the standards (and as a result the cost) to which the UAS is built can be downgraded without increasing the risk to human life. On the other hand, piloted aircraft have the advantage of much shorter mission planning times, flexibility to mission changes or current situation, and they can be used in much less structured, more highly integrated and congested airspace given the ability of the pilot on-board to de-conflict visually with other aircraft.

Evolution, Technological Limits and Disruption Potential

The current state of technology for UAS suggests that the technologies will continue to evolve down the intermediating lines previously described. In addition, the performance requirements currently outstrip the delivered capability by wide margins. In this environment, Christensen, Raynor, and Verlind suggest that the most successful approach will be highly integrated, interdependent, proprietary architectures [63]. Interestingly enough, the current UAS providers of large, highly capable UAS platforms have yet to take advantage of this fact in their design and implementation of equipage that could provide significant competitive advantage with respect to the operational flexibility of their UAS over that of their competitors.

In all likelihood, there will be "natural technological limits" on what can be achieved with equipage on UAS platforms—at least in the current airspace structure and management scheme. The FAA's almost insatiable appetite for safer airspace operations suggests that it will be difficult to arrive at a point in which the "customer" is over served by the technology being implemented on UAS platforms. In this sense, it is hard to see there being significant "disruptions" in the technology base, at least from an organic source. A comparison with the development of piloted aircraft technologies would seem to bear out a comparable intermediating trajectory for innovation in the UAS field. Two exceptions from external events are possible. The first would be a major media event like a mid-air collision that could induce Congress to act in a unilateral manner to further stipulate safety equipage requirements. The second would be a major policy shift on the part of the FAA to eliminate all non-cooperative traffic, significantly reducing the equipage requirements on UAS for seeing and avoiding other aircraft. This second event is unlikely to happen within the next 15 years, however, and the military need for UAS access is already outweighing any of these policy developments and will continue to do so over the next five to ten years.

Key Customer Segments and Applications

There is a growing demand for unmanned aircraft systems (UAS). Most of the intensive development of pilotless aircraft has been in the United States, which in 2005 accounted for nearly 73% of the worldwide research and production spending on UAS [64]. There are plans to continue increasing funding for U.S. military programs, and civil, as well as, international interest has also grown since documented UAS successes in the Middle East.

In order to understand potential applications, it is helpful to employ the UAS categorization scheme defined by the European Unmanned Vehicle Association, which uses a six-tiered approach. There is the *micro-UAS,* which are tiny air vehicles with a wingspan and length of no more than 15 cm. There is the *close range* group, which includes UASs that fly within a range of less than 25 km and are usually hand-launched. The *short-range* group operates at a range of 25-100 km. *Medium range* UAS are able to fly out to 100-200 km. These aircraft generally have more advanced control systems due to higher operational performance parameters. *Long Range* UAS can fly out to 500 km, and these platforms generally have highly advanced communication and guidance systems. *Endurance* class vehicles are able to operate at ranges well beyond 500 km, and they can stay in the air more than 20 hours. These are considered the most sophisticated of the UAS family [65].

UAS may also be categorized by the function it performs such as logistics, reconnaissance, research, civil, or combat. Another categorization is the altitude at which a UAS can fly. These include medium altitude long endurance (MALE), that fly at an altitude up to 30,000 ft with a range of over 200 km, and high altitude long endurance (HALE), UAS that fly above 30,000 ft and have an indefinite range. There are others, such as Hypersonic, which are high-speed, sub-orbital with a range of over 200 km. As might be suspected, all of these categorization schemes suggest that there is an extremely diverse set of ways that customer segments can be addressed. For this report, we characterize the customer base in an outcome-oriented manner [66]. Is the intended outcome defense related, civil government oriented, or commercial market in scope? This categorization scheme provides an integrative perspective over and against the UAS vehicle class categorization scheme described in the previous paragraph.

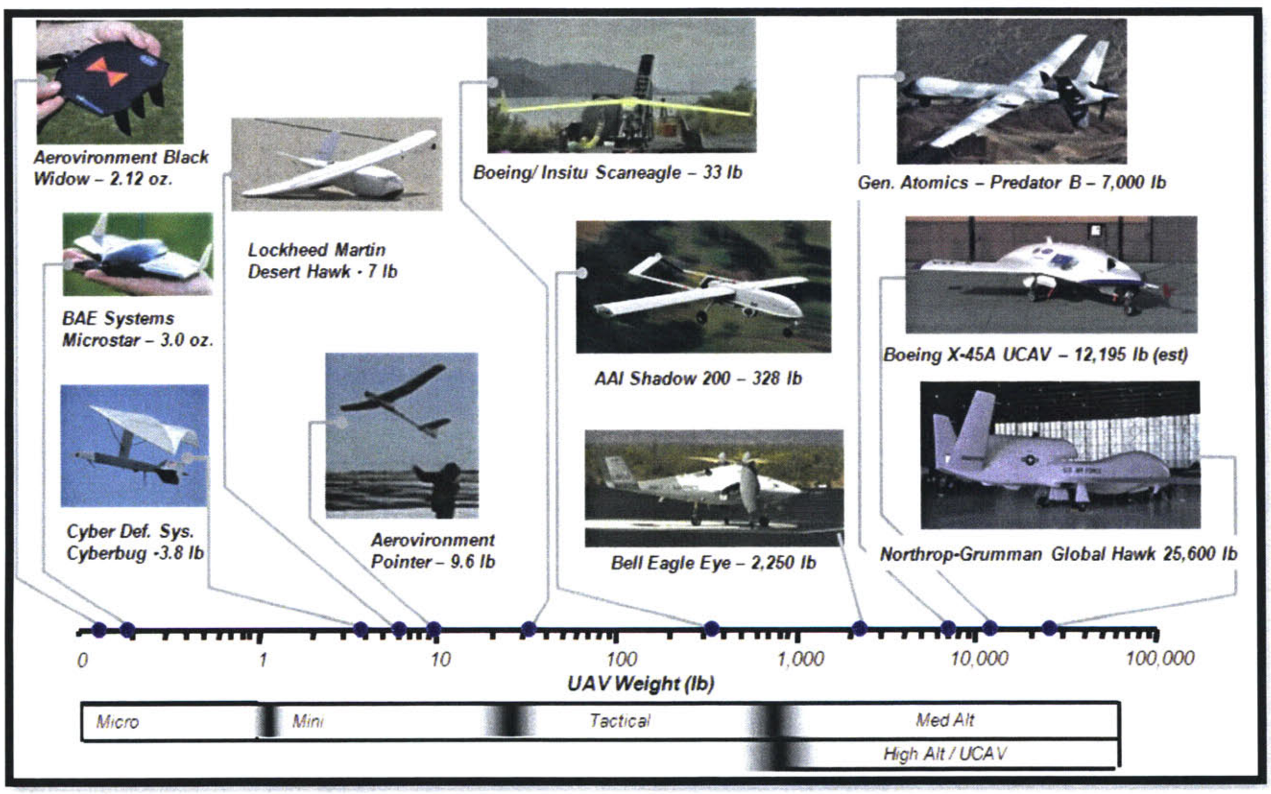

Figure 19: UAS Spectrum by Weight [67]

The U.S military has found UASs extremely effective for reconnaissance, surveillance and target acquisition. They have been used for deception operations, as well as maritime missions such as naval fire support, over the horizon targeting, anti-ship missile defense and ship classification. Growing fields of use as the electronics systems grow in complexity, but shrink in size, include electronic warfare and signals intelligence. UAS also facilitate special psychological operations, radio and data relay functions. They have successfully accomplished meteorology missions, battle damage assessment, and payload transport [31].

These core capabilities apply directly to many of the civil applications proposed. Wild fire suppression missions where UAS are equipped with infrared sensors to detect forests fires can notify ground stations and/or deliver fire suppression chemicals. Customs and Border Protection (CBP) are looking at utilizing UAS for border interdiction where they can be utilized to patrol land and sea boarders. Search and Rescue for ship and aircraft accidents is a direct transition from the military's use of UAS for battle damage assessment. Communications relay, HALE UAS could be used as satellite surrogates during emergencies such as hurricane Katrina when most of the infrastructure has been destroyed. They can also provide aerial platforms for cameras and real time surveillance in events such as earthquakes, disaster and emergency management. Research of environmental and atmospheric pollution is also a viable application given the appropriate payload. Industrial applications such as crop spraying, nuclear plant surveillance, and vessel escorts have also been proposed [65].

Customer Needs, Diffusion and Adoption

The evolution of customer needs in this context is both constant and expanding. Even from their first use in 1849, UASs have provided military units with the ability to enhance their application of the principle of maneuver. Not much has changed in the past 160 years from that standpoint. The military is still using UAS assets to augment their ability to "take the high ground," to locate the enemy, and use that collected information to create tactical and strategic advantages on the battlefield.

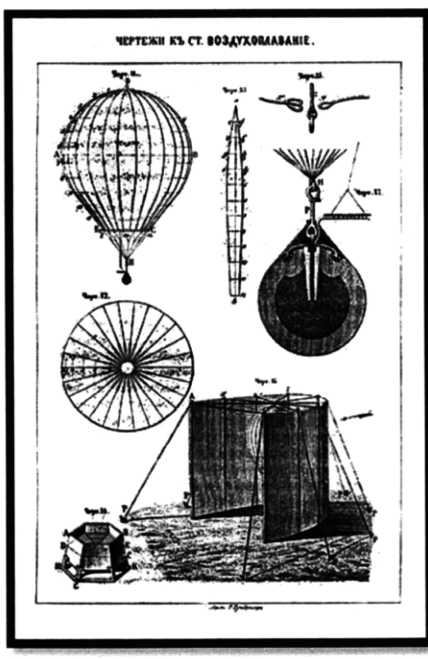

Figure 20: Schematic of Austrian "Balloon" Bombing Device, 1848 [68]

While the overall intent or need may not have changed considerably in the military context (at least from an operational perspective), the customer's expectation for how that need will be met has evolved tremendously from those early days in 1849 when the Austrians were using balloons to bomb Venice (See Figure 20). The degree of control, precision, and speed with which modern battlefield commanders expect and anticipate the information needed to enable maneuver warfare strategies and tactics in the 21st century are orders of magnitude beyond what they were even 25 years ago.

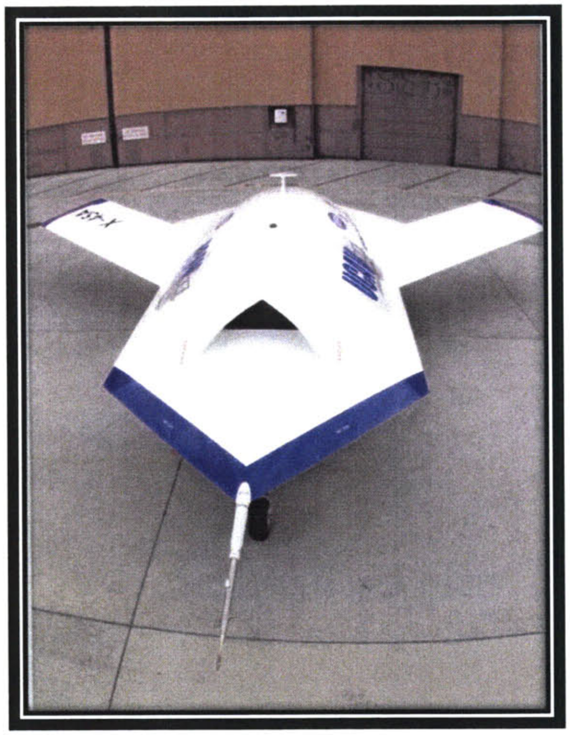

Figure 21: Picture of the X-45 Air Vehicle 1 Test bed [69]

A basic understanding of this difference in customer expectation in the delivery or service of the need to maintain the advantage of the principle of maneuver can be obtained by a simple comparison between Figure 20 and 21. In contrast to a fairly well developed and documented evolution in the military segment, the civil government and commercial sectors are just beginning to recognize to the possibilities UASs could bring to their efforts.

The key elements in the diffusion and adoption of UAS were tied historically to three critical aspects in the UAS technology development arena: automatic stabilization, remote control, and autonomous navigation. The important point to note here is that UAS diffusion and adoption was limited primarily by technological capability and not by military doctrine or operational strategies and tactics [70]. As each of these technological hurdles was overcome, the use of UAS continued to expand into broader fields of application. By 1918, the stabilization issue had been resolved and the first successful flight of a powered unmanned aircraft occurred. By 1924, a UAS could be commanded with a significant set of remote commands, and by the 1930's their use had expanded significantly in the target drone arena. The German's made headway with rudimentary navigation for V-1 rockets in World War II, and the inertial navigation system that was perfected in the 1950's allowed the full potential of UAS assets to be realized.

The last five years in particular have seen a massive diffusion and adoption of UAS into mainstream military operations, and the expansion into additional mission sets and operational scenarios shows no sign of slowing in the immediate future. The use of UAS in the broader civil sector has not been nearly so rapid, due primarily to the regulatory hurdles associated with flying these platforms alongside piloted aircraft in the civil airspace. In a sense, this regulatory requirement could be viewed as the fourth, and final, key element in UAS adoption and diffusion. Unlike the first three, however, this last element is a complex and interwoven set of policy, procedural, and technological issues. Once it is solved, there will literally be a floodgate of UAS applications unleashed in the civil arena [2].

