FOCUSED LENS ON UNMANNED AERIAL SYSTEMS: AN EVALUATION OF DEPARTMENT OF DEFENSE'S UNMANNED AERIAL VISION 2011

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Unmanned Aerial Systems (UASs) have become standard in U.S.'s conflicts. However, current UASs are limited by the need for unchallenged airspace or stealth technology, as UASs have almost no defensive capability. Draw-down of the U.S. military after Operation Iraqi Freedom and Enduring Freedom, the U.S. Department of Defense (DoD) is placing considerable emphasis on employing a lighter, leaner, and more lethal military force to meet strategic objectives mandated by politicians. As a result, the DoD, *Unmanned Systems Integrated Roadmap FY2011-2036*, identified seven areas the U.S. must focus to ensure the U.S. remains at the forefront of UAS development and employment. Does the current roadmap address the correct focus areas to ensure UASs will provide force multiplying effects in the future? This paper examines the Roadmap's focus areas to determine if the DoD has selected the correct areas for focus and if the DoD is progressing to meet the *Unmanned Systems Integrated Roadmap FY2011-2036* vision. UASs are an important element in future military operations, but the DoDs UAS Roadmap must be an effective developmental guide for future UASs. Anything less will adversely affect the military's ability to integrate systems and employ UASs across the spectrum of future military operations.

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ABSTRACT

FOCUSED LENS ON UNMANNED AERIAL SYSTEMS: AN EVALUATION OF DEPARTMENT OF DEFENSE'S UNMANNED AERIAL VISION 2011, by Major Jeffrey A. McKiernan, 108 pages.

Unmanned Aerial Systems (UASs) have become standard in U.S.'s conflicts. However, current UASs are limited by the need for unchallenged airspace or stealth technology, as UASs have almost no defensive capability. Draw-down of the U.S. military after Operation Iraqi Freedom and Enduring Freedom, the U.S. Department of Defense (DoD) is placing considerable emphasis on employing a lighter, leaner, and more lethal military force to meet strategic objectives mandated by politicians. As a result, the DoD, *Unmanned Systems Integrated Roadmap FY2011-2036*, identified seven areas the U.S. must focus to ensure the U.S. remains at the forefront of UAS development and employment. Does the current roadmap address the correct focus areas to ensure UASs will provide force multiplying effects in the future? This paper examines the Roadmap's focus areas to determine if the DoD has selected the correct areas for focus and if the DoD is progressing to meet the *Unmanned Systems Integrated Roadmap FY2011-2036* vision. UASs are an important element in future military operations, but the DoDs UAS Roadmap must be an effective developmental guide for future UASs. Anything less will adversely affect the military's ability to integrate systems and employ UASs across the spectrum of future military operations.

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ACRONYMS

DoD	Department of Defense
FAA	Federal Aviation Administration
ISR	Intelligence, Surveillance, Reconnaissance
MUM-T	Manned Unmanned-Teaming
NAS	National Airspace System
RPA	Remotely Piloted Aircraft
SATCOM	Satellite Communications
STANAG	Standardization Agreement
UA	Unmanned Aircraft
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicles

CHAPTER 1

INTRODUCTION

> We have just won a war with a lot of heroes flying around in planes. The next war may be fought with airplanes with no men in them at all. It certainly will be fought with planes so far superior to those we have now that there will be no basis for comparison. Take everything you've learned about aviation in war and throw it out of the window and let's go to work on tomorrow's aviation. It will be different from anything the world has ever seen.[1]
>
> — General Hap Arnold,
> *War Without Men: Robots on the Future Battlefield*

The Department of Defense (DoD) has enjoyed the fruits of intelligence collected from unmanned systems specifically during the ongoing conflict in the Middle East and more secretively in other locations around the world. Commanders in planning cells and soldiers, sailors, and airmen on the battlefield have had access to very actionable information by literally watching a television screen. Full motion video has delivered understandable intelligence with the ability to act on it almost instantaneously. In essence, Unmanned Aerial Systems (UASs) have become the commander's window to the battlefield.

The UASs emerged from the shadow of manned aircraft in the mid-1990s, and became an integral weapon in the Global War On Terror. The UAS has finally been accepted by the DoD as a viable weapons system. Major strategic-level functions and offices have declared the UAS to be a vital, even transformational, component in the fight

[1]Steve M. Shaker and Alan R. Wise, *War Without Men: Robots on the Future Battlefield* (New York: Pergamon-Brassey's, 1988), 87.

against global terrorism.[2] UASs have been utilized by DoD primarily in an intelligence gathering role and have virtually operated at will in uncontested airspace. Due to the terrain and sensor suites UASs make available to commanders; military forces have grown incredibly reliant UASs. In the decades ahead unmanned systems have significant potential to continue to increase U.S. military effectiveness across a range of priority missions, including enabling new U.S. Concept of Operation. This will require relatively modest financial commitment, but more pronounced strategic commitment, particularly to encourage experimentation that will uncover the most promising areas for investment and emphasis.[3]

The DoD has articulated that over the next two decades forces will operate in a geostrategic environment of considerable uncertainty with traditional categories of conflict becoming increasingly blurred.[4] Unmanned systems can help in countering these threats by reducing risk to human life and increasing standoff from hazardous areas. In the age of a downsizing military and diminishing defense budgets, the key to success will lie in UASs capable of performing multiple missions while overcoming traditional unmanned limitations. As technology flourishes, the tendency to want bigger and better systems with more and more capabilities seems to be the rule. As the DoD continues to

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[2]Richard P. Schwing, "Unmanned Aerial Vehicles–Revolutionary Tools in War and Peace" (Strategy Research Project, Army War College Carlisle Barracks, PA, 2007), 12.

[3]Samuel J. Brannen, "Sustaining the U.S. Lead in Unmanned Systems Military and Homeland Considerations through 2025" (Center for Strategic and International Studies, February 2014), 1.

[4]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036* (Washington, DC: Government Printing Office, October 2011), 4.

draw-down its forces, UASs will significantly enhance the U.S. military's ability to remain the dominant force in combat. It is critical, as more countries delve into UAS employment that the U.S. remains at the forefront of UAS research and development.

The DoD's *Unmanned Systems Integrated Roadmap FY2011-2036* was released to promote integration of unmanned systems into the military machine. Within the roadmap, interoperability, autonomy, airspace, integration, communications, training, propulsion and power, and Manned Unmanned-Teaming (MUM-T) were identified as focus areas in which the DoD must synchronize and improve their efforts to promote unmanned system integration.[5] Each area selected is intended to complement the DoD strategy for future conflicts. The discussion in this paper is focused primarily on UASs because they have progressed the most technologically, and will continue to vastly outnumber unmanned systems in the ground and maritime domains. This study evaluates the focus areas to conclude if the DoD is advancing in the selected areas. In the course of this study a secondary question will be to evaluate the six focus areas to answer if the DoD has identified the correct focus areas to promote UAS integration.

Assumptions

The following assumptions are relevant to this research project. The United States could, in the near future, be involved in a peer-to-peer full spectrum conflict in which area access denial will be a factor. Based on general contemporary thought, the United States will continue to develop, integrate, and employ UASs in future operations both in small scale and large scale conflicts. Additionally, assumptions made during the research

[5]Ibid., v-vi.

for this paper include acknowledging that the technological capabilities of foreign UASs equal what their manufacturers, or government officials claim. Employers of UASs will most likely have a high degree of understanding as to how to defeat adversary UASs. The U.S. military's greatest concern with regard to UAS policy in the future may be countering other countries' use of them. The relatively low cost of UAS, the broad potential for their future operational use, and the increasingly global availability of the technology all raise the need to consider whether existing countermeasures are sufficient.[6] Therefore, it is valid to believe that any country owning or employing UAS technology has a good understanding of UASs current and future capabilities. This paper will use the term "Unmanned Aerial Systems" (UASs) for ease of discussion. In many previous writings the term Unmanned Aerial Vehicles (UAV) have been used. The most common definition cited by previous authors use Tom Ehrhard's definition from *The U.S. Air Force and Unmanned Aerial Vehicles* dissertation at Johns Hopkins University, 1999. His definition of a UAV is a self-propelled aircraft that sustains flight through aerodynamic lift. It is designed to return and be rescued, and it does not have a human onboard. Encompassed in the definition is an autonomous vehicle, historically a term to describe the concept of an aircraft without human pilots. Readers should understand that the new terminology, UAS encompasses Tom Ehrhards definition but goes further to describe all facets of UASs. The new more correct terminology is UAS. The Federal Aviation Administration (FAA) defines UAS as an unmanned aircraft (UA) and all of the associated support equipment, control station, data links, telemetry, communications and

[6]Brannen, *Sustaining the U.S. Lead in Unmanned Systems Military and Homeland Considerations through 2025*, 12.

navigation equipment necessary to operate the unmanned aircraft.[7] The UA is the flying portion of the system, flown by a pilot via a ground control system, or autonomously through use of an on-board computer, communication links and any additional equipment that is necessary for the UA to operate safely.