Technology Stages and Episodes in Evolution

As discussed previously, there are three markets for UAS technology, which include the military, civil government, and commercial uses. UAS technology is mainly prospering in the military community versus other markets due to its successful use in the first Gulf War and its continued success, expansion, and value added in the current conflicts in Iraq and Afghanistan. The United States is leading in the UAS technological innovations and employment but ironically the current restrictions on flying UAS in the National Airspace greatly hinder further progression in the civil and commercial markets. As a result, the civil and commercial markets for the UAS evolution are still in the *early ferment* phase due to the current obstacle of airspace restrictions and hesitant investors who are not comfortable in moving forward on such a costly technology with a lack of data to support success [71]. In contrast, the current stage of evolution for the UAS appears to be transitioning from the *early ferment* stage to the *dominant design* stage in the military market due to recent advances in computer technology, software, navigation, data links, sensors, and light weight structural components [2].

Some dominant designs have possibly emerged in several of the UAS categories. Based on the Abernathy and Utterback dynamic model of innovation criteria, a *dominant design* emerges when the number of companies entering the market is at its peak [72]. Examining the entrance and exits of companies involved in the UAS market (depicted in Figures 22 and 23) reveals that the peak number of companies occurred in 2000.

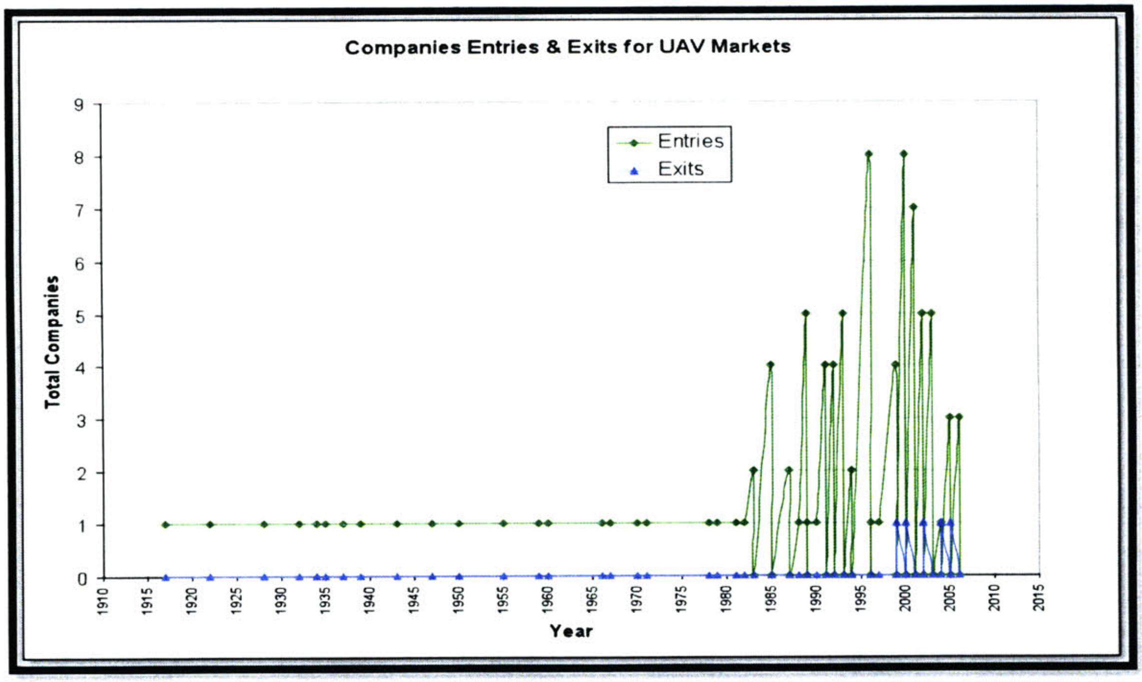

Figure 22: UAS Companies Entry and Exit Market Activity [73]

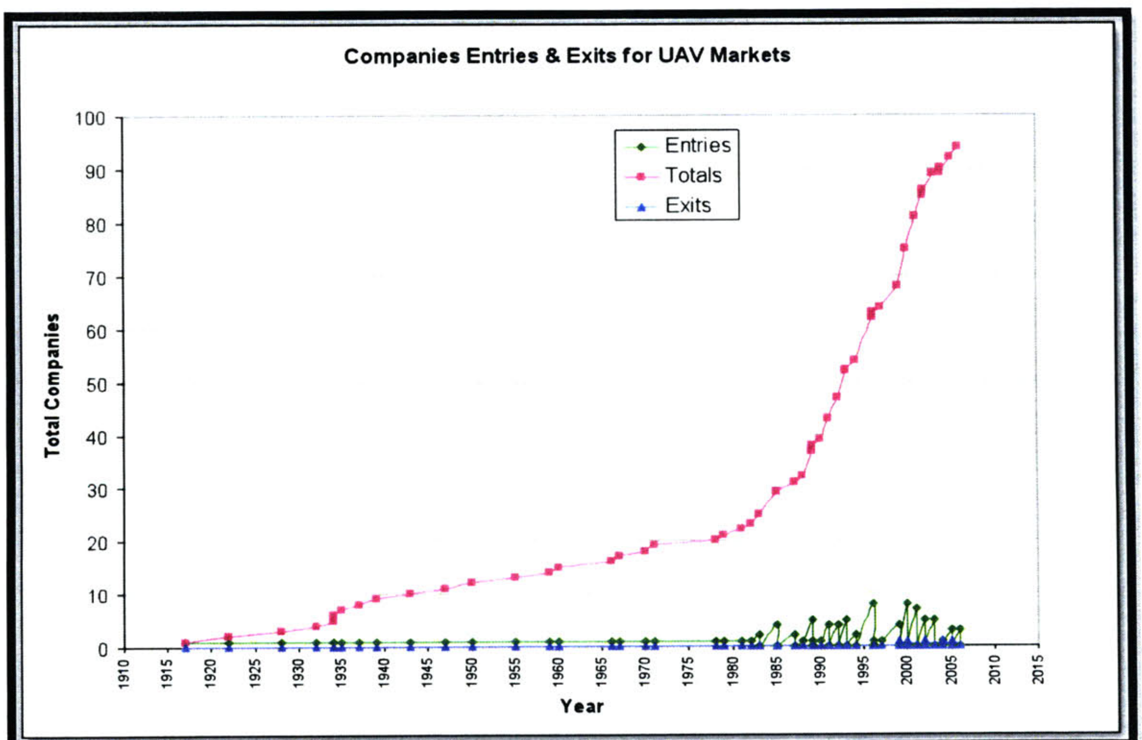

Figure 23: UAS Companies Entries, Exits, and Totals [73]

The chart in Figure 23 demonstrates that the UAS market exhibited a *Fluid State* pattern between 1980 to approximately 2000 at which time in the year 2000 the number of companies peaked. However, between 2000 and 2006, the number of new entrants into the UAS market began a decline which may suggest that the market is in transition and moving to the *Transition State*; an indication that a dominant design may have emerged or is beginning to emerge in each UAS category in accordance with both the lifecycle of innovative markets and the Utterback model [74].

Along with the metric of number of companies entering and exiting the UAS market, other objective parameters that characterize each stage in the lifecycle of the UAS include: the number of UAS designs by category and companies associated with those designs (Figures 25 and 26), the number of patents and scientific journals (Figures 24, 25, 26), the UAS R&D spending/forecast (Figure 1), number of flight hours (Figure 27), safety records/number of mishaps, and cost of procurement/operation (Figure 2). Evaluating the various trends and changes of these metrics throughout the life of the UAS technology will indicate the innovation trajectory, rate of adoption of the technology, and movement between early ferment, dominant design, incremental innovation, maturity, and eclipse/renewal stages [71]. Furthermore, the three different markets of military, civil, and commercial will most likely experience these stages at different times with the military in the lead and civil and commercial markets running generally parallel to each other, but behind the military market.

There are a host of available mechanisms that may provide insight into the underlying life-cycle state of UAS technology in each customer segment identified. What will be important in deciphering these indicators is not to get trapped into making analogies between customer segments, but rather going back to the fundamental drivers in each of these segments and understanding what these metrics are saying about how the industry as a whole is moving. This provides the opportunity to reassess mental models, and consider if there are fundamental changes that are occurring that would be indicative of movement from one stage to another.

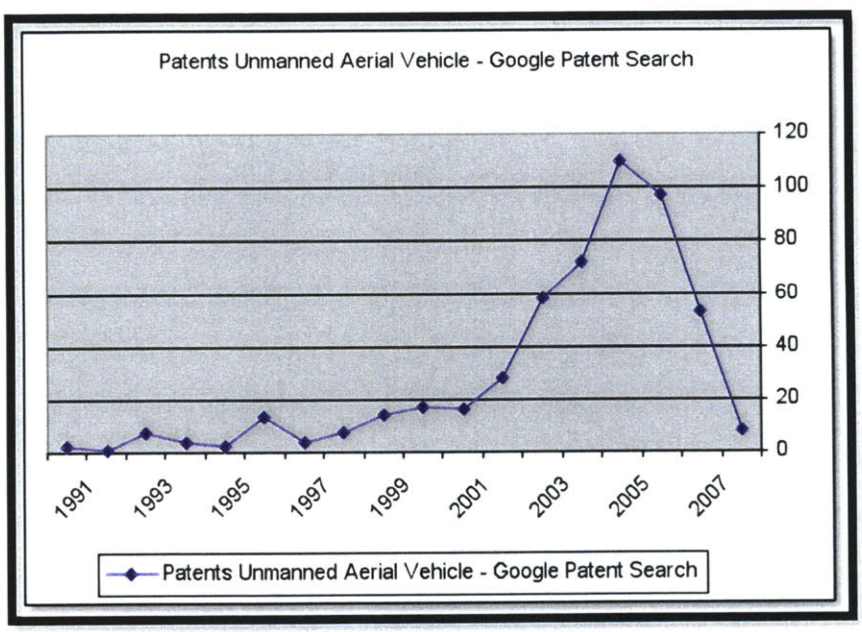

Figure 24: Patents Filed for UAS designs [73]

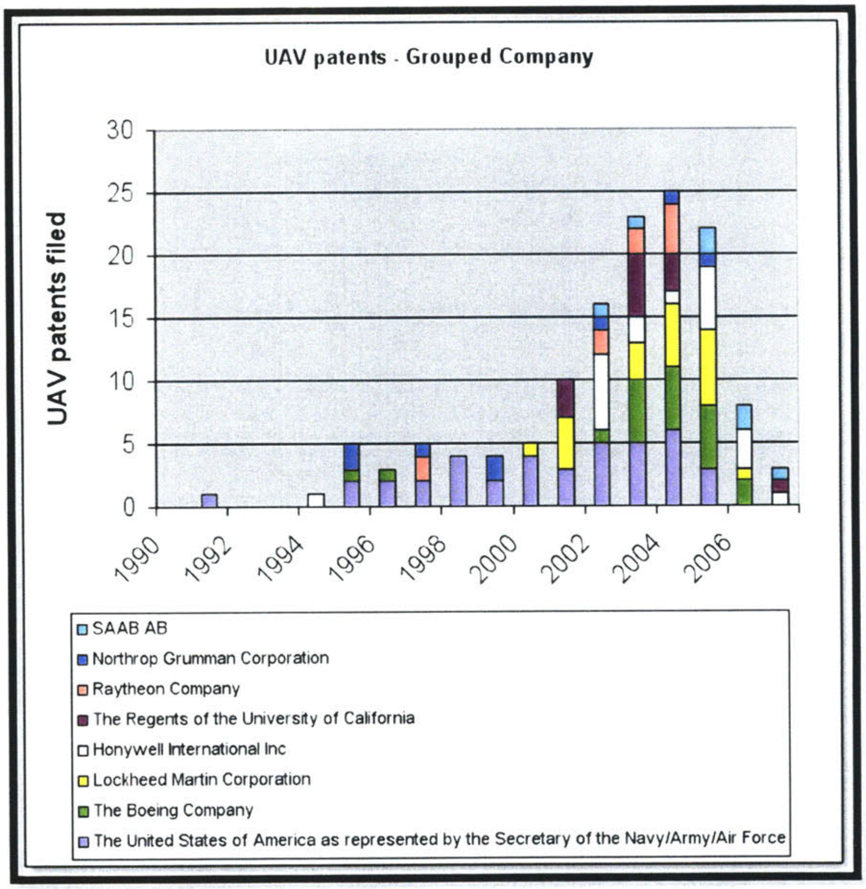

Figure 25: UAS Patents Grouped by Stakeholder [73]

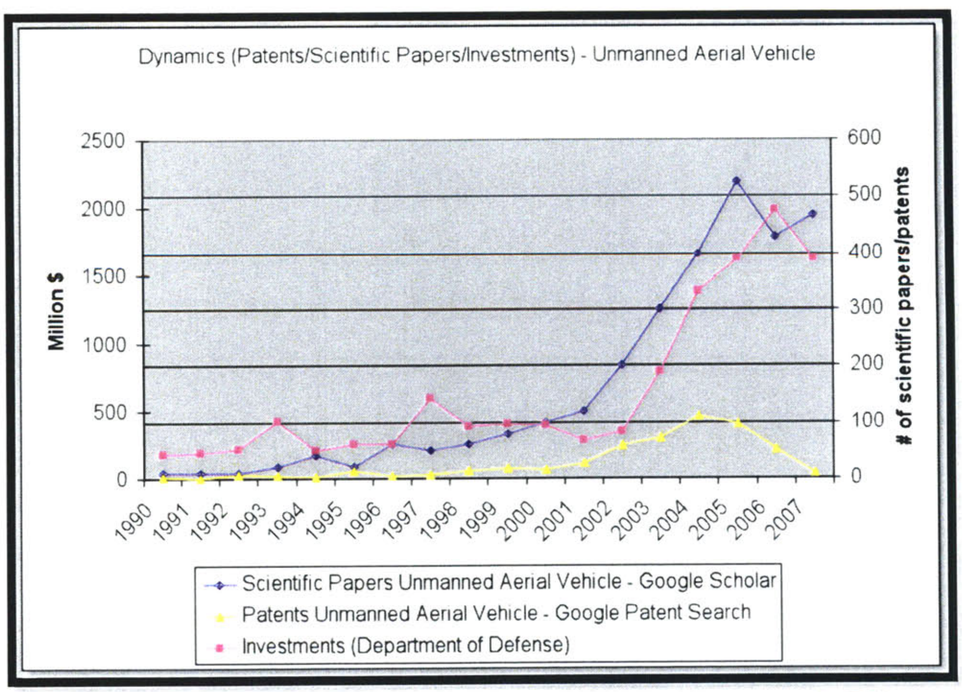

Figure 26: Patents, Scientific Papers, and Investments in UAS [73]

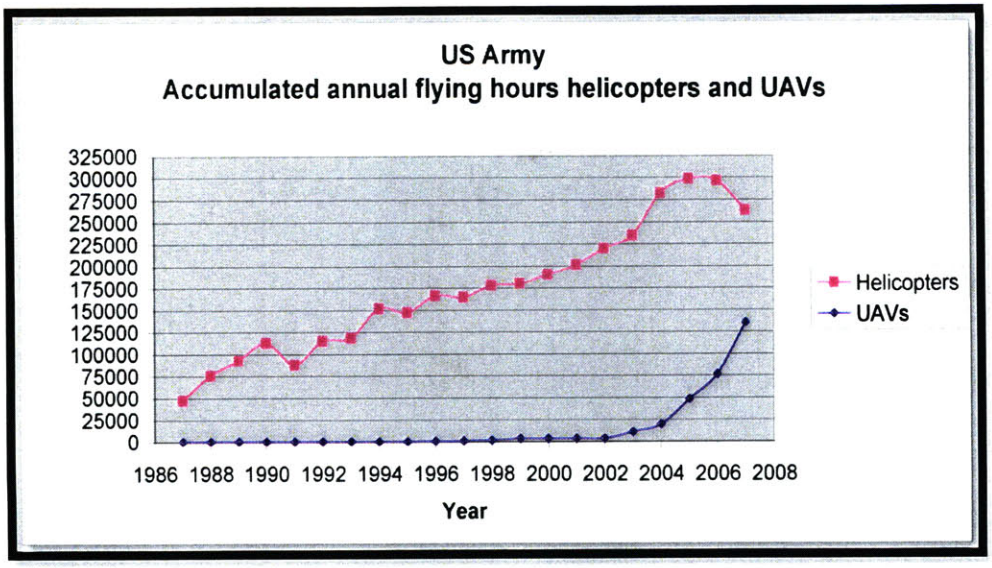

Figure 27: Total Flight Hours per year for Army Helicopter and UAS [16]

Key Niches, Players, and Roles

As presented by Professor Michael A.M. Davies, a *niche* can be defined as follows:

1. *A situation or activity specially suited to a person's interests, abilities, or nature*
2. *The position or function of an organism in a community of plants and animals*
3. *The status of an organism within its environment and community (affecting its survival as a species)* [75].

The key niches within the UAS domain are as follows: aviate, navigate, communicate, operate, safety, and size. The first three niches define the functional requirements of the UAS within the broader context of flight operations, regardless of the type of aircraft being flown [76]. The demands within the UAS flight arena, however, place specific requirements on the expertise and capabilities of a UAS manufacturer to create distributed systems capable of specific levels of performance. The peculiarities of each of these functional domains justify their categorization as independent niches.

The fourth niche, operate, is specific to UAS operations in which the unmanned aircraft is being used as a platform from which to accomplish some other function besides flight through the airspace. For instance, the U.S. military uses UAS extensively as intelligence, surveillance, and reconnaissance (ISR) platforms where sophisticated electro-optical, infrared, or radar sensors are mounted on the UAS and used to collect intelligence information and/or real-time video in the battle space. This functional requirement is completely distinct from the previous three, and it engages a very different set of skills and expertise than the first three functions.

The safety niche is called out specifically because of the prominent role it takes in the broader effort to push UAS into wider civil airspace usage, both from the military and commercial industry. The result is that safety considerations play the dominant role in determining how the ecosystem will evolve, or depending on the scenario, survive. Each of the four functional niches previously described are conducted against this safety backdrop.

Finally, the size niche is distinct because it classifies different market segments, from small toy size to UAS capable of flying at over 60,000 ft and the size of a Boeing 737. These distinctly different niches share some functional similarities, but the manner in which the other niche capabilities (aviate, navigate, communicate, etc) are delivered tend to be driven by fundamentally different technology and business dynamics. As a result, size is categorized as its own niche.

Within the United States, the current UAS ecosystem consists of the following types of players: government customers (both federal and state), industry developers and manufacturers, government research and development labs (and their associated federally funded research and development centers or FFRDCs), airspace regulators, standards development organizations, existing airspace users, academia, and the general public (See Figure 28 below). These same types of players also extend to the international scene, but the leadership in certain categories will shift depending on the country and the topic.

Figure 28: UAS Ecosystem

Leadership roles in each of these categories are played by a number of organizations. From a government customer standpoint, the military services are forging the way ahead on both operational and technological advancement, making strong use of a significant amount of funding ($25B plus annual budgets over the next several years) to shape both the capabilities, type, and number of UAS in use [31]. Industry leadership is less clear; however, significant market share in different UAS classes is readily apparent: Northrop Grumman in the high-altitude, long-endurance segment, General Atomics in the medium-altitude, long endurance segment, AAI in the ~500 lbs weight class, and then a number of smaller corporations producing a large diversity of different platforms at the small UAS end of the spectrum. The Army Research Lab, the Air Force Research Lab, MITRE Corporation's Center for Advanced Aviation System Development (CAASD), and the MIT Lincoln Labs are the dominant organizations in the research and development role as it relates to standards development. FAA UAS Program Office (UAPO) along with FAA UAS Group are the two offices primarily responsible for the airspace regulator category on the government side. The Radio Technical Commission for Aeronautics (RTCA) is leading the standards development organizations. The University of North Dakota and New Mexico State University both have a strong presence in the domain from an academia standpoint. Existing airspace users are represented through strong and vocal participants from the Air Line Pilots Association (ALPA) and the Aircraft Owners and Pilots Association (AOPA) organizations. The public interest is currently under the purview of the FAA's regulatory function, and there are currently no other "home grown" activist groups with specific agendas or issues in the UAS domain.

The Department of Defense and the FAA are the primary organizations shaping the UAS domain. The DoD has significant influence for two reasons: It has a tremendous level of resources against which it is determining the technological evolution of these capabilities, and secondly, under current regulatory conditions, the only authorized operators of UAS in the civil airspace are public aircraft operators—which means that governmental organizations are the only entities to whom commercial industry can legally sell UAS platforms. The FAA is the other dominant influence in shaping the UAS domain through its role as the regulatory agency governing the operation of UAS in the civil airspace. Many on the international scene are also watching the FAA's handling of UAS before taking definitive action on their own, while some countries such as Israel, Australia, and South Africa are moving forward on their own.

Specialist or follower roles are played by just about the entire remaining field of players from those already identified as leaders in their respective fields. See Appendix 1 for a more complete list of actively engaged organizations in the UAS ecosystem.

Business Models and Capturing Value

Because DOD is the primary driver for the UAS technology, two dominant business models for companies delivering complete UAS systems rise to the surface. The first is the classic defense industry business model in which the military provides a request for proposal on a required capability and then awards a contract to a company that provides the best value contract to develop the capability. Generally, a company captures value by underbidding the initial research and development phase. They then plan to be able to make up the difference and profit during the production phase of the effort. They also capture value through sustainment activities in which they contract out to repair and maintain the assets once they are put in the field. The biggest drawback to this type of business model is that the government typically owns a significant degree of the intellectual property that results from these efforts since they fund the bulk of the development activity. On the other hand, the tacit information required to successfully build a design is difficult to acquire for complex systems, and the practical result is that the government rarely changes contractors in mid-stream once it has made an award. This is the business model that was used by Sikorsky in the production and sustainment of the UH60 Blackhawk helicopter, by Boeing in the production and sustainment of the AH64 Apache Helicopter, and by Northrop Grumman in the production of the Global Hawk.

As John Sterman noted in his book *Business Dynamics Systems Thinking and Modeling for a Complex World*, there are many ways of dispersing the up-front costs of development [78]. Examining the model below in Figure 29, it becomes apparent how these firms have gained the cumulative experience, which sets them up for market leadership at the outset (Reference the R3 "Learning Curve" reinforcing loop). "This learning or experience curve has been documented in a wide range of industries from commercial aircraft to broiler chickens" [78].

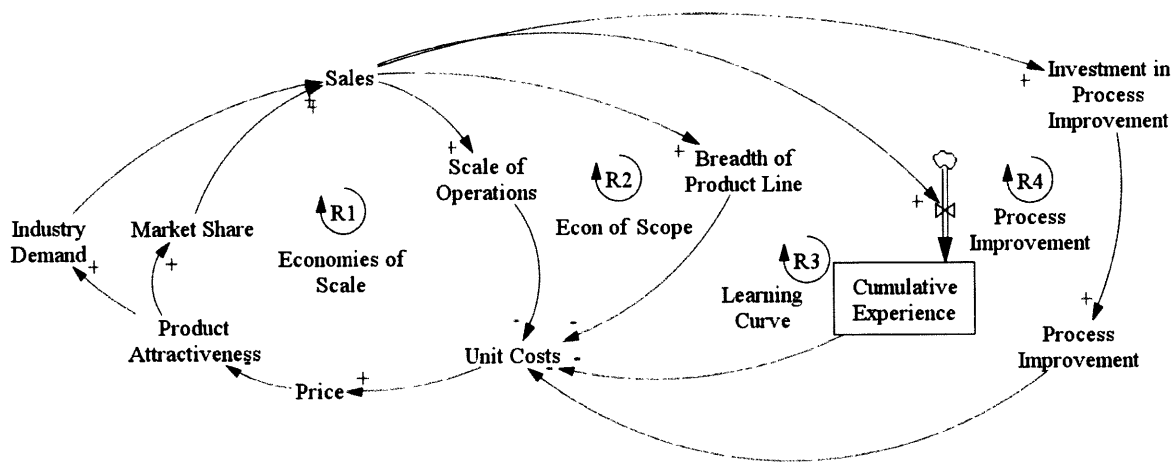

Figure 29: Price and Product Costs

The second business model is one in which the individual corporation has done the vast majority of the development work themselves, and literally shows up on the government's doorstep with a working UAS platform for sale. In this case, the corporation itself owns nearly all of the intellectual property, as well as the risk in developing and marketing the product, so it has a much more secure position with respect to the competition and future designs related to its work. If the government acquires this platform, these companies typically have much higher margins as well, since the government will usually buy the product on a firm fixed price contract rather than the cost plus fixed fee arrangement described under the first business model. The downside is that the corporation's risk exposure is large compared to that taken by the typical defense contractor arrangement. This second business model is much more typical in the smaller UAS domain where the cost of entry is much lower.

Different businesses have failed in the UAS domain primarily as a result of not keeping up with the innovation clock-speed, especially in the small UAS arena [78]. On the small UAS scene, businesses must have a much faster turn-around time on innovation and fielding because the platforms themselves are undergoing such rapid evolution. For this reason, a typical defense contract business model, at least in this segment, has generally resulted in obsolescence rather quickly since companies using this business model cannot maintain the same clock-speed on innovation as a company employing the "build it and they will come" model. The small UAS segment operates in the emergent dominant design stage in the technology life cycle or alternatively, the expansion phase of a business ecosystem, and price is a key differentiator as the available technology on the small platforms becomes more ubiquitous [71].

On the higher end UAS segments, the companies with incumbent status tend to have significant first mover advantages since the cost of entry into the market is so high, and both the speed of innovation and the rate at which the market is moving tends to be significantly slower than within the small UAS segment [79]. At this point, there have been no significant business failures, and the early entrants still maintain an almost total choke-hold in their respective segments. As pointed out in previously, the overall trajectory of the high-end UAS domain is still largely in the early ferment stage, and platform capability remains the key differentiator.

Other Factors

On the high end of the UAS segment (those of medium size or larger), the cost of entry into the market is significant, and the availability of resources is a significant limiting factor in creating a viable alternative to the existing platforms currently in use [80]. There is also a significant amount of intellectual property in the command and control element of these platforms, as different companies attempt to implement more robust and reliable systems with varying degrees of autonomy.