Key Terminology

Previous authors have used a variety of terms to identify UASs in their writings. When those differences exist, the paper will use the term UAS. Historically, unmanned systems have had specific names applied to them that were descriptive rather than the generic term UAV. One term that is worth discussion now is "drone". Drones are aircraft programmed to fly a profile either prior to take off or in flight, but they do not have a human pilot in direct control of the platform. Drone is a term used most recently by news agencies and laymen to refer to UAV in a negative context. The Central Intelligence Agency has increased its use of unmanned aerial aircraft resulting in increased media visibility. This is the context in which UAV become synonymous under the term drones. Originally drones simply meant aircraft that are programmed to fly a profile without a pilot in direct control from the cockpit.

This thesis only researches unclassified material openly available through public sources and will discuss UASs in the unclassified arena. No doubt there is much development in the classified arena on this topic. The focus of work does not include all unmanned air assets or other unmanned systems, like unmanned ground, surface and undersea systems. The progression and integration of unmanned systems logically

[7]Federal Aviation Administration, "Fact Sheet–Unmanned Aircraft Systems (UAS)," April 29, 2014, http://www.faa.gov/about (accessed May 24, 2014).

bridges terrain mediums. Each DoD service; Army, Navy, Air Force, Marine and many other governmental and private organizations are integrating technology into other manned systems that will operate under sea, on land, and in the air. Of unmanned systems, UASs are not the leader in all areas of development, but do integrate technologies pioneered form non-aviation unmanned systems. Research and development by so many countries, companies, and consortiums naturally produces proprietary technology. As a result, available unclassified information is usually not very detailed and tends to be restricted to concepts more than detailed data.

An additional constraint is the quickly evolving technology that contributes to the UAS field; therefore, many references may be dated very quickly due to the dynamic nature of the technology development. Most recently the rapid growth in UAS operations and public interest is brought on by two developments. First, the U.S.'s globally publicized use of UASs being wildly successful in non-traditional roles in the Operation Iraqi Freedom and Operation Enduring Freedom. Secondly, the explosion of technology in miniaturization and application of sophisticated computer systems has enabled the laymen to employ various types of UASs. The conclusions in this paper will likely not sway DoD planning, but will, hopefully raise concern for future unmanned aerial system integration into DoD operations.

While this paper's aim is to discuss primarily military challenges identified by the *Unmanned Systems Integrated Roadmap FY2011-FY2036* focus areas, one must be fully aware that research in the civilian and public context has been vital to UAS development and employment. For example agricultural companies developed techniques to use multispectral imagery to identify soil composition, plant density, and foliage health and pesticide distribution that increase UAS civilian and government (non-military) uses. Readers should also note that developments effecting general UAS use will have a direct impact on military UAS integration. Likewise, as with many technologies, military advancements will eventually flow into non-military applications by commercial and civilian organizations.

Currently the DoD classifies UAS into five general categories based on size and capability (see Appendix A). Group One UASs are highly portable and can be hand launched. They are intended to allow small troop units to find out what's happening behind the next hill. Group One UASs payload capacity is typically less than three to four pounds and their endurance is an hour or less.[8] Group Two UASs are typically medium-sized, catapult-launched, mobile systems that usually support brigade-level and lower Intelligence, Surveillance, Reconnaissance (ISR) and target acquisition requirements.[9] Group Three UASs are larger than Group One or Two systems. They operate at medium altitudes and usually have medium to long range and endurance. Some Group Three UASs carry weapons. They usually operate from unimproved areas and may not require an improved runway.[10] Group Four UASs are relatively large systems, operate at medium to high altitudes, and have extended range and endurance. Group Four UASs must meet DoD airworthiness standards or possess a FAA Certificate Of Airworthiness prior to operation in National Airspace System (NAS). Group Four UASs have the capability to

[8]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* (Washington, DC: Government Printing Office, 2010), 12.

[9]Ibid.

[10]Ibid., 13.

carry larger or more numerous munitions payloads without sacrificing as much endurance as Group Three. Group Four UASs normally require improved areas for launch and recovery. Lack of Satellite communication links could inhibit Beyond Line Of Sight capability for some Group Four UASs.[11] Group Five UASs are the largest systems; operate in the medium to high altitude environment. Group Five UASs must meet DoD airworthiness standards or possess a FAA Certificate Of Airworthiness prior to operation in NAS.[12] Group Five UASs include the Navy's MQ-4 Broad Area Maritime Surveillance UAS and the experimental Unmanned Carrier Launched Airborne Surveillance and Strike, the Air Forces Global Hawk, Predator, and Reaper UASs.

This paper's author is an Air Force officer with combat aviation experience supporting joint operations in the Middle East and Libya as well as homeland security and humanitarian assistance missions. As an Air Battle Manager, this author has a keen respect for integration of air assets in support of air and ground operations, therefore some concepts may be extrapolated from the author's previous experiences.

Significance of Research

UASs provide amazing capabilities to the warfighter and are well suited for the war on terror, but their utility for the U.S. will not end with the current conflict. As UAS technology advances, more opportunities will arise in which UASs may either augment or even replace manned aircraft in the accomplishment of assigned missions. The capabilities of UASs are exciting and appear to be the center point of the United States

[11] Ibid.

[12] Ibid.

military force in the future; however, developing a full understanding of UASs employment challenges in future operations could be the defining point in United States military operations. The DoD recognizes UAS's value to military operations which is why the *Unmanned Systems Integrated Roadmap FY2011-2036* is worthy of scrutiny.

CHAPTER 2

LITERATURE REVIEW

Conventional thinking suggests that the next major conflict the U.S. military will be tasked to fight will be against a hybrid threat. The DoD anticipates a threat that may fuse conventional forces and unconventional warfare to defeat U.S. forces.[13] The Global War On Terror has brought many potential adversaries into the U.S.'s warfare arena. Along with the hybrid threat it is entirely possible that the U.S. faces a nation state that has very robust offensive and defensive capabilities. A nation state could possess a wide spectrum of capabilities the US has not faced since the collapse of the Soviet Union. Emerging threats to the US undoubtedly possess many of the same advanced technologies the US employs. The US military's recent shift to the Pacific Theater also indicates that the largest military and political players in the region could be the US's next conflict adversaries.[14] The DoD is trying to ascertain how best to formulate its future unmanned aircraft fleet so that it could operate inside contested airspace while also maintaining its ability to continue the US's aerial campaign against various terrorist groups around the world.[15] The US's role in promoting global security will be varied and wide spread of which US UASs will no doubt play a major role. This study will evaluate

[13]White House, *National Security Strategy 2010* (Washington, DC: Government Printing Office, May 2010), 14.

[14]Jim Garamone, "Rice Re-emphasizes Importance of U.S. Shift to Pacific," *American Forces Press Service,* November 21, 2013, html://www.defense.gov (accessed December 18, 2013).

[15]Dave Majumdar, "USAF Studying Future Unmanned Aircraft Fleet Mix," Flight Global, July 3 2013, http://www.recreationalflying.com (accessed January 26, 2014).

if the DoDs seven integration focus areas described in *Unmanned Systems Integrated Roadmap FY2011-2036* are advancing UAS development in these areas and are the focus areas the correct areas to focus UAS integration efforts?

At minimum readers should be familiar with the *Unmanned Systems Integrated Roadmap FY2011-2036* to gain knowledge of the DoD's understanding of how UASs will be employed by joint forces in future conflicts. *Unmanned Systems Integrated Roadmap FY2011-2036* is the guiding document for US UAS systems integration.

Following the DoD's publishing of 2009 version of the Unmanned Systems Roadmap, each service developed their respective roadmap or equivalent document. The US Army produced an *Unmanned Aircraft Systems Roadmap* in 2010, the Marine Corps published its *Concept of Operations for Unmanned Aircraft Systems Family of Systems*, the Navy published *Information Dominance Roadmap for Unmanned Systems in 2010*, and the Air Force released *Unmanned Aircraft Systems Flight Plan* in 2009. With each Service's attributes in mind, The *Unmanned Systems Integrated Roadmap FY2011-2036* was produced to address issues faced by all services and articulate a common vision for unmanned systems.[16] As such the document identifies seven areas that the DoD must address in order to maintain a successful logical progression in UAS development and employment in support of national objectives. Interoperability, autonomy, airspace integration, communications, training, propulsion and power, manned unmanned-teaming (Manned Unmanned or MUM-T) are the challenge areas that are identified in *Unmanned*

[16]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 2.

Systems Integrated Roadmap FY2011-2036. Furthermore, its inclusion to the research informs the audience of the DoD's strategic direction regarding US military UASs.

Many helpful documents for this research have come from several Military Master of Art and Science monographs and theses completed through the United States Army Command and General Staff College. The present information from early UAS development, acquisition, employment, and integration into fielded Army units. Research in these documents provides specific military detail into the ever changing UAS world. While no single paper fully addresses the questions posed in this paper, each paper referenced provides a slice of information needed to build a more complete picture.

Major Gaub's monograph "The Children of Aphrodite" investigates UAS threats to United States forces. He explores how World War I airpower growth and proliferation among the Allied and Central Powers compares to UAS growth and proliferation today. His research assists in developing an understanding of the basic life cycle of unmanned vehicles in the United States. Gaub focuses his monograph on the protection from state and non-state actors' uses against American forces envisioning how UASs might be, or have been used in conflict.

Major Jaysen Yochim presents a master's thesis titled "The Vulnerabilities of Unmanned Aircraft System Common Data Links to Electronic Attack" exploring some disadvantages UASs display when compared to manned aircraft. He focuses primarily on the need for UASs to have constant "link" with operators in order to complete their missions. Yochim's ultimate conclusion is that UASs still have a long way to go to operate at the same level of effectiveness as manned aircraft.

A review of the literature has uncovered numerous journal articles of various types that discuss technological developments of UASs. The efficiencies of airframe design and the improvements have been addressed in depth. Many defense companies are engaged in addressing specific design shortfalls and attempting to saddle UASs with every possible mission set. Much effort is being placed on stealth and loiter time.

Additionally, numerous web pages, UAS discussion forums, and online magazines provide valuable insight into overall UAS employment, emerging technologies, ethical considerations, and expected future capabilities of UASs. Web pages range from how to negate government UASs from spying on the public to agricultural applications of UAS's and even synopsis of recent UAS tests and exercises. UAS discussion forums hold the bulk of "conspiracy theories around UASs, but interestingly do provide a high degree of factual data regarding UAS potential capabilities. Furthermore, to completely understand the public's distrust and ethical concerns revolving around UASs, discussion forums provide a wide range of concerns for the DoDs continued use of UASs. Finally, online magazines where proven to be a good tool to help build a mental framework to understand UASs evolution in modern warfare.

Each service continues to publish their respective UAS roadmaps even after the DoD has published several iterations of UAS roadmaps. Each service roadmap molds UAS operations into areas that fit more completely into their unique service requirements. However, of note are several Department of Defense joint publications. They function to bridge the joint operational gap to concentrate on training, operation, and command and control of UASs stressing the integration of UASs throughout the operational environment and detail the advantages incorporating UASs into planning. However, they do not provide specific guidance to employment in an access denied area. They simply suggest that UASs should be integrated in planning and be used when able to maximize effects. Furthermore, there are numerous inconsistencies between Joint Publications usages for unmanned systems terminology. JP 3-55.1, *Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles* is the most definitive in regards to UAS operations, but focuses mostly on the aspect of air space coordination and does not address employment or considerations of armed UASs.

FY2009–2034 Unmanned Systems Integrated Roadmap, dated April 2009 details the importance of current UAS in the combat environment and lays out the military's future UAS strategy. Due to the dynamic nature of the UAS field and budget constraints this strategy became outdated during the research for this thesis. The DoD replaced the April 2009 edition with *Unmanned Systems Integrated Roadmap FY2011-2036*. The longevity of this document is also in question in light of the continuing DoD draw downs and will most likely be readdressed in the near future again. Of note, this document brings to light the targeted reductions in UAS acquisitions and the increasing desire to maximize UAS potential in numerous mission sets. Research of this Joint Publications establishes the purpose, direction, and standards for future operations and to explain the significance of interoperability in the joint fight.

CHAPTER 3

RESEARCH METHODOLOGY

Chapter 1 illustrated the current UAS landscape regarding DoD UAS utility to commanders on the battlefield. In light of their most recent successes the DoD seeks to enhance and further integrate unmanned systems into its forces. UAS trends favor an unmanned force if lower cost and sustained effectiveness can be proven. In 2002 the DoD's estimation of UAS cost expectation as based on the UAS's generally smaller size and the mission of those systems needed to support a pilot or aircrew, which can save 3,000 to 5,000 pounds in cockpit weight. Beyond these two measures, however, other cost saving measures to enhance affordability tend to impact reliability.[17] What now appears to be lost in the cost of UASs is the factor of reliability and more specifically the UASs survivability in an access denied theaters.

As of 2011 the DoD's 25 year vision for UAS integration requires further development to UAS interoperability, autonomy, airspace integration, communications, training, power and propulsion, and manned unmanned teaming. Further developing and refining these capabilities across the UAS fleet is imperative to meet the DoD's goals.

To answer the questions this paper poses, a qualitative study examining the DoD's progress in the areas the *Unmanned Systems Integrated Roadmap FY2011-2036* identifies as important focus areas needing development in order achieve future DoD needs. This study evaluates the DoD's UAS focus areas to answer the question: Is the DoD advancing UAS development in these areas? And secondly, are the focus areas

[17]Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap 2002* (Washington, DC: Government Printing Office, December 2002), 185.

sufficient to further the US's UAS fleet to meet the dynamic challenges facing the US military in future conflicts.

To answer the question posed by this study, each area will be evaluated using the goals found in the executive summary of the *Unmanned Systems Integrated Roadmap FY2011-2036*.

The *Unmanned Systems Integrated Roadmap FY2011-2036* requires that interoperability of UAS systems must be improved so that UASs can operate seamlessly across the domain of air to improve utility and reduce life-cycle costs.[18] The *Unmanned Systems Integrated Roadmap FY2011-2036* guidance requires DoD to advance interoperability by providing common capability descriptions in system requirements, design common open architectures for system design, and incorporate common components in system acquisition strategies. To evaluate this focus area a literature review was accomplished consisting of current UAS standards for interoperability. Research was not only limited to US military, but additionally interoperability standards in the international military community. Providing a standardized baseline to measure DoDs progress in interoperability, the *Unmanned Aerial Vehicle Roadmap 2002* was consulted. Literature reviews also encompassed interoperability of ground control stations, unmanned to manned systems, and physical design aspects of UASs. All of which assisted in determining current and past interoperability capabilities to determine if the *Unmanned Systems Integrated Roadmap FY2011-2036* goal for interoperability is being achieved or if further development is required.