The other major consideration is the issue of compatibility. As the number of assets continues to increase, the switching cost with moving to a different architecture goes up with the total number of assets in use [81]. This is especially true in the sustainment arena. In addition, the ability to interface with the existing ISR infrastructure is critical, especially for those UASs used to collect strategic intelligence. If the data collected from these platforms cannot be seamlessly integrated into the existing tasking, processing, exploitation and dissemination infrastructure, the utility of the asset goes down radically. This is already occurring in Iraq and Afghanistan as UAS and recon/attack helicopters are combined as "sensor-to-shooter" teams in order to rapidly provide and exchange real-time video on the fluid battlefield. Thus far compatibility between sensors, video display, bandwidth, and antennas has emerged as a priority for the intelligence, aviation, and maneuver communities. Compatibility with the existing ISR infrastructure and the ability to use existing ISR tools for exploitation are key elements to UAS functionality. Referring to Sterman's model of complementary goods shown in Figure 30, it illustrates that the interface standards would increase the ability for third party entry with complementary goods [77]. Technology in this "information age" is getting smaller, cheaper and more powerful almost daily. Right now, however, the cost of entry for many possible third party venders at the high-end UAS segment is limited because of the large upfront costs and the relatively "closed" military market. Until the FAA puts out UAS standards, it is unlikely that this situation will change dramatically without a new acquisition program on the part of the DoD.

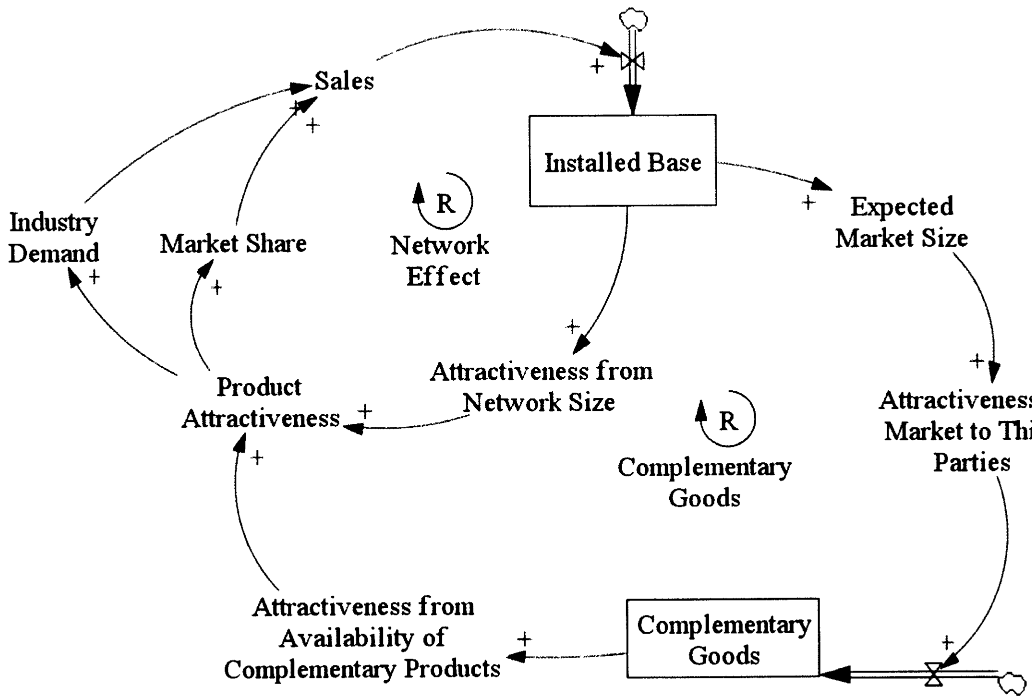

Figure 30: Complimentary Goods Model

Transformation Plan

John Walker, co-chairman of RTCA Special Committee 203, equated UAS integration to the billions of dollars and decades spent fielding TCAS on passenger aircraft. Developing a comparable *sense and avoid* capability for unmanned aircraft will be more difficult than the development of TCAS and require a rigorous systems engineering approach.

> *"The dates keep slipping to the right. The only way we're going to have the dates go to the left is to have industry involvement"*[82]

Technology Innovation: Where to Go from Here?

Understanding how to make sense of one's time and to seize the opportunities it presents is fundamental to the success and growth of a business or industry [83]. Northrop Grumman (NG) is at an interesting position in the UAS technology domain with respect to its posture in the High-Altitude, Long Endurance (HALE) unmanned aircraft system (UAS) market segment. Within the broader scope of the aerospace environment, the immediate context surrounds their UAS product line and the direction they should take technology development efforts. Should NG look to extend its position within the defense aerospace sector by focusing on the unmanned air combat vehicle (UCAV) development effort by the Navy? Or would it be more profitable to drive evolutionary developments by building on the success of the RQ-4 Global Hawk platform and their recent win of the Navy's Broad Area Maritime Surveillance (BAMS) contract, leveraging their experience with the HALE mission? Alternatively, they could also bolster the efforts of the UAS industry as a whole in expanding the realm of UAS markets by aggressively pursuing and aiding in the development of the appropriate equipage standards to access larger government and civil markets with their technology. These scenarios, depicted in the illustration below, can be categorized generally as new defense aerospace markets (UCAV), consolidation and expansion of existing defense aerospace markets (HALE and MALE), and non-defense or civil markets.

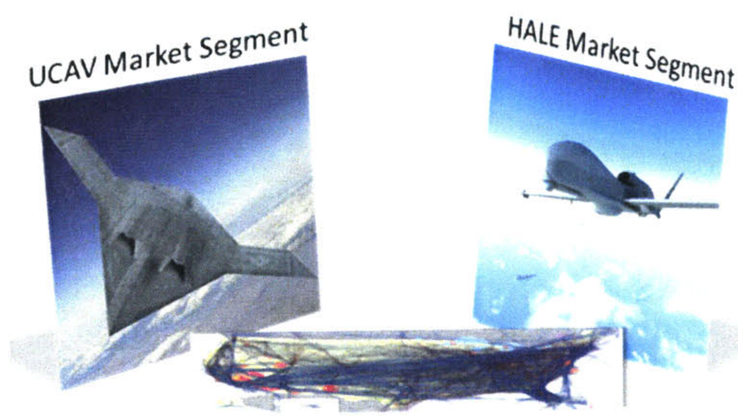

Figure 31: Potential Market Investment Opportunities for Northrop Grumman [84]

To get to the bottom of these questions, both the demand opportunity and the technology evolution and trajectory must be assessed. First, it is critical that the demand environment be appropriately characterized for each of the three scenarios represented in the three questions raised in the above paragraph. The UCAV market segment is considered to be an area of future growth in the defense aerospace market segment, and one that many believe will ultimately replace the manned bomber mission as the technologies continue to mature. The largest uncertainty with the UCAV development effort is the long-term viability of the program itself. Without getting into the history of the effort, the current situation has pitted NG and Boeing Company against each other for what is sure to be a long, drawn-out acquisition program with the Navy for a carrier-based UCAV capability that provides long-range, high-endurance, and low observable intelligence, surveillance, and reconnaissance (ISR) capability to the fleet. Current estimates put the expected number of total systems at around the 70 aircraft mark [85]. NG was awarded one of the N-UCAS development contracts for a total of $637M, responding to a Navy Request for Proposal (RFP) worth a total of $1.9B over the next 6-year technology demonstration program [86].

The UCAS effort is squarely within the *early ferment stage* of technological development and NG would need to pursue an aggressive architectural or potentially radical innovation strategy to be successful in this effort against Boeing [71]. In contrast, the technological innovation required for improving on the existing Global Hawk and BAMS product line would shift the focus to an incremental or potentially modular innovation effort (See Figure 32 below). In addition, the higher degree of maturity in the Global Hawk technology puts the overall effort further along the trajectory evolution path, with the emphasis shifting from providing purely functional capabilities housed in highly integrative designs to a more incremental innovation approach that capitalizes on NG's apparent dominant design with the Global Hawk.

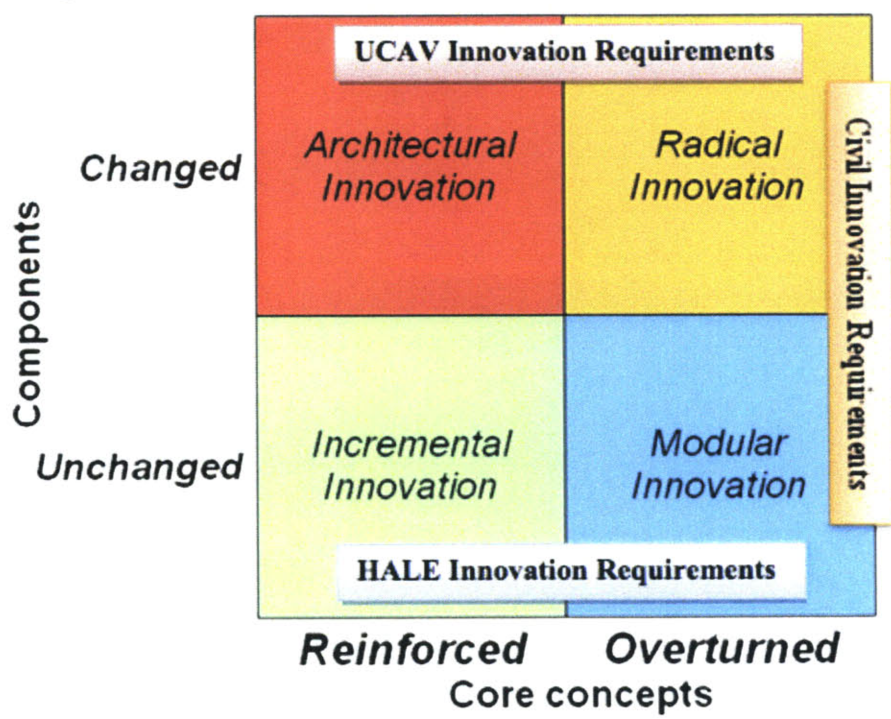

Figure 32: Types of Innovation Required with Respect to Various Market Segments [71]

With the award of the BAMS contract, this also puts NG in a position to begin a "descent" into the Medium Altitude, Long Endurance (MALE) market segment dominated up to this point by General Atomics with the MQ-1 Predator and MQ-9 Reaper. In contrast to the UCAV market segment, the HALE market segment is currently exclusively dominated by NG, and at least in the immediate future, their position in this segment appears to be safe from any significant threat from one of the other major defense aerospace contractors (assuming that Lockheed Martin's protest of the BAMS contract award is unsuccessful). The biggest question is what the demand opportunity is if NG stays in the HALE niche, even if it tries to expand into the upper end of the MALE segment. The BAMS contract is worth $1.6B over an 89-month contract period to take the program through system design and development (SDD) [87]. Total expenditures for the full complement of 68 systems are budgeted for approximately $3B [88].

The third market segment is the non-defense aerospace sector with an expansion into other governmental markets and beyond that into the commercial arena. This market segment is completely uncharted territory and is unlikely to see any major penetration for some time to come. The size of this market is difficult to estimate given the lack of any good analogous information from anything other than the defense aerospace domain. Initial looks into various niches of this broader market suggest orders of magnitude size differential in this segment than those just cited for the defense sector (See Figure 33 for methodology on understanding UAS markets within the civil airspace structure. For instance, in the small UAS segment, the law enforcement application market potential was estimated at $3.5B, and this represents just a single niche within one segment of UAS applications (NG also has highly successful UAS platforms in the small UAS market segment, including the Hunter and Fire Scout) [89].

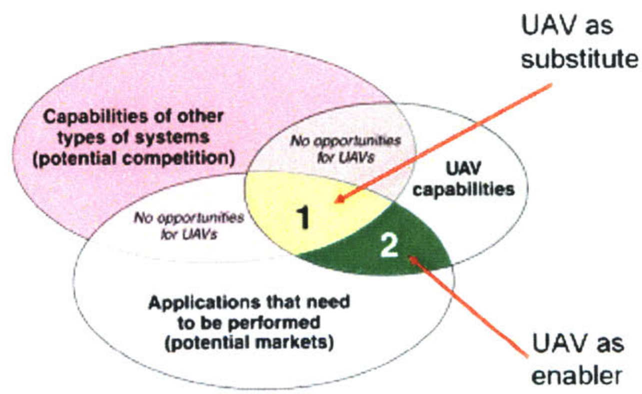

Figure 33: Targeting Civil Airspace Markets for UAS Applications [90]

Given the access, the civil market potential is easily in the tens of billions of dollars with significant headroom to continue to grow as the technology drives down cost and brings performance up. The major hurdle to market penetration is the lack of FAA UAS type certification standards for commercial UAS use. Without type certification standards, UAS providers are limited to selling UAS platforms to self-certifying, public aircraft operators like the DoD. Sales of UAS for civil and commercial applications cannot be done legally until the FAA establishes the appropriate type certification standards and then provides the needed certifications to requesting UAS manufacturers. Estimates on the publication of these standards range from 2015 to 2025 depending on the scenario used and assumptions made about the political and national security context within which the FAA operates the National Airspace System (NAS) [91].

Clearly, the long-term payoff and market growth potential is within the commercial and civil applications sector. Access to this untouched market space will be an arduous process that will require a significant degree of insight into the broader UAS ecosystem and the value propositions each of the major stakeholders have in bringing this market into play. A bold, well-played move on the part of NG in this arena could pay dividends in the future that would make the UCAV and HALE/MALE defense sectors look insignificant in comparison.

Building the Ecosystem

So what does NG need to implement in order to break into the civil market segment and capture significant value for their efforts? First and foremost, NG must realize that it requires a long-term perspective on the growth potential in this market segment. The work done over the next 5 to 10 years will not show up in positive quarterly earnings statements for some time to come; however, the ground work that is laid for establishing a viable civil UAS ecosystem will provide intangible benefits in the future that will be difficult if not impossible for competitors to match once the market finally opens up [92].