[18]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, v.

To improve UAS autonomy, the *Unmanned Systems Integrated Roadmap FY2011-2036* also requires that DoD pursue technologies and policies that introduce a higher degree of autonomy, reduce manpower and reliance on full-time high-speed communications links while reducing decision loop cycle time. Furthermore, advancements must consider affordability, operational utilities, technological developments, policy, and public opinion.[19] This paper will analyze the improvements to autonomy in UASs to evaluate current autonomous capabilities, challenges and future expectations. However, increasing autonomy in the DoD, while technologically challenging, is not the main area of focus regarding the employment of autonomous UASs. Public perceptions and realities of autonomous operations will also be explored to assess if the *Unmanned Systems Integrated Roadmap FY2011-2036* focus on autonomy is appropriate for the DoD. The scientific aspects of autonomy will not be discussed in depth with this paper due to the highly technical nature and scientific equations that are the bases for developing autonomy in UASs. However, the concept of autonomous operations has a direct impact on the research conducted to form conclusions in this paper. The technological difficulty and the challenges military, academic institutions and commercial companies are facing should not be discounted from future UAS discussions as higher levels of autonomy are achieved and incorporated into unmanned systems.

The *Unmanned Systems Integrated Roadmap FY2011-2036* requires that DoD work to improve UAS airspace integration. The DoD must work with the FAA to ensure unmanned aircraft systems have routine access to airspace needed within the NAS to

[19]Ibid., vi.

meet training and operations requirements.[20] Research and development efforts are under way to mitigate obstacles to safe and routine integration of UAS into the national airspace, however, these research and development efforts cannot be completed and validated without safety, reliability, and performance standards.[21] Chapter 4 outlines and discusses challenges to airspace integration within the US as well as the DoD's integration of UASs in current and future combat theaters. To answer whether or not the DoD is progressing in airspace integration as the *Unmanned Systems Integrated Roadmap FY2011-2036* envisions, government produced milestones will be evaluated for time accountability. Furthermore, challenges and improvements will be explored to assess the DoDs capability to integrate in national airspaces. Finally, achievements of the DoD in regards to airspace integration will be examined to decide if the *Unmanned Systems Integrated Roadmap FY2011-2036* is correct to identify airspace integration as one of its areas of focus for UAS development.

Communications capability is the bedrock of UAS command and control. The *Unmanned Systems Integrated Roadmap FY2011-2036* asserts that the DoD must address frequency and bandwidth availability, link security, link ranges, and network infrastructure to ensure availability of unmanned systems. Additionally UAS must move toward onboard pre-processing to pass only critical information.[22] The DoD relies

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[20]Ibid.

[21]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development* (Washington, DC: Government Accountability Office, February 15, 2013), forward.

[22]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, vi.

heavily on communication architectures to command and control every aspect of UAS operations. UAS communications limitations and known vulnerabilities are discussed in chapter 4. Current challenges to contemporary communication systems and enhancements to improve UAS communications will be evaluated to measure the *Unmanned Systems Integrated Roadmap FY2011-2036* goals versus actual progress. Secondly, evidence presented in the following chapter allows a conclusion to be made regarding the validity of making communications a focus area in the *Unmanned Systems Integrated Roadmap FY2011-2036*.

The UAS training methods and production capability are vital to fielding UAS in military operations. The *Unmanned Systems Integrated Roadmap FY2011-2036* directs the DoD to ensure continuation and joint training requirements are in place against which training capabilities can be assessed. An effective strategy will improve basing decisions, training standardization, and promote common courses resulting in improved training effectiveness and efficiency.[23] The research focused on the evolution of UAS training to evaluate DoD's progress regarding training of UAS operators (pilots) including sensor operators. The literature review examined past training capabilities and "school house" output to determine if training quality and quantities are sufficient to achieve DoD 25 year vision. As forces drawdown in theater and redeploy, the services will require comprehensive continuation and joint-forces training in the peacetime environment. Failure to prepare for this eventuality will result in a loss of combat gained experience.[24] This study measures the vision provided by *Unmanned Systems Integrated Roadmap*

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[23]Ibid.

[24]Ibid., 74.

FY2011-2036 against the reality of DoD's adherence the roadmaps guidance in the area of UAS training. Additionally, the evaluation of the training structure and output of trained operators will assist in answering whether the DoD was correct to include training as a focus area in the *Unmanned Systems Integrated Roadmap FY2011-2036.*

Of the seven areas identified by the *Unmanned Systems Integrated Roadmap FY2011-2036*, only six will be analyzed for this paper. The *Unmanned Systems Integrated Roadmap FY2011-2036* directs the DoD to continue to improve propulsion and power directing the DoD to enhance motor performance and reduce life-cycle costs of US UASs.[25] This seventh area, propulsion and power, will not be evaluated as in this study due to the expected limited impact propulsion systems will have on future UASs, and the highly technical nature of the unclassified information available. Additionally, the affects of power and propulsion are not specific to unmanned aircraft but is an issue that directly affects all aircraft. However the reader should understand that UASs suffer from many of the same difficulties as early airplanes. Issues with flight controls, lack of engine power due to their small designs, and susceptibility to wind, rain, and other weather phenomena all combine to limit the types of missions UASs currently perform. Yet, designers continue to envision and develop unmanned systems achieving drastic improvements to power and propulsion.

Finally, the *Unmanned Systems Integrated Roadmap FY2011-2036* identified MUM-T concept as an evolutionary step in UAS development. Therefore, to achieve full MUM-T potential the DoD must implement technologies and evolve tactics, techniques and procedures (TTP) that improve the teaming of unmanned systems with the manned

[25]Ibid., vi.

force.[26] Research into MUM-T relies heavily on articles and conceptual data to formulate conclusions about the DoDs current and potential future MUM-T capabilities. To evaluate the DoD's progress in this area, previous roadmaps and currently fielded systems will be examined to conclude if MUM-T inclusion in the *Unmanned Systems Integrated Roadmap FY2011-2036* is appropriate to further UAS development and subsequent integration into mainstream military operations.

[26]Ibid.

CHAPTER 4

ANALYSIS

> We are entering an era in which unmanned vehicles of all kinds will take on greater importance in space, on land, in the air, and at sea.[27]
>
> — President Bush,
> "President Bush Speaks on War Effort to Citadel Cadets"

The role of UASs played during the wars in Iraq and Afghanistan permitted each service to rush UASs into operations without fully testing and validating their capability, life-cycle costs, and future utility. UASs of the last ten years sacrificed redundant control systems, robust self-protection measures, and other additional performance enhancing capabilities because they were developed specifically to fight in uncontested air space where there was little threat to the aircraft. As the US moves out of the wars in the Middle East, the DoD is developing UASs that possess better capability to employ as multi-role aircraft. The DoD is currently largely invested in permissive ISR environments that resemble Afghanistan where air superiority has been established. When it comes to the future, however, the circumstances will likely be much different for U.S. forces. Currently the DoD's UAS mix is not capable of integrating into all military mission sets. The US is over-invested in permissive ISR and must act to transform the force to fight and win in contested environments faster than adversaries develop anti-UAS capabilities. The *Unmanned Systems Integrated Roadmap FY2011-FY2036* outlined seven areas that the DoD must focus on to progress UAS integration to meet future needs. Six of the seven areas will be evaluated in this chapter beginning with interoperability.

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[27]The Citadel Newsroom, "President Bush Speaks on War Effort to Citadel Cadets," December 11, 2001, http://www.citadel.edu (accessed April 1, 2014).