A key piece to building this ecosystem (see Figure 28 for UAS ecosystem) is to identify the other key players and a transition path out of the current defense sector ecosystem into the new one. The differences in these environments could scarcely be more diverse. In the DoD environment, performance is paramount, and a significant amount of budget and schedule will be traded away to get the last ounce of weight, speed, or range out of a design. Safety considerations, while important, take a back seat to mission capability and effectiveness. The civil environment is a different dynamic altogether. In fact, if the defense sector is likened to a heavily forested landscape with plenty of "cover" in which to continue pushing the technology, the civil environment is a veritable desert for the high degree of exposure it leaves the inhabitant to the scrutiny and judgment of the existing civil airspace players.

The dominant presence on this civil landscape is the FAA. Their role as the regulator of civil airspace puts them in a unique and powerful position with respect to the strategy NG will need to pursue if they are to successfully penetrate this market. In addition to the FAA, the NG plan will also need to address a myriad of other players, including existing civil airspace user lobbying groups like the Air Line Pilots Association (ALPA) and the Aircraft Owners and Pilots Association (AOPA). The dearth of standards will also require active engagement with various standards writing bodies like the RTCA, the federal advisory committee to the FAA on proposed rule changes. NG will even need to build relationships with other UAS manufacturers and equipment providers that may on the surface appear to be direct competitors in this market space. This would include companies like General Atomics, Raytheon, Sierra Vista, and others that may have similar motivations for seeing the civil airspace opened up for commercial UAS use.

The one consistent element in the transition across this landscape from the defense sector to the commercial environment is the DoD. Surprisingly, perhaps, the DoD has a keen interest in seeing UAS flight capable in the NAS. (See Figure 34 below for historical and projected growth of DoD requests for UAS access to the NAS). This provides a strong alliance and a technology/funding bridge that NG may be able to leverage to their advantage in establishing themselves in this new ecosystem. Having the DoD in the mix is not to be underestimated in considering the challenges associated with trying to build a UAS presence in the civil airspace ecosystem. There is intense competition for resources within this arena (both in terms of air traffic services and access to airspace), and incumbents see the UAS capability itself as a program that will suck resources out of the entire system.

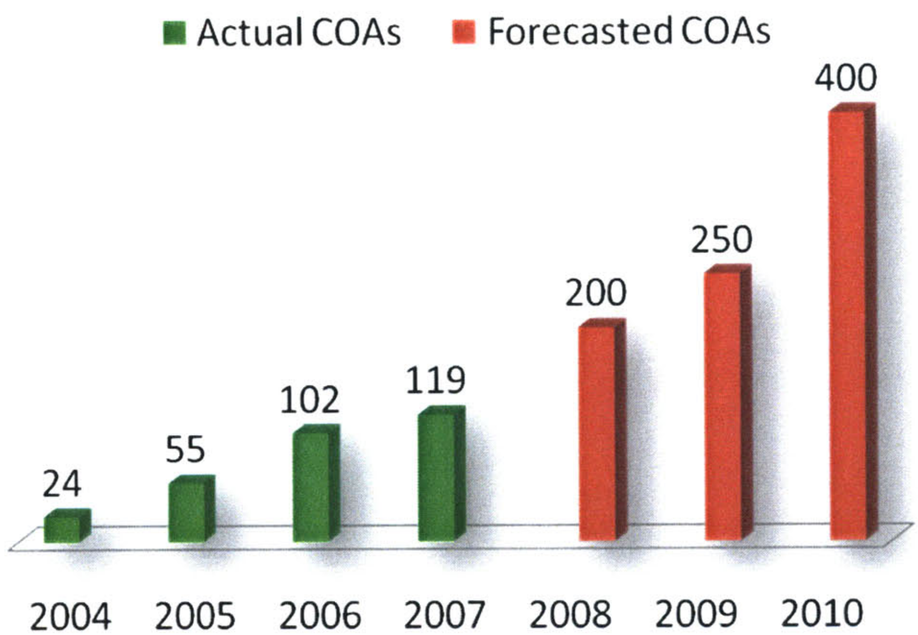

Figure 34: Actual and Anticipated Requests by the DoD for UAS Access to the NAS [31]

In addition, there are a whole host of market niches (See Figure 35) that see the UAS as a potential disruptive technology in their area of application because the UAS may be able to provide comparable or better performance at significantly lower costs [63]. A major component to a successful UAS transplant in the civil ecosystem will be a well-planned, symbiotic relationship with the DoD, and solid alignment with a targeted civil UAS application niche that provides a way to establish a foothold in the broader civil airspace.

Figure 35: Potential UAS Applications and Market Niches [93]

The key considerations in light of these factors devolve primarily down two specific lines. The first set of issues deal primarily with how NG relates to the FAA and the DoD in attempting to build out the UAS civil ecosystem. The second pertains to the lateral and downward focused relationships needed with the rest of the ecosystem players for the effort to be successful. As might be imagined, these two arenas are highly coupled, and the constraints in the first set of considerations will drive to a significant degree the strategy that will be recommended in the second. These two sets of considerations can be thought of within the frameworks of creating value versus capturing value.

Value Creation

Value creation occurs across the domains of demand opportunity, business ecosystems and technological infrastructure [94]. The primary consideration for NG in the area of value creation is how to go about delivering what is important to the decision makers holding the keys to civil airspace access for UAS, primarily the FAA. Prior work accomplished in the area of FAA value definition with respect to flying both military and civil UAS in the NAS very clearly established the need for safe operations as the most critical factor in the FAA's considerations [55]. This value priority with the FAA is depicted in Figure 36.

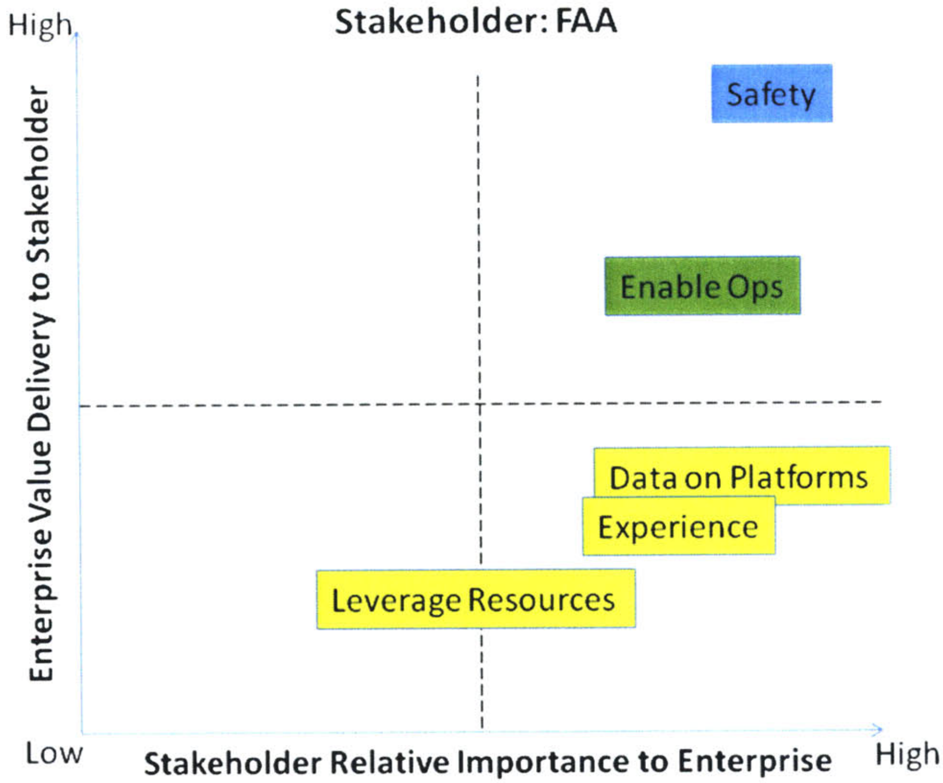

Figure 36: FAA Value Delivery and Importance in UAS Operations

The single largest barrier UAS face to the safety challenge is the ability to *see and avoid* other aircraft, as defined in Title 14 Code of Federal Regulations, Chapter 1, Part 91—General Operating and Flight Rules. Essentially, the FAA wants assurance that a UAS will have the ability to comply with this part of the regulations despite no longer having a pair of human eyes and the brain that accompanies it in the aircraft. There are significant technological and legal challenges intertwined in this topic, and both sets of issues must be resolved before the FAA's value proposition will be sufficiently addressed to warrant opening the civil airspace up to commercial UAS use.

The technological piece required for the *sense and avoid* capability is the ability to sense other aircraft on or in the proximity of the UAS flight path, determine the potential for a collision, and then take the appropriate evasive maneuver to ensure that a collision does not occur. This must be accomplished in all flight conditions for which the aircraft is certified, and it must be capable of performing its function even when command and control links may have been lost with the ground station, implying a level of autonomy in the flight control system that has never been required or tested—at least as flight critical hardware and software. Figure 37 provides the overall structure and considerations that must be addressed in the civil airspace environment.

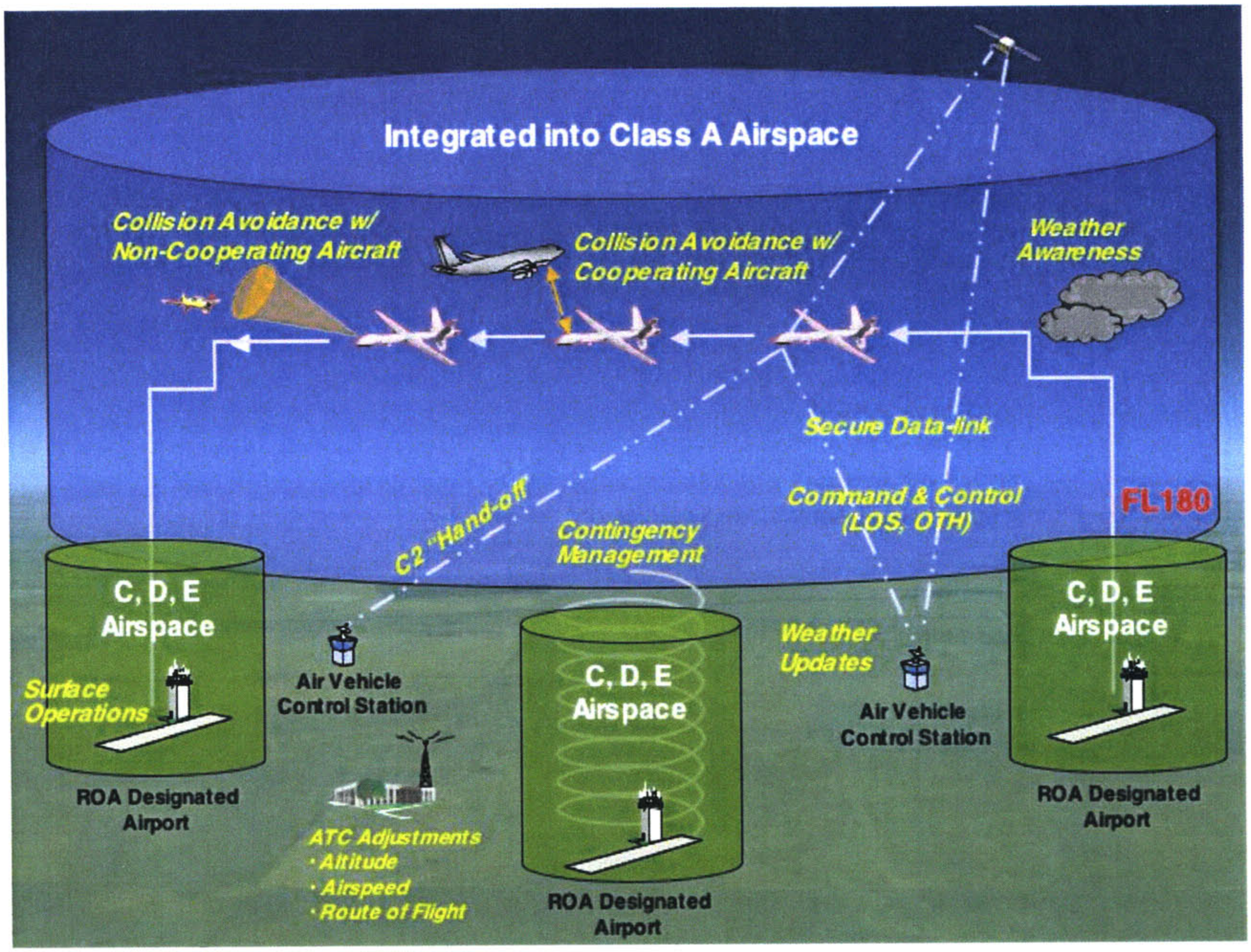

Figure 37: Overview of Civil UAS Operational Requirements [76]

The legal issues pertain to the development, implementation, and "ownership" of the collision avoidance algorithm by which the UAS will determine which actions to take for the avoidance maneuver described above. Current collision avoidance systems aboard passenger aircraft employ a system that was developed, tested, and mandated by the FAA under Congressionally mandated requirements and at a cost of billions of dollars. These piloted aircraft collision avoidance resolution advisories provide simple climb or descend instructions to the pilot who then determines whether the course of action prescribed by the system is appropriate. The FAA owns all of the liability associated with the proper functioning of these algorithms. In the UAS case, no such ownership currently exists, and the FAA has not been funded by Congress to move forward and develop an equivalent set of avoidance algorithms for UAS use.