Interoperability

The first focus area that the *Unmanned Systems Integrated Roadmap FY2011-FY2036* describes is UAS interoperability. Direction and support for UAS interoperability futures is very strong from the Secretary of Defense and within the Defense Department. This support stems from a viewpoint of a smaller, more agile and responsive force that incorporates the best possible use of technology, recent UAS successes, warfighter needs and requests for more UASs, and the ability to integrate them into the joint force in order to fight more effectively in the future. The *Unmanned Systems Integrated Roadmap FY2011-2036* asserts open architecture (OA) and open interfaces need to be leveraged to address problems with proprietary robotic systems architectures.[28] The *Business Dictionary* provides a clear definition of open architecture for the non-technical reader. It defines open architecture as:

> Vendor-independent, non-proprietary, computer system or device design based on official or/popular standards. It allows all vendors (in competition with on another) to create add-on products that increase a system's (or device's) flexibility, functionality, interpretability, potential use, and useful life. And enables the users to customize and extend a system's capabilities to suit individual requirements.[29]

With a goal of enhancing competition, and lowering life-cycle costs will provide warfighters with enhanced unmanned capabilities that enable commonality and joint interoperability on the battlefield.[30]

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[28]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 5.

[29]Business Dictionary, "Open Architecture," http://www.businessdictionary.com (accessed March 20, 2014).

[30]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 5.

Historically, private sector industry has produced the most unmanned system technology resulting in compatibility issues regarding proprietary software and hardware. This poses a specific financial issue for development. One must assume that if proprietary technology is developed for a system, the cost of the development will not be shared among all consumers over the life of the system, but will actually be an expense incurred by the original developer. As one of the leaders in UAS development, the US can expect to incur higher costs in fielding systems than a partner nation that receives the system at a later date. The DoD is now addressing the technical and tactical issues that face interoperability of controlling UASs by ensuring industry and coalition nations are aware of the OA structure that the DoD hopes will encourage commercial UAS technology competition. The Army's One System Ground Control Station for its MQ-5 Hunter, RQ-7 Shadow, and MQ-1 Warrior UAS is an example of this level of existing materiel interoperability. The Universal Ground Control Station will further promote OA and incorporate Office of the Secretary of Defense/Joint Unmanned systems interoperability profiles.[31]

This effort provides for a more compatible and streamlined UAS force has lead to more information sharing. For example the Air Force is contemplating interoperability in their UASs and they recognize the need to share information across the domains of air, space, land, and sea. The *Air Force Aerial Layer Networking Enabling Concept* dated December 2012 asserts that an information sharing infrastructure must be established and managed to achieve end-to-end capabilities and interoperability. This information sharing

[31]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 16.

infrastructure will leverage the rapid advancement of technology and economy of scale cost reductions in the commercial sector to enable on-demand, real-time and secure exchange of voice, data, video, control and management of information across the aerial layer, and with the space and surface layers. Scalability is important as transformation from Tactical Data Links to more open and modular networking approaches will take place incrementally over several years.[32]

UASs have been proven effective as weapons of war and they have been used for that purpose predominantly over areas of the world with little or no commercial air traffic. A large factor in the effectiveness of future US armed forces is operations in the joint realm, which means the services must plan for interoperability now. However, this is not a new revelation for the DoD. The *Unmanned Aerial Vehicle 2002 Roadmap* published in 2002 stated UAS interoperability requirements exist within the framework of existing manned aviation, ISR system, and strike system interoperability architectures and are not unique requirements. But it seems only now that the DoD is translating the guidance to action. The DoD is currently working on upgrading UASs so that they can fly in hostile environments. In the Middle East and Africa, Reaper and Predators have what many call "unrestricted use of the air." The DoD is considering operating UAS in other countries and is currently working with countries such as Italy, Australia, Germany and France to provide them with the technology to fly their own UASs.[33]

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[32]Department of the Air Force, *Air Force Aerial Layer Networking Enabling Concept* (Washington, DC: Government Printing Office, December 2012), 12.

[33]Jason Koebler, "Autonomous Killing Drones 'Years and Years' Away," *USA News*, April 24, 2013, http://www.usnews.com/news/articles/2013/04/24/air-force-general-autonomous-killing-drones-years-and-years-away (accessed April 15, 2014).

The DoD's main line of effort to addressing interoperability between systems both unmanned and manned systems is the adoption of an open systems architecture concept. This concept seeks to set a baseline for programming and acquisition of unmanned systems. One of the key issues facing UAS interoperability and standardization is the degree to which the collection regime can be made common between differing types of UASs, particularly regarding mission planning and system control functions.[34] As more and more unmanned systems are fielded, the need for a common method of communicating between those systems becomes more important. It is necessary to implement better procedures that require new and innovative technologies, with better and safer capabilities in the automation and optimization of mission planning in unstructured environments within the entire flight envelope.[35]

Interoperability standards provide a common medium, serving as the "glue" for unmanned systems.[36] Two of the most prominent interoperability standards employed by unmanned systems today are Joint Architecture for Unmanned Systems and Standardization Agreement (STANAG) 4586.[37] STANAG's are agreements that NATO

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[34]Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap 2002*, 138.

[35]Adrian Muraru, "An Overview on the Concept of UAV Survivability" (Paper presented at the 2011 International Conference of Scientifics Brasov, Romania, 26-28 May 2011), 6.

[36]Jorgen Pedersen, "Interoperability Standards Analysis," Interoperability Standard, Robotics Division, The Standards Committee of the National Defense Industry Association, November 2007, http://www.ndia.org/Divisions/Divisions/Robotics/Documents/Content/ContentGroups/Divisions1/Robotics/Interoperability%20Standards%20Analysis%20(ISA) (accessed March 24, 2014), 3.

[37]Ibid., 5.

member nations agree to and implements within their own military. STANAG 4586 supports multinational partners sharing data from multiple UASs from several countries. Compliance with STANAG 4586 allows NATO member nations to jointly support military operations using their own UASs and ground control station equipment. This increases interoperability and allows data and information processed by member nation UASs to be shared real-time through a common ground interface.[38] Promoting interoperability with NATO partners the FAA in 2009 established an agreement with the European Union to initiate, coordinate, and prioritize the activities necessary for supporting the development of provisions required for the evolution of UAS to full recognition as a legitimate category-of-airspace user.[39] STANAGs and European Union agreements reinforce the DoD's continued efforts to become more interoperable with partner nations and joint UASs. But one must recognize that these agreements were signed prior to the *Unmanned Systems Integrated Roadmap FY2011-FY2036* publication.

There has been action to consolidate UAS development under a "joint" umbrella concept but it seems this only applies to technology interoperability development and not to physical aircraft characteristics. Interestingly, not until the *Unmanned Systems Integrated Roadmap FY2011-2036* publishing has there been a desire to develop a standardized UAS airframe. Commonality, including airframes, control stations,

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[38]Boeing Media Room, "Boeing ScanEagle Team Achieves Compliance with NATO UAV Interoperability Standard," http://boeing.mediaroom.com/2007-02-07-Boeing-ScanEagle-Team-Achieves-Compliance-with-NATO-UAV-Interoperability-Standard (accessed March 24, 2014).

[39]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 8.

payloads, and power sources, decrease logistics burdens including training, stocking and resupplying. This provides for economies of scale, enabling production of more equipment at less per unit cost. Currently, the Joint Strike Fighter has been developed using a universal base structure with only the internal components being specifically adapted to meet each service components needs. Following this model the *Unmanned Systems Integrated Roadmap FY2011-2036* now calls for enhanced modularity "Plug-and-Play" in future UAS designs among similar components of the same or different systems. As a sub-component of interoperability, the *Unmanned Systems Integrated Roadmap FY2011-2036* envisions future UASs that can change configurations to meet the mission with the plug-and-play use of different sensors on an unmanned vehicle.[40] In order to allow UASs to be more multi-role capable, their components and software must be interoperable with foreign and domestic ground control stations. UAS sensors and the data collected must allow for configurations where data can be translated and transmitted across several dissimilar computer systems. Finally, UASs must be responsive to the commander on the battlefield, meaning, the same UAS employed for electronic jamming must also have the ability to conduct ISR on the next mission with minimal reconfiguration. While there is much information, primarily from commercial companies vying for contracts to build common UAS platforms, no unclassified literature was found to verify that the DoD has met the *Unmanned Systems Integrated Roadmap FY2011-2036* goal of integrating commonality in physical UAS designs. However, it is clear the DOD

[40]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 30.

seeks to establish OA and physical modularity standards to improve UAS development across both civilian and military agencies and improve autonomous UAS capabilities.

Autonomy

The DoD will continue to seek unmanned systems that promote autonomy and that gradually become more and more autonomous. Dramatic progress in supporting technologies suggests that unprecedented levels of autonomy can be introduced into current and future unmanned systems.[41] The increased focus on autonomy is in response the financial global climate facing nearly every military. In the end, this comes down to budget constraints. Under the original rules of sequestration DoD faced up to $500 billion in cuts over the next 10 years, and even with new reforms it could face cuts of as much as $50 billion in 2014 alone. This report readily admits that a set of algorithms with human-level versatility is but a “pipe dream” today, but takes it as a foregone conclusion that there is no way to both increase global dominance and decrease spending without significant cuts to manpower.[42]

Autonomy does not mean that once the power switch is activated the unmanned system is on its own. There are four levels of autonomy in any system that dictate how much and how often humans need to interact with the unmanned system. They are human operated, human delegated, human supervised, and fully autonomous. A human operated UAS has a human at the helm at all times. A human operator makes all decisions. The

[41]Ibid., 43.

[42]Garaham Templton, “DoD: To Conquer Nations and Budgets, Combat Must Go Totally Autonomous,” ExtremTech, December 27, 2013, http://www.extremetech.com (accessed April 15, 2014).

system has no autonomous control of its environment although it may have information-only responses to sensed data. A human delegated UAS is a vehicle that can perform many functions independently of human control when delegated to do so. This level encompasses automatic controls, engine controls, and other low-level automation that must be activated or deactivated by human input and must act in mutual exclusion of human operation. Manned aircraft and some UASs currently operate with human delegated capabilities. For example, commercial aircraft (and military) utilize autopilot during various stages of flight. The autopilot function is capability in which a pilot can set parameters of altitude, speed, and azimuth and the aircrafts computer manages the aircraft control systems to remain within the prescribed limits in put by the pilot. Adding a little more autonomy, a human supervised UAS can perform a wide variety of activities when given top-level permissions or direction by a human. Both the human and the system can initiate behaviors based on sensed data, but the system can do so only if within the scope of its currently directed tasks. The top level of autonomous operation is called fully autonomous. A fully autonomous UAS receives goals from humans and translates them into tasks to be executed.[43] This is the stuff of science fictions movies like *Terminator, Blade Runner, and I, Robot*. The robot, or UAS, is give a mission and sent on its way, only to return with it is completed. No action is required past fueling and programming and the system will utilize massive computing power to analyze and "decide" every action it will take based on its programming. If a system is fully autonomous, it must be programmed to take off, fly to the mission area, complete its

[43]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 46.

assigned task, and defend themselves from all attacks, return and land at their home base without assistance without human intervention. An expert on military technologies, James Canton, at the Institute for Global Futures stated that “autonomy, even for armed robots is coming,” including a machine that will hunt, identify, authenticate, and possibly kill a target without a human in the decision loop.[44]

Technological advances over the centuries have consistently increased the physical and emotional distance between an attacker and his target, resulting in ever-higher levels of destructiveness. During the Gulf War of 1991, critics were arguing that the “videogame” and “electronic narrative” aspect of fixing a target in the crosshairs of an aircraft flying at 30,000 feet before dropping a precision-guided bomb had made killing easier, at least for the operator and the public. Things were taken to a greater extreme with the introduction of attack drones, with US Air Force pilots not even having to be in Afghanistan to launch attacks against extremist groups there, drawing accusations that the U.S. conducts an “antiseptic” war.[45]

Lieutenant General David A. Deptula, the USAF’s deputy chief of staff for ISR, stops short of using UASs in a completely autonomous operation for all missions. “With onboard computer processors rated equivalent to that of the human brain, air-to-air fighters could be remotely piloted. So far, technology does not allow the 360-degree spherical situational awareness necessary for a pilot to sense a rapidly changing situation

[44]Ronald Arkin, *Governing Lethal Behavior in Autonomous Robots* (Boca Raton: Chapman and Hall/CRC, 2009), 8-9.

[45]J. Michael Cole, “When Drones Decide to Kill on Their Own,” The Diplomat, October 1, 2012, httml: //www. thediplomat.com (accessed April 15, 2014).

and take the appropriate action in a split-second battle."[46] For the near term, UASs cannot be trusted yet to wield lethal power without the over-watch of a human. Furthermore missions that involve nuclear weapons, face further scrutiny. Lieutenant General David A. Deptula says "I don't know that we want to relegate the decision authority to an automated device. I don't think we're that close."[47]

In an Army War College Strategy Research Paper by Lieutenant Colonel Trimble titled, "*USAF Role in Future Air Warfare: Manned or Unmanned?*" suggests "It seems unlikely, however, that mega-computers with speeds and memory equal to that of the human mind could ever activate the innate abilities, cognitive thought processes, or integration of empirical data necessary to make humans' split-second decisions." But the potential exists for networked UASs to work together autonomously as a swarm. Autonomous attack differs from "swarm" attack in that a swarm has one, or multiple controllers that use cues from other UASs to complete tasks, whereas autonomous UASs would be networked and have no active controller. During the mission a UAS could have the ability to make its own decisions based on conditions or enemy actions without controller input.

A *Popular Science* article explains swarm technology in biological terms. A swarm is a collection of individuals that manifest complex behavior without a leader calling the shots. Imagine birds spontaneously gathering on a single tree, only to lift-off en masse moments later. Scientists have applied swarm intelligence to driving robots, but they now have the processing power and sensing capability to apply it to flying ones

[46]John A. Tirpak, "The RPA Boom," *Air Force Magazine* (August 2010): 9.

[47]Ibid.

too.[48] Swarm technology is progressing as interest and development advances in the civilian and military sector increase. The swarm concept in the civilian realm is touted as a way to achieve better crop pollination, surveillance, or traffic monitoring. In the military context, the concept for swarm UASs is more aggressive. UAS swarms could be used to overwhelm integrated air defense systems. Theoretically, masses of UASs could present so many radar returns that an air defense system could not distinguish which target to engage or track. Timothy Chung of the Naval Postgraduate School points out that the only army big enough to stop a swarm would be another army that posses their own arsenal of swarm UASs.

To say that swarm technology is in its infancy stage is an understatement. The concept of swarming robots has been in the minds of humans for many years but technologically the practicality of swarm is more in the embryonic stages not infancy. Swarm technology has not been mastered by any means of the imagination. The computing power and communications systems required have not been achieved to make this a reality. However, several university and private organizations have proven very limited concepts that allow mini-UASs to perform swarm-like tasks in confined spaces. Swarming does have the potential to maximize budgets and does pose an overwhelming threat to our adversaries, but swarm cannot be used as a fully autonomous UAS in the near future. Any near term use of “swarm UASs” will be in a very limited human delegated autonomous role. That is to say, technology available now will only allow for UASs controlled from a host station (launch vehicle, computer station) with pre-

[48]David Hambling, “The Future Of Flight: Swarms Will Dominate The Sky,” *Popular Science Magazine*, July 2, 2013, http://www.popscie.com (accessed December 20, 2013).

programmed routes. The idea that masses of UASs could operate in concert with other UASs without a high level of human input simply is not achievable anytime soon.

The evolution of autonomy is not recognized as a linear acquisition process; rather the DoD is willing to apply varying levels of autonomy on a case-by-case basis. Unmanned systems already in use may be modified to a human delegated status or human supervised if the unmanned system is capable to accept the upgrade. In the future, the DoD seeks to acquire fully autonomous unmanned systems developed specifically for that purpose.