Fortunately, developing solutions to these two very difficult challenges does not have to be done by NG attempting to "go it alone." In fact, if done correctly, NG should be able to leverage many of the previously mentioned contracts in place with the defense sector to underwrite significant portions of this work. The Air Force already has several million dollars in contract with NG to begin exploratory work on a true *sense and avoid* capability for Global Hawk, and it has budgeted upward of $80M over the next four years to attempt a prototype implementation of an *sense and avoid* system. In addition, the BAMS requirements document put out by the Navy also includes the ability to do integrated airspace operations as a key performance parameter. Both of these venues give NG a significant leg up on the competition when it comes to a funding stream for sorting through the technology development challenges described above.

In addition, NG has also established strategic research and development efforts with the Army Research Laboratory and the Air Force Research Laboratory (AFRL) to expand the current flight control algorithms to accept inputs from other feeds into the autopilot routines. An initial set of tests were conducted with the FAA's participation back in the Summer and Fall of 2007, which tested the overall performance of an electro-optical sensor package running a proprietary detection algorithm and connected into the flight control algorithms used by Global Hawk. While the results of the testing demonstrated that a significant amount of work remained before this particular *sense and avoid* architecture would be viable, enough progress was made to convince the Air Force to fund the more significant effort mentioned above. It also provided an opportunity for NG to interface with a *sense and avoid* sensor provider to begin to understand a number of the processing and size, weight and power (SWaP) requirements for this kind of a system. Perhaps the most important conclusion to come out of this series of tests was the realization that a single sensor type would not be sufficiently robust to meet the FAA's safety concerns. This pushed the technology pursuits further afield to address multisensory fusion techniques (Example of this type of sensor suite is shown in Figure 38 below). Interestingly, with the recent emergence of the Army's GBSAA technology, NG could get involved in the Army's efforts with the Shadow UAS as well.

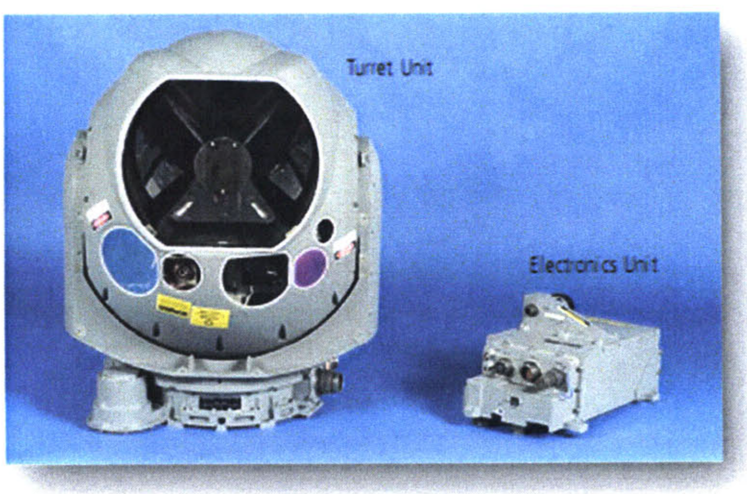

Figure 38: Raytheon MTS-B Multispectral Targeting System [95]

Value creation is also possible for the sensor and algorithm subsystem providers. As additional capability is sought to increase the *sense and avoid* performance, NG continues to investigate other vendors' capabilities for potential applications or solutions. Viable alternative technologies in the electro-optical, infrared, and radar arenas are actively being investigated and pursued. The implementation of a successful *sense and avoid* capability would provide a path for several leading contenders in the sensor subsystem and algorithm processing fields to contribute to advancing UAS platforms into mainstream civil airspace use.

Value creation for NG can be considered as the locus between the demand opportunity represented by the civil UAS airspace market, the on-going work NG is already on contract to perform for both the Air Force and Navy within the military UAS ecosystem, and the technology insights that have resulted from recent R&D efforts with AFRL and several sensor subsystem manufacturers. The final issue is to describe how NG brings that value creation to materialization and captures a significant amount of the profits as the fruit of its labors.

Value Capture

Achieving a significant capture of value in this endeavor will require NG to do a number of things that may be well outside of its comfort zone. Essentially, NG must deal with the issues of *sense and avoid* design and architecture in a way that allows it to balance the competing demands of an integrated vs. modular architecture as it relates to a significant standards development effort. No one wants to "own" the collision avoidance/*sense and avoid* algorithms as a proprietary standard. In addition, NG must be very deliberate about how it creates the *sense and avoid* architecture. As Christensen et al. indicate, NG must stay in the game where significant performance gains are still needed. Christensen makes the following statement with respect to anticipating where the profit is headed:

> *"The power to capture attractive profits will shift in the value chain to those activities where the immediate customer is not yet satisfied with the functionality of available products. It is in these stages that complex, interdependent integration occurs-activities that create steeper economies of scale and greater opportunities for differentiation"* [63].

The implications of the above observations provide a clear path ahead for NG. First, the collision avoidance algorithm should be "open sourced" on the part of NG. They already have a significant position within the military UAS ecosystem with their flight control algorithms and the additional work they have accomplished with AFRL on preliminary collision avoidance algorithm integration. The smartest move they could make would be to offer up their control algorithms to the community as a point of departure for a more robust, community-wide set of algorithms that could eventually be transferred over to the FAA for safe keeping and configuration control, just as the current piloted aircraft collision avoidance algorithms are.

Open sourcing the flight control algorithm opens additional resources up for NG to use in pursuing those aspects of the value chain they do want to own, primarily the know-how to integrate the entire system in a way that satisfies the FAA's demand for safety performance. This is an area where the sum of the parts is almost always greater than the whole. The tacit knowledge NG gains in this area as it develops and deploys initial *sense and avoid* capability on the Air Force's Global Hawk will be both expensive and timely for others to attempt to replicate. NG can also expand its expertise to the Army's efforts with GBSAA and the Shadow UAS. This puts them in a position of inimitability and durability with respect to their end-to-end system integration capabilities and provides them with a distinctive competence that few, if any others will be able to claim. It also gives them potential *first-mover advantages* in the market, which, when coupled with what will likely be a high degree of tacit knowledge, makes it plausible that NG will be able to sustain this advantage for a considerable period of time (See Figure 39) [96]. The advantage they cultivate in the current "calm waters" market condition of the UAS civil. The advantage they cultivate in the current *calm waters* market condition of the UAS civil segment, however, will have to be jealously guarded by continuing investments in the appropriate technology as the market opens up and the dynamic shifts to a *technology leads* market place.

The Situation Your Company Faces	First-Mover Advantage: Short-Lived	First-Mover Advantage: Durable	Key Resources Required
Calm Waters	**Unlikely** Even if attainable, advantage is not large.	**Very likely** Moving first will almost certainly pay off.	Brand awareness helpful, but resources less crucial here
The Market Leads	**Very likely** Even if you can't dominate the category, you should be able to hold onto your customer base.	**Likely** Make sure you have the resources to address all market segments as they emerge.	Large-scale marketing, distribution, and production capacity
The Technology Leads	**Very unlikely** A fast-changing technology in a slow-growing market is the enemy of short-term gains.	**Unlikely** Fast technological change will give later entrants lots of weapons for attacking you.	Strong R&D and new product development, deep pockets
Rough Waters	**Likely** A quick-in, quick-out strategy may make good sense here, unless your resources are awesome.	**Very unlikely** There's little chance of long-term success, even if you are a good swimmer. These conditions are the worst.	Large-scale marketing, distribution, production, and strong R&D (all at once)

Figure 39: The Durability of First Mover Advantage in Various Types of Markets [79]

Given their history in radar sensors, they may also consider the potential for developing a *sense and avoid* targeted radar that is specifically designed to address the size, weight, and power (SWaP), and performance needs of the *sense and avoid* space. Current radar technology has been tuned for significantly greater ranges. There are currently no viable low-SWaP radars capable of doing the *sense and avoid* mission. This would also meet Christensen's recommendation to focus on those areas that are currently lacking the required functionality.

In the end, the success of this approach will depend to a significant degree on how well NG can balance the performance needs of the *sense and avoid* system with the advantages that a modular approach may provide to the broader ecosystem, and the resulting relationships that it needs to establish with other sensor providers. This should occur in a phased approach that allows NG to pursue fairly tightly integrated systems initially that then migrate to more modular architectures as the technology improves and additional vendors begin to enter the market. Once the FAA finally approves the standards, there will be a massive wave of new entrants into the market space. If NG has not already transitioned to a modular approach for significant sensor providers, it will face the very real possibility of losing much of the market share to faster moving, smaller companies. A modular approach, while providing upfront performance challenges, provides for a relatively quick and cheap way to "plug-and-play" different components in the architecture should one fail, or another becomes available that is cheaper or does the job faster. As a result, NG must establish and build the relationships that will help it preserve its unique market position as the ecosystem leader by providing the motivation and mechanisms by which other subsystem vendors can find niche markets and establish enduring relationships.

The final point to be made with respect to the modularity of the *sense and avoid* architecture decision is the fact that the FAA evaluation approach will make doing highly integrated *sense and avoid* systems a much more costly way of attempting development. Without a modular architecture, it will be difficult, if not impossible, to decouple major elements of the system in order to isolate the root cause of a problem. Beyond that, it will require the redesign of the entire system to fix a shortfall or deficiency with the product. A modular approach, while providing upfront performance challenges, provides for a relatively quick and cheap way to "plug-and-play" different components in the architecture should one fail, or another becomes available that is cheaper for does the job faster.

To provide the needed overall direction and strategy to the effort, NG should employ a *simple rules strategy* that focuses on a couple of critical processes and relies on a set of standard criteria against which to make design and implementation decisions [97]. This approach works well when there is a significant amount of uncertainty in the way in which the environment will develop, and it provides a good match with recommendations for how the FAA and the DoD themselves should consider addressing this issue [98]. By establishing a set of clear guiding criteria for making resource allocations and design decisions, NG will put itself in a place where others will begin using the same set of criteria, fostering a greater degree of unanimity in the approaches and implementation paths taken in the community. By instituting several critical processes with the FAA, DoD and other SAA subsystem providers, NG can stay on top of the coordination and R&D game between interested and concerned parties.

Recommendations

To take full advantage of its current position on the HALE UAS defense sector, NG should implement a pioneering approach to tackling the lack of FAA type certification standards. By stepping up to provide a catalyst in the UAS civil market arena, NG has the potential of seeing significant first mover advantages, as previously described. Specifically, NG should carefully consider the move to putting its algorithm for flight control out in the open source community to help foster transparency and begin the process of building to an industry wide standard. They should leverage their existing work with the DoD to build their core expertise around the end-to-end integration of systems, and pursue the subsystem design for specific sensor technologies where it already has a strong presence, such as that for radars.

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Section 4: Conclusion

Leadership for Success

Context based leadership involves a lifecycle of opportunity structure spanning from entrepreneurial, managerial, and leadership personnel. Each represents the early phase, growth phase, and declining phase respectively of the traditional lifecycle of business opportunities [99]. Companies within the airline industry parallel this traditional lifecycle. In fact, many of the early industry leaders were "larger than life" executives who helped create the foundation of the entire industry [100]. As dominant business models emerged, a different type of executive was attracted to the industry – those who could assist in the growth and maturity of the airline industry. Moreover, the airline industry now dictates that it requires leaders who can reinvent the business model and focus on realignment, restructuring, and cost management.

The airline business is an interesting example of an industry that has evolved as a result of not only just the technological evolution of aviation operations but also the interdependencies of the various leaders and the contextual factors. Interestingly, the emergence of the UAS industry and the pursuit of their integration into the NAS appears to follow a similar trend in that leadership is a significant factor for the business evolution. Furthermore, the UAS technology is currently in a growth phase yet the actual operation of UAS is within the early phase of the traditional lifecycle. However, since the UAS industry is emerging within the well-established aviation community, UAS operations may push commercial airline operations through a regenerative lifecycle as opposed to a complete decline. The majority of the current stakeholders and leaders within the UAS community are also heavily involved in the commercial aviation community. As a result, leadership roles are played by a number of organizations. The military services are forging the way ahead on both operational and technological advancement, making strong use of a significant amount of funding to shape both the capabilities, type, and number of UAS in use [31].

UAS technology is quite advanced with some dominant designs beginning to emerge. Professor Anthony Mayo makes the following observation with respect to the industry evolution of the airline industry, which directly applies to the development and evolution UAS industry:

> *"During these intense inflection periods within industries, leaders emerge to make sense of the chaos and define a new business model that is more aligned with the changing contextual landscape. This model may have the potential to become the new dominant business model, or alternatively, it may set the stage for a parallel opportunity for success. Leaders reintroduce variation and change into the stability of the past to create new opportunities for success, and in so doing they help to regenerate the lifecycle of the entire industry"* [100].

The hindrance to the UAS industry is access to the commercial airspace, which requires managerial activity to ensure efficiency and standardization as opposed to the entrepreneurial activity normally associated with an industry in its early phase. Much of this is due to the rapid technological advancement of UASs, their implementation into military operations due to global events, and a lack of access to the tightly regulated aviation market and airspace. The technology is ready, but the process is not, so a managerial leader with a touch of the entrepreneurial spirit from a well-established aerospace business will help forge the integration of UAS into the civil and commercial markets and continue to promote innovation throughout the entire aviation industry.

Final Thoughts

Enterprise architecture is a holistic way of thinking which is essential to modern enterprises, such as the National Airspace, that have highly interconnected systems. It is necessary to integrate management processes, lifecycle processes, and enable infrastructure systems. Furthermore, enterprise architecting balances the needs of multiple stakeholders working within and across boundaries and enables a full understanding of the value exchange, expectations, needs, and interactions. Technology in the UAS industry is advancing very rapidly and current military operations provide an optimal test bed for such innovation, which will assist the transition of UAS operations within the civil and commercial markets. Both Enterprise Architecture and Technology Strategy focus on a holistic approach and integrate enterprise strategic objectives, value capture and creation, in a systematic approach to achieve success in a complex, highly technical enterprise system.

History has shown that technological advances associated with military aircraft eventually make their way in the civilian sector [2]. Federal agencies are planning to increase their use of UASs. State and local governments envision using UASs to aid in law enforcement and firefighting. Potential commercial uses are also possible such as power and pipeline monitoring, search and rescue, environmental monitoring, delivery services, and imaging/mapping. UASs could perform some piloted aircraft missions with less noise and fewer emissions. The new UAS technologies under development today will have a profound impact on the entire aviation industry. The investments and the technological advances made by military organizations have generated a growing interest in their potential use for civil government, scientific research, and commercial applications. Enabling routine access to the NAS by leveraging existing procedures for piloted flight operations, and using current guidance for unique military operations will yield a path for NAS integration and significant growth in the civil and commercial UAS market will immediately follow.

Revolutionary new technologies are not only being introduced in the current conflicts in the Middle East, but also used in increasingly greater numbers with novel and unexpected effects. Everything that seems so futuristic in the field of UAS development and artificial intelligence is playing out in the current state, and parallels familiar historical patterns in past aviation development. These new technologies are being used in ways that were previously thought impossible, capabilities that were not possible before, and creating new issues as well as complicating old ones. UASs are doing amazing things in Iraq and Afghanistan and this robotics revolution forces many to reshape, reevaluate, and reconsider what the future holds for flight operations and applications in the National Airspace System.

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Appendix 1: Complete Stakeholder List [76]

Title	Company	Country Name
Queensland University of Technology	Australian Research Centre for Aerospace Automation (ARCAA)	AUSTRALIA
Senior Airworthiness Officer	Civil Aviation Safety Authority (CASA) Australia	AUSTRALIA
UAS Business Development Manager	V-TOL Aerospace Pty Limited	AUSTRALIA
Chief Design Engineer	Wackett Aerospace Centre	AUSTRALIA
	EUROCONTROL	BELGIUM
Executive Board Member Technical Affairs	Executive Board Member Techical Affairs	Belgium
Captain	Canadian Air Force	CANADA
Trade Commissioner, Aerospace, Defence and Security	Foreign Affairs and International Trade Canada	CANADA
Contributing Editor	Jane's	CANADA
Unmanned Aircraft Systems Engineer	MDA - Airborne Systems	CANADA
Aircraft Certification	Transport Canada	CANADA
Secretary-Treasurer	Unmanned Vehicle Systems Canada Inc.	CANADA
President	UVS Canada	CANADA
Chief, Air Traffic Management	ICAO Air Navigation Bureau	Canada
	CS Communication & Systèmes	FRANCE
	Dassault Aviation	FRANCE
	DSNA/DTI	FRANCE
Senior Programme Manager	SAGEM Défense Sécurité	FRANCE
	Thales Alenia Space	FRANCE
President	UVS International	FRANCE
	DFS Deutsche Flugsicherung GmbH	Germany
Military Air Systems (MAS)	EADS Deutschland GmbH, Willy Messerschmitt Straße	Germany
Head of Airspace Management, Navigation and Procedures	German Air Navigation Services Headquarters	Germany
	Industrieanlagen Betriebsgesellschaft mbH	GERMANY
Manager Marketing and Sales	Northrop Grumman Electronic Systems	Germany
Airworthiness Manager	Israel Aircraft Industries, Ltd	Israel
CTO Certification Policy Manager	Alenia Aeronautica S.p.A.	ITALY
Ph.D Candiate	Nara Institute of Science & Technology	JAPAN
R&D Engineer	National Aerospace Laboratory NLR	NETHERLANDS
President	TGR Helicorp Ltd.	NEW ZEALAND
Boeing Research and Technology Europe	Boeing	SPAIN
Technology Expert	BOEING RESEARCH & TECHNOLOGY EUROPE, S.L	SPAIN
Product Manager, Airborne ATM	BAE Systems	UNITED KINGDOM
Chief Airworthiness Engineer and Head of Flight Safety	BAE SYSTEMS - Regional Aircraft	UNITED KINGDOM
Managing Director	Barnard Microsystems Limited	UNITED KINGDOM
Air Traffic Standards Department	CAA	UNITED KINGDOM

Secretary	Eurocae WG73 UAV	UNITED KINGDOM
ISRALPA President	ISRAirline Pilots Association President	UNITED KINGDOM
	QinetiQ	UNITED KINGDOM
Commercial Executive	Thales	UNITED KINGDOM
Chief Systems Engineer	Thales UK	UNITED KINGDOM
Policy & Standards, Safety Regulation Group	UK Civil Aviation Authority	UNITED KINGDOM
	University of Birmingham	UNITED KINGDOM
Executive Director	AUVSI	UNITED STATES
Sr. Software System Safety Engineer	US Army AMRDEC/SED Aviation Division	UNITED STATES
Director, Advanced Technologies	AAI Corp	UNITED STATES
	AAI Corporation	UNITED STATES
	Academy of Model Aviation	UNITED STATES
Staff Engineer	ACSS - Aviation Communication Surveillance Systems, LLC	UNITED STATES
Senior Systems Engineer	Adsystech	UNITED STATES
President	Advanced Ceramics Research	UNITED STATES
	AERO&SPACE USA INC	UNITED STATES
Sr. Systems Engineer	Aerodyne	UNITED STATES
Business Development Manager	Aerosonde	UNITED STATES
Editor	Aerospace Daily	UNITED STATES
CFO and CTO	Aerotonomy, Inc	UNITED STATES
	AeroVironment	UNITED STATES
	AFRL	UNITED STATES
	AFRL/HEAS	UNITED STATES
	AFRL/UAC	UNITED STATES
	AFRL/VACC - Control Systems Dev	UNITED STATES
	AIA	UNITED STATES
	Air Force	UNITED STATES
Lieutenant Colonel	Air Force, 452 FLTS/DO	UNITED STATES
	Air Force, AFRL/VACC	UNITED STATES
	Air Force, RSW/XRX	UNITED STATES
	Air Line Pilots Association	UNITED STATES
	Air War College	UNITED STATES
Consultant	Aircraft Owners and Pilots Association	UNITED STATES
Manager, Regulatory Affairs	Aircraft Owners and Pilots Association	UNITED STATES
	Airline Pilots Association	UNITED STATES
	Alias Science	UNITED STATES
	AmTech Center for Collaboration	UNITED STATES
Director, Business Development	Analytical Graphics Inc	UNITED STATES
Senior Analyst	ANSER	UNITED STATES

Government Analyst. Air Traffic Services	AOPA	UNITED STATES
Chief Engineer	ARINC Engineering Services, LLC	UNITED STATES
Sr Dir. Frequency Management	ARINC Incorporated	UNITED STATES
Cognitive Engineering Specialist	ARINC, LLC	UNITED STATES
Aerospace Engineer	Army	UNITED STATES
Program Manager	Arthur Feinberg Assoc.	UNITED STATES
Manager	ASTM International Technical Committee Operations	UNITED STATES
Range Safety Team Lead	Atlantic Test Ranges	UNITED STATES
Chief Knowledge Officer	AUVSI	UNITED STATES
	Aviation Management Associates, Inc	UNITED STATES
President	Aviation Management Associates, Inc	UNITED STATES
President	Aviation Support Associates	UNITED STATES
President	AvioniCon	UNITED STATES
Senior Member of Tech Staff	BAE Systems-Communications, Navigation, Identification and Reconnaissance	UNITED STATES
VP, International and Gov't Sales	Ballistic Recovery Systems, Inc.	UNITED STATES
	BattleSpace, Inc.	UNITED STATES
Flight Technology Engineering - IPT Lead	BELL HELICOPTER	UNITED STATES
President	BLR Group of America, Inc.	UNITED STATES
	Booz Allen Hamilton	UNITED STATES
Associate Professor	Brigham Young University	UNITED STATES
	BTC Inc	UNITED STATES
UAS Project Office	CAS, Inc.	UNITED STATES
	Center of Excellence/JUAS COE/NDGI	UNITED STATES
	Certification Services, Inc.	UNITED STATES
Research and Advanced Technology	Cessna Aircraft Company	UNITED STATES
President	Cloud Cap Technology	UNITED STATES
	Coast Guard	UNITED STATES
	Computer Networks & Software, Inc.	UNITED STATES
Executive Consultant Aerospace	Consultant	UNITED STATES
	Continental Airlines Inc.	UNITED STATES
Director, Systems Engineering	CSSI, Inc.	UNITED STATES
CNS/ATM Engineer	DCS Corporation	UNITED STATES
Unmanned Aerial Systems (UAS) Programs	Defense Research Associates, Inc	UNITED STATES
Alaska Regional Director	Departement of the Interior	UNITED STATES
	Department of Defense	UNITED STATES
Deputy Director C3 ISR Plans & Policy	Department of Homeland Security, US Customs and Border Protection	UNITED STATES
	Department of Industrial and Systems Engineering Rutgers University	UNITED STATES
	DHS, CBP Air & Marine	UNITED STATES
	DHS/ CBP Air & Marine	UNITED STATES
	DRA, Inc.	UNITED STATES
Director	Drexel University Autonomous Systems Lab	UNITED STATES

	DRS Technologies EWNS	UNITED STATES
	DSC Corporation	UNITED STATES
	DuaneMorris	UNITED STATES
	Dynamic Aerospace Inc	UNITED STATES
PMA209 Collosion Avoidance Systems	Eagan, McAllister Associates Inc.	UNITED STATES
Professor	Embry-Riddle Aeronautical University	UNITED STATES
Professor of Computer and Software Engineering	Embry-Riddle Aeronautical University - Daytona Beach Campus	UNITED STATES
Director, New Business Development	Essex Industries, Inc.	UNITED STATES
	Evergreen	UNITED STATES
	Evergreen Unmanned Systems	UNITED STATES
Senior Vice President	F.J. Leonelli Group, Inc.	UNITED STATES
Engineering Psychologist	Federal Aviation Administration	UNITED STATES
DFS Liaison Officer to the Federal Aviation Administration	Federal Aviation Administration - Air Traffic Organization	UNITED STATES
Engineering Research Psychologist	Federal Aviation Administration R&D Field Office, AAR-210	UNITED STATES
	Federal Aviation Administration Technical Center	UNITED STATES
Trajectory Based Operations Integration Manager	Federal Aviation Administration, ATO Operations Planning (ATO-P)	UNITED STATES
Standards Staff	Federal Aviation Administration, Rotorcraft Directorate	UNITED STATES
Electrical Engineer	Federal Communications Commission	UNITED STATES
	FEDEX	UNITED STATES
	FJ Leonelli Group Inc	UNITED STATES
	Flight Safety Technologies	UNITED STATES
Software Services Sales Manager	Foliage Software Systems, Inc	UNITED STATES
President	Frequentis Defense, Inc.	UNITED STATES
	Garmin International, Inc.	UNITED STATES
	GE Aviation	UNITED STATES
Systems Engineer	General Atomics	UNITED STATES
	General Atomics Aeronautical Systems	UNITED STATES
Airworthiness Project Engineer	General Atomics Aeronautical Systems Inc	UNITED STATES
Program Manager	General Atomics Aeronautical Systems, Inc	UNITED STATES
	General Atomics, Aeronautical Systems, Inc	UNITED STATES
	General Atomics-ASI	UNITED STATES
Program Manager, UAS	General Dynamics Robotics Systems	UNITED STATES
UAS Operations Specialist	Geneva Aerospace	UNITED STATES
Consultant	GKN & Associates	UNITED STATES
GSA - MTA - FAIRS Coordinator	GSA - OGP - MT - MTC	UNITED STATES
	GT Aeronautics, LLC	UNITED STATES
	GulfStream Aerospace Corp	UNITED STATES
	Hanchuck Consulting Services	UNITED STATES
Senior Principal Engineer	Harris Corporation	UNITED STATES
	Harris Technologies LLC	UNITED STATES
Human Factors Engineer	Hi-Tec Systems	UNITED STATES
Product Line Manager – D&S Flight Controls	Honeywell	UNITED STATES
Staff Engineer	Honeywell Inc., Aerospace Electronic Systems	UNITED STATES
Fellow	Honeywell International, Inc	UNITED STATES
Major	HQ AF Flight Standards	UNITED STATES