The DoD's true challenge with UAS autonomous operations is not that of the technological restraints but that of the public perception of "robot" warriors, that could go crazy and kill randomly. The perpetual news reporting that constantly refers to unmanned systems as "drones" has done nothing to further the public's opinion of UASs. Additionally, policy makers at local and state governments are adding to the UASs unpopularity make it even more difficult for UASs to become mainstream tools. Drew Cohen in his article "Autonomous Drones and the Ethics of Future Warfare" provides a very plausible scenario fully autonomous UASs may face. His scenario is pulled from the context of US's most recent conflicts; he asked how an autonomous UAS can distinguish the threats in an environment where most individuals are not combatants? He cites autonomous weapons inability to assess individual intention; (i.e., a butcher chopping meat in a busy market or a child playing with a toy gun).[49] Although the use of drones substantially increases operational effectiveness it adds to the emotional distance between

[49]Drew F. Cohen, "Autonomous Drones and the Ethics of Future Warfare," *Huffington Post Politics*, December 15, 2013, http://www.huffingtonpost.com/drew-f-cohen/autonomous-drones.html (accessed April 13, 2014).

operator and target they remain primarily an extension of, and are regulated by human decision-making.[50] Lieutenant General Larry James, Air Force Deputy Chief of Staff for Intelligence, Surveillance and Reconnaissance pointed out in April 2014 that despite growing public resentment toward drone strikes overseas, unmanned aircraft are not going anywhere anytime soon.

Any exchange of hostilities between manned with unmanned systems could be viewed in potentially dissonant ways by military and civilian leaders in different countries. A country may feel more entitled to destroy an unmanned system because there is no loss of life, while the country whose unmanned system was destroyed may view the attack as equally escalatory as an attack on a manned system. Thus, escalation dynamics could become unpredictable. To date, there has been no known engagement between two unmanned systems, but that is increasingly likely as more countries acquire UAS and air-to-air capabilities are developed.[51]

The DoD must address several issues before committing to fully autonomous UASs. Concerns such as integrating UASs into the NAS, collision avoidance with other manned and unmanned aircraft, air-to-air refueling operations, employment of UASs in contested airspace with multiple air-to-air and surface-to-air threats, adhering to complex rules of engagement and other legal issues, and dealing with the dynamic complexity of the fog of war—all such issues need to be resolved before fully autonomous operations can be implemented. Designing and winning public support for autonomous UASs is a

[50]Cole, "When Drones Decide to Kill on Their Own."

[51]Brannen, *Sustaining the U.S. Lead in Unmanned Systems Military and Homeland Considerations through 2025*, 13.

monumental task by itself, however, a more timely issue facing UASs of all types is that of UAS airspace integration, which will discussed next.

Airspace Integration

Unmanned Aerial Vehicle 2002 stated UAS reliability is the first hurdle in airspace considerations because it underlies UAS acceptance into civil airspace—whether domestic, international, or foreign. One of the major challenges of integrating UASs into the NAS is developing a see-and-avoid capability that enables UASs to avoid conflicting air traffic, hazardous weather, terrain, and other obstructions.[52] The NAS is the common network of U.S. airspace-air navigation facilities, equipment, and services; airports or landing areas; aeronautical charts, information and services; rules, regulations, and procedures; technical information; and manpower and material.[53] The *Unmanned Systems Integrated Roadmap FY2011-FY2036* released nearly a decade later continues to address this long standing issue with UAS airspace integration. The DoD has only met limited success with FAA coordination and continues to operate UASs only in relatively small military training areas.

DoD identified airspace integration as a challenge to unmanned systems because they are currently restricted to operations and training areas. All services have a robust and repeatable airworthiness certification process for manned aircraft. Since the

[52]Kelly J. Haywurst et al., *Unmanned Aircraft Hazards and Their Implications for Regulation*, http://shemesh.larc.nasa.gov/people/jmm/5B1_201hayhu.pdf (accessed March 12, 2014), 8.

[53]Department of Transportation, *Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap* (Washington, DC: Government Printing Office, 2013), 8.

prototype for military UASs comes initially from the model aircraft mindset, current DoD UASs only meet a level of airworthiness that supports restrictive segregated flight operations. Early unmanned aircraft platforms did not have the airworthiness rigor normally associated with manned aviation.

Both in training and combat, UASs are restricted in time and space in order to minimize accidents. To many it may seem the UAS's size and weight does not present a danger to other aircraft. Because most UASs are small and slow, it is difficult for combat systems to detect and track the UASs, creating situational awareness (SA) issues for other aircraft and controllers.

Unmanned aircraft (UA) may be operated in the airspace controlled by each joint force component, multinational forces, and other government agencies. The established principles of airspace management used in manned flight operations will normally apply to UA, but since UA may be difficult to visually acquire and may not always provide a clear radar or electronic signature, UA operations require special considerations in terms of airspace control and usage.[54] Unmanned aircraft will not achieve their full potential military utility to do what manned aircraft do unless they can go where manned aircraft go with the same freedom of navigation, responsiveness, and flexibility.[55] For example, UASs are limited in areas and altitudes because most UASs do not have anti-icing capabilities and cannot fly in freezing precipitation or icing conditions. Furthermore, they lack a fundamental capability to see and avoid external threats. "See-and-avoid" is a

[54]Joint Chiefs of Staff, Joint Publication (JP) 3-52, *Joint Air Space Control* (Washington, DC: Government Printing Office, May 2010), xiv.

[55]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 52.

common aviation term in which the pilot uses all his senses in an effort to identify a dangerous situation such as a mid-air collision. A more appropriate term for UASs is “sense-and-avoid”. Some UASs do possess this capability though a variety of sensors, but in many cases the sensors required to accomplish the task are simply too large or too heavy to incorporate into the airframe and remain combat effective. Pilots mitigating external factors while flying sometimes find it a taxing job with large numbers of aircraft operating in areas where there are numerous aircraft and obstacles. Adding more, smaller aircraft to the already congested areas possess an additional risk to aircraft.

Concerned with the pace of progress toward integrating UAS into the national airspace, in February 2012, Congress established specific requirements and set deadlines for FAA to expedite UAS integration in the FAA Modernization and Reform Act.[56] The FAA recently created the UAS Integration Office, within FAA, to coordinate all intra-agency UAS efforts and provide organizational leadership.[57] The UAS Integration Office under operates under one executive to provide stable leadership and focus on the FAA UAS integration efforts. The UAS Integration Office was formally created in January 2013.[58]

Congress directed the FAA to provide UAS with widespread access to domestic airspace by 2015, but the agency is behind in developing regulations and is not expected

[56]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 2.

[57]Ibid., Forward.

[58]Ibid., 8.

to meet that deadline.[59] The Government Accountability Office reported in February 2013 that FAA has several efforts under way to satisfy the 2012 Act's requirements, most of where to be achieved between May 2012 and December 2015. The FAA has made progress toward only a few selected requirements. Of the seven deadlines that had passed the FAA had completed two as of January 2013. Two areas completed were the expedited the issuance of a Certificate Of Airworthiness for public safety entities and the development of an Arctic UAS operation plan and initiate a process to work with relevant federal agencies and national and international communities to designate permanent areas in the Arctic where small unmanned aircraft may operate 24 hours per day for research and commercial purposes.[60] Neither milestone does much to further overall UAS technology development or NAS integration. There are nine other requirement areas that had deadlines within 2012 and 2013, all of which have not been achieved. UAS technology will pour billions of dollars into the U.S. economy in just a few years but companies chafing under current FAA restrictions are uncertain that the agency will work out the "kinks" by the 2015 deadline set by the Obama Administration.[61]

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[59]Tia Goldenberg, "Israel Is World's Largest Drones Exporter," *The World Post*, May 6, 2013, http://www.huffingtonpost.com/2013/06/05/israel-world-largest-drone-exporter.html (accessed April 7, 2014).

[60]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 9.

[61]Dan Parsons, "Booming Unmanned Aircraft Industry Straining to Break Free of Regulations," *National Defense Business and Technology Magazine,* May 2013, html://www.nationaldefensemagazine.org (accessed September 30, 2013).