MQ-1 Predator & MQ-9 Reaper Programmatic Support	HQ AF/A2ZC	UNITED STATES
	ICF International	UNITED STATES
MS, P.E., P.M.P	Idaho National Laboratory	UNITED STATES
Chief Engineer	Innovative Solutions International, Inc.	UNITED STATES
ATC Marketing Manager	ITT Industries	UNITED STATES
Deputy Director, Washington Office	Japan International Transport Institute	UNITED STATES
	JIL Information Systems	UNITED STATES
Assistant Professor	John D. Odegard School of Aerospace Sciences University and Tulane	UNITED STATES
Associate Professor	John D. Odegard School of Aerospace Sciences, University of North Dakota	UNITED STATES
Senior Professional Staff	John Hopkins University/ APL	UNITED STATES
	Johns Hopkins University Applied Physics Laboratory	UNITED STATES
Lt. Col	Joint UAS Center of Excellence	UNITED STATES
Tactical Operations/ Aviation Safety Officer	Joint UAS Center of Excellence, JFCOM	UNITED STATES
UAS Airspace SME	Joint Unmanned Aircraft Systems, Center of Excellence (JUAS COE)	UNITED STATES
	JSWalker Group/Aviation Solutions, Inc.	UNITED STATES
CEO	JUS-ISAC, LLC	UNITED STATES
	Kansas UAV Consortium	UNITED STATES
	Kutta, Inc.	UNITED STATES
Manager of Product Certification	L-3 Communications Corp	UNITED STATES
	Lockheed Martin	UNITED STATES
	Lockheed Martin Aeronautics Co	UNITED STATES
Principal Research Engineer	Lockheed Martin Aeronautics Company	UNITED STATES
Engineer Senior Staff	Lockheed Martin Corporation	UNITED STATES
Senior System Engineer – Air Traffic	Lockheed Martin Information Technology Services	UNITED STATES
	Lockheed Martin Missiles and Fire Control	UNITED STATES
K-MAX Programs - Chief Engineer	Lockheed Martin Systems Integration	UNITED STATES
	LuftKing Aerosolutions	UNITED STATES
Product Manager, Marketing Analyst	Lycoming Engines	UNITED STATES
President	Metron Aviation	UNITED STATES
Sr. Electro-Optic Engineer	Milsys Technologies	UNITED STATES
	MIT Lincoln Laboratory	UNITED STATES
Project Manager, International Operations	MITRE	UNITED STATES
	MITRE	UNITED STATES
Lead Communications Engineer	MITRE CAASD	UNITED STATES
	MITRE Corporation	UNITED STATES
Project Team Mgr	MITRE Corporation/CAASD	UNITED STATES
Principal Engineer	MITRE Corportation/CAASD	UNITED STATES
Project Team Manager	MITRE/CAASD	UNITED STATES
	MITRE-CAASD	UNITED STATES
	MITRE-CAASD	UNITED STATES
Senior Engineer	Modern Technology Solutions, Inc	UNITED STATES
	Modern Technology Solutions, Inc.	UNITED STATES
President and Principal Analyst	Mosaic ATM	UNITED STATES
Sr. Operations Research Analyst	MTSI	UNITED STATES
President	Mulkerin Associates Inc.	UNITED STATES
Airborne Science Manager	NASA	UNITED STATES
	NASA Ames Research Center	UNITED STATES
Project Manager, Ikhana (Predator-B)	NASA Dryden Flight Research Center	UNITED STATES
	NASA Langley	UNITED STATES
	NASA Langley Research Center	UNITED STATES

	NATCA	UNITED STATES
NATCA Liaison to ATO-R	National Air Traffic Controllers Association	UNITED STATES
Associate Editor	National Defense Magazine	UNITED STATES
	National Science and Technology Council	UNITED STATES
	National Transportation Safety Board	UNITED STATES
	NAV AIR	UNITED STATES
Director for Advanced Technology Directorate	NAVAIR	UNITED STATES
Joint C3 SIPT Lead	NAVAIR/4.5	UNITED STATES
UAV Flight Clearance Engineer	Naval Air Systems Command	UNITED STATES
UAV System Safety Engineer	Naval Air Warfare Center	UNITED STATES
Human Systems Analyst	Navy	UNITED STATES
Asst. to Sr. VP Ops	NBAA	UNITED STATES
Deptuy Director	New Mexico State University/Pysical Science Laboratory	UNITED STATES
	New Vistas International	UNITED STATES
Marine & Aviation Ops	NOAA	UNITED STATES
Staff Assistant to Director	NOAA Marine and Aviation Operations Centers	UNITED STATES
LCDR	NOAA/Dryden Flight Research Center	UNITED STATES
PhD Student	North Carolina State University	UNITED STATES
	Northrop Grumman	UNITED STATES
Senior Systems Physicist	Northrop Grumman Corporation	UNITED STATES
BAMS Chief Engineer	Northrop Grumman Corporation	UNITED STATES
Senior Staff Engineer	Northrop Grumman Corporation- ES	UNITED STATES
	Northrop Grumman Integrated Systems	UNITED STATES
Aviation Engineering Division (AS-40)	NTSB	UNITED STATES
Human Performance Investigator	NTSB, Office of Aviation Safety (AS-50)	UNITED STATES
	Office of Naval Research	UNITED STATES
Coordinator, Joint Robotics Program	Office of Secretary of Defense, Department of Defense	UNITED STATES
Research Engineer	Ohio University Airport	UNITED STATES
Research Engineer	Penn State Electro-Optics Center	UNITED STATES
	Predesa	UNITED STATES
Operations/Business Development	Prioria Inc.	UNITED STATES
CEO	Procerus Technologies	UNITED STATES
PhD Student	Purdue University	UNITED STATES
Senior Airspace Operations Specialist	QSS Group, Inc	UNITED STATES
Senior Partner	R3 Consulting	UNITED STATES
	Raytheon IIS	UNITED STATES
Sr Principal Sys Engineer	Raytheon Systems Company	UNITED STATES
	RCAPA	UNITED STATES
President	Research Integrations	UNITED STATES
Principal Systems Engineer	Rockwell Collins, Inc.	UNITED STATES
Program Director	RTCA, Inc.	UNITED STATES
Consultant	Russell Systems	UNITED STATES
President	Saab International USA	UNITED STATES
Director, Washington Operations, Aerospace	SAE International	UNITED STATES
	SAF/AQIJ	UNITED STATES
	Sagem Morpho, Inc.	UNITED STATES
Communications Engineer	SAIC	UNITED STATES
Director, Business Development	Satcon Applied Technology	UNITED STATES
	Scientific Applications & Research Associates	UNITED STATES
PhD	See Aero	UNITED STATES
Strategy and Development	Sensis	UNITED STATES
	SETA II/Federal Aviation Administration	UNITED STATES
Mgr-Sys Engr/Mfg Tech	Sikorsky Aircraft Corporation	UNITED STATES
Manager	SITA	UNITED STATES
	Sky Tech Aerial Imagery Copter Wrights, LLC	UNITED STATES
	Smiths Aerospace Electronic Systems	UNITED STATES
Dir Sys Safety Engineering	Solers, Inc	UNITED STATES

President	Sparrow-Tech Inc.	UNITED STATES
U-Systems Programs Manager	SRA	UNITED STATES
UAS Operations Analyst	SRA International, Inc.	UNITED STATES
	Student	UNITED STATES
President	Swift Engineering Inc	UNITED STATES
	Systems Engineering & Consulting, Inc	UNITED STATES
MSC PSL	TAAC Airspace Operations	UNITED STATES
MSC PSL	TAAC UAS Program Manager	UNITED STATES
Proprietor	Telenergy	UNITED STATES
	Telephonics Corp	UNITED STATES
Director, Government Affairs Homeland Security	Textron, Inc.	UNITED STATES
Consultant	The Beacon Group	UNITED STATES
Engineering and Information Technology	The Boeing Company	UNITED STATES
	The Drake Group	UNITED STATES
Director, East Coast Ops	The Insitu Group, Inc	UNITED STATES
	The Insitu Group, Inc	UNITED STATES
Director	Transportation Security Admistation	UNITED STATES
Sr. Engineer	Tucson Embedded Systems, Inc	UNITED STATES
Chief Technical Advisor	TUV America, Inc.	UNITED STATES
Human Factors Engineer	U. S. Army	UNITED STATES
SAA SE Lead	U. S. Navy	UNITED STATES
	U.S. Navy	UNITED STATES
Commander	UAS FIT	UNITED STATES
	UAV Communications, Inc	UNITED STATES
Vice President of Business Development	UAV Flight Systems, Inc.	UNITED STATES
President and CEO	UAV Marketspace, Inc	UNITED STATES
President	UAV National Industry Team (UNITE)	UNITED STATES
Executive Director	UNITE	UNITED STATES
Secretary-Treasurer	United Airline Pilots Master Executive Council	UNITED STATES
	United Airlines, Inc.	UNITED STATES
	US Airways	UNITED STATES
Project Manager	US Army	UNITED STATES
Senior Research Engineer	US Army AMRDEC	UNITED STATES
Lieutenant Colonel	US Army TSM-UAS	UNITED STATES
Aviation Engineering	US Coast Guard	UNITED STATES
	US Department of the Interior, National Business Center Aviation Management Directorate	UNITED STATES
	US DOT Volpe Center	UNITED STATES
UAS Airspace Integration	US Navy	UNITED STATES
Manager, Systems Architecture & Applications	ViaSat, Inc.	UNITED STATES
USDOT/Research and Innovative Technology Administration	Volpe National Transportation Systems Center	UNITED STATES
	Washington Consulting Group	UNITED STATES
	William Mitchell College of Law	UNITED STATES
AFSOC UAS Airspace Management	WinTec Arrowmaker	UNITED STATES

Appendix 2: Stakeholder Salience: Power, Legitimacy, & Urgency [52]

Power Factor	Level Description	Level Range
Coercive	The stakeholder threatening position to obtain the outcomes desired from the integrated enterprise is null or very low	0-2
	The stakeholder uses threatening arguments to obtain the outcomes it desires from the enterprise	2-4
	The stakeholder is able to pose real threats regarding his claims on the enterprise	4-6
	The stakeholder is capable of using some elements of force, violence, or restraint to obtain benefits from the enterprise	6-8
	The stakeholder is determined and totally capable of using force, violence, or any other restrain resource to obtain desired outcomes from the enterprise	8-10
	Coercive Power Level	
Utilitarian	The stakeholder has null or very low control over the resources (material, financial, services, or information) used by the enterprise	0-2
	The stakeholder has some control over some of the resources used by the enterprise	2-4
	The stakeholder controls the use of some of the resources used by the integrated enterprise	4-6
	The stakeholder heavily administers significant number of the resources used by the enterprise	6-8
	The stakeholder extensively administers most of the resources used by the enterprise	8-10
	Utilitarian Power Level	
Symbolic	The stakeholder does not use or barely uses normative symbols (prestige, esteem) or social symbols (love, friendship, acceptance) to influence on the enterprise system	0-2
	The stakeholder uses some level of normative symbols or social symbols to influence on the enterprise system	2-4
	The stakeholder uses moderate levels of normative symbols or social symbols to influence on the enterprise system	4-6
	The stakeholder relies on normative symbols and/or social symbols to claim his stakes from the enterprise system	6-8
	The stakeholder extensively uses normative symbols and social symbols in order to obtain value from the enterprise system	8-10
	Symbolic Power Level	
	Power Attribute (Weighted) Average	

Legitimacy Factor	Subtypes	Level Description	Level
Broad definition		Generalized perception or assumption that the actions of a stakeholder are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions.	0-10
Pragmatic	Exchange Legitimacy	Extent to which the stakeholder maintains a materialistic (based on goods, services, or any other type of exchange) relationship with the enterprise, and the importance of those exchanges to the welfare of the enterprise system	0-10
	Influence Legitimacy	Extent to which the stakeholder helps in defining the strategic or long-term interests of the whole enterprise and its submission to those interests before its own welfare.	0-10
	Dispositional Legitimacy	Degree to which the stakeholder is predisposed to share or adopt the enterprise values demonstrating honesty, decency, and trustworthiness in the relationship	0-10
		Pragmatic Legitimacy Average Level	
Moral	Consequential Legitimacy	Degree to which the accomplishments of the stakeholder are perceived by the whole enterprise system as "the right thing to do"	0-10
	Procedural Legitimacy	Extent by which the stakeholder's value creation *process* are perceived as sound and good efforts to achieve some, albeit invisible, ends as valued by the enterprise system	0-10
	Structural Legitimacy	The degree by which the stakeholder is perceived as having the right internal organizational structure to perform its assigned role in the enterprise system	0-10
	Personal Legitimacy	Extent by which the leaders of the stakeholder organization are perceived as having the adequate charismas, personalities, and authority to perform the job the stakeholder is supposed to do for the enterprise system	0-10
		Moral Legitimacy Average Level	
Cognitive	Comprehensibility Legitimacy	Degree of existence of cultural models that provide plausible explanations for the stakeholder participation in an enterprise and its related endeavors	0-10
	Taken-for-grantedness Legitimacy	Degree to which the legitimacy of the stakeholder is taken for granted without an explicit evaluative support	0-10
		Cognitive Legitimacy Average Level	
		Legitimacy Attribute (Weighted) Average	

Criticality Factor	Level Description	Level range
Urgency	The stakeholder is time insensible or has very low demands for a timely response to its claims at risk in the enterprise	0-2
	The stakeholder asks for its stakes or values with enough anticipation allowing the enterprise to attend them in a timely manner	2-4
	The stakeholder requires attention to its stakes in plausible or reasonable times	4-6
	The stakeholder calls for a prompt attention to the stakes at risk in the enterprise	6-8
	The stakeholder demands immediate attention to the stakes it compromise in the enterprise and their associated payoffs	8-10
	Urgency Level	
Importance	The stakeholder has null or very low dependency on the stakes it puts at risk in the enterprise	0-2
	The stakeholder shows low dependency on the values obtained from the enterprise	2-4
	The stakeholder relies on the values obtained from the enterprise for its future actions or operations	4-6
	The stakeholder shows high dependency on the stakes it contributes at risk in the enterprise	6-8
	The stakeholder demonstrates very high dependency on the stakes it puts at risk in the enterprise and on the values obtained from it	8-10
	Importance Level	
	Criticality Attribute (Weighted) Average	