The FAA initiated UAS integration into the NAS by identifying equipment, personnel, and operations and procedures as three primary areas to focus regulations.[62] "Equipment" is discussed within the interoperability and autonomous sections and "personnel" is covered in the following "training" section of this paper. Procedures aspect of FAA's efforts falls in line with the limited international standards produced by the International Civil Aviation Organization (ICAO). The ICAO is a special agency of the United Nations, promotes "the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for aviation safety, security, efficiency, and regularity, as well as aviation environmental protection."[63] Specifically regarding ICAO interest in unmanned aviation, it has published ICAO Circular 328, *Unmanned Aircraft Systems (UAS) Circular*. This document provides a fundamental international regulatory framework to support routine operation of UAS throughout the world.[64] The document essentially added UASs to the same regulations that govern manned aircraft operations. As member nation of the United Nations organization, ICAO rules and guidelines are generally followed by member nations but non-member nations are not accountable to those same rules, which means there is not a global standard for UAS within international airspace. However, the FAA continues to adhere to ICAO policies for manned aircraft and is working to incorporate

[62]Department of Transportation, *Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap*, 9.

[63]Ibid., 10.

[64]Ibid.

Certificate Of Airworthiness standards that are complementary to US domestic UAS integration.

The FAA is challenged further by ensuring that UAS integration is consistent with domestic privacy and civil liberties considerations.[65] The FAA does not enforce policies regarding privacy or civil liberties, but to negate some of the concerns raised in these areas, they have taken them into considerations by selecting six controlled UAS test sites in locations that will minimize public concern while testing techniques and technologies for UAS integration into the NAS. The FAA signed military operating understandings with NASA and DOD regarding research and development and the availability of safety data, respectively. The FAA has also involved industry stakeholders and academia through the UAS Aviation Rulemaking Committee and RTCA SC-203. For example, the RTCA SC-203 (a standards-making body) is developing safety, reliability, and performance standards for UAS operations.[66]

The FAA has made limited progress toward meeting the 2012 Act's requirements, and as of January 2013, it has missed several of its deadlines.[67] Though evolution of technology cannot be disputed, the rate it will evolve is speculative. All technological ventures involving dependence on future growth and development are subject to the uncertain future. The technology does not yet exist that would allow a UAS to sense and

[65]Ibid., 11.

[66]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 6.

[67]Ibid., Forward.

avoid other objects and aircraft, creating an obvious safety concern.[68] Sense-and-avoid technology for UASs is the key to opening the civilian market. It will revolutionize the civilian airspace internationally. So the search for a successful solution has obsessed the industry. Sensing and avoiding cooperative aircraft is easily managed by off-the-shelf Traffic Collision and Avoidance Systems (TCAS) that allow air vehicles to send signals to other friendly aircraft, as well as to air traffic controllers. But identifying and avoiding non-cooperative aircraft is a more complex matter.[69] UASs have historically been restricted by weight. Without on-board crew and passengers, redundant safeguards are unnecessary which is a cost-saving benefit of unmanned aircraft.[70]Small power plants that propel or lift the aircraft do not produce enough thrust to counter-act additional weight of avoidance systems.

The FAA, through subordinate agencies, is in the process of developing minimum standards for Sense-and-Avoid (SAA) and control and communications regulations.[71] Additionally the FAA is developing acceptable UAS design standards that consider the

[68]Parsons, "Booming Unmanned Aircraft Industry Straining to Break Free of Regulations."

[69]Barbara Opall-Rome, " Israel Tackles The Last Frontier Of UAS Technology: Israel Moves Closer Toward Flying UASs In Civil Airspace," *Defense News International ISR*, June 3, 2013, http://www.defensenews.com/article/20130603/C4ISR01/306030015/International-ISR-Israel-tackles-last-frontier-UAS-technology.httml (accessed April 1, 2014).

[70]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 66.

[71]Department of Transportation, *Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap*, 16.

aircraft size, performance, mode of control, and mission criticality for use in the NAS.[72] While the FAA is attempting to meet the challenge of UAS integration into the NAS by setting regulations, many in the UAS community do not believe the FAA has the legal authority to do so as John Weaver explains in this article *Free the Beer Drones*. Weaver asserts that the U.S. code and regulations that give the FAA its authority do not define UAS. Forty-nine US Code 40102 nor Fourteen Code of Federal Regulations 1.1 define UASs as aircraft therefore, the FAA cannot regulate them.[73] Validating Weaver's claim, Judge Patrick Geraghty found in a recent case regarding a small UAS that the FAA fine of $10,000 levied against a citizen for flying a small UAS was not enforceable because the FAA has no regulations that apply to unmanned aircraft systems.[74] Until the FAA can fully develop regulations for UAS operations in the NAS, the FAA has identified airspace separate from public airspace. This effort aims to reduce risk to civilian air travel and the population centers.

Research and development efforts by FAA, DOD, among others, suggests that potential solutions to the sense and avoid obstacle may be available in the near term.[75] To date, no suitable technology has been deployed that would provide UASs with the capability to sense-and-avoid other aircraft and airborne objects and to comply

[72]Ibid., 17.

[73]John Weaver, "Free the Beer Drones," Slate.com., March 5, 2014, http://www.Slate.com, March 5, 2014 (accessed March 6, 2014).

[74]Bill Carey, "Judge Rules against FAA in 'Landmark' UAV Challenge," *AINonline*, March 7, 2014, http://www.ainonline.com (accessed March 10, 2014).

[75]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 13.

completely with the FAA's manned regulatory requirements of the national airspace. Ground-based sensors are just one of the technologies the FAA and DoD are exploring to resolve sense and avoid issues. To test this and other technologies, the FAA has procured six test ranges with various solutions. The FAA selected the following ranges to further test UAS integration in to the NAS: University of Alaska test range because of its diverse climatic zones, State of Nevada test ranges to test operator standards and certification requirements; New York's Griffiss International Airport to test FAA safety oversight; North Dakota Department of Commerce ranges to conduct human factors research; Texas A&M University- Corpus Christi testing airworthiness and protocols; the sixth site being Virginia Polytechnic Institute and Virginia Tech to conduct UAS failure tests in order to study technical risks areas.[76]

In a "lost link" scenario, the command and control link between the UAS and the ground control station is broken because of either environmental or technological issues, which could lead to loss of control of the UAS. To address this type of situation, UAS generally have pre-programmed maneuvers that may direct the UAS to hover or circle in the airspace for a certain period of time to reestablish its radio link. If the link is not reestablished, then the UAS will return to "home" or the location from which it was launched, or execute an intentional flight termination at its current location.[77] Until procedures for a lost link scenario have been standardized across all types of UAS, air

[76]Federal Aviation Administration, "Fact Sheet–Unmanned Aircraft Systems (UAS)."

[77]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 14.

traffic controllers must rely on the lost link procedures established in each Certificate Of Airworthiness to know what a particular UAS will do in such a scenario.[78]

The Army is the lead service for Ground-Based Sense-and-Avoid (GBSAA) radar and the Air Force is the lead service for Airborne Sense And Avoid (AFSAA) radar.[79] The GBSAA is a radar-based program that allows UAS increased access to the NAS, thus improving the Army's training capabilities. The ABSAA is an onboard SAA system that may not be practical or possible for smaller UAS due to weight and power restrictions. Additionally, overcoming the complex technical hurdles for a final qualified ABSAA system translates to this capability being years away from practical use in the field.[80]

An explosive growth in unmanned aircraft occurred during the conflicts in Iraq and Afghanistan. From 2007 to 2009, the Air Force's primary unmanned aircraft, the Predator, logged more than 250,000 flying hours. The Air Force started with one Predator orbit patrolling the skies in Afghanistan in 2001. In 2009 that number jumped to 37 orbits in Iraq and Afghanistan. The Chief of Staff of the Air Force, General Norton Schwartz, stated the number of orbits jumped to 50 by the end of 2010.[81] These numbers have only increased in the past 12 years and General Schwartz was only describing a confined highly controlled combat airspace. In 2013 due, to sequestration and other budget

[78]Ibid.

[79]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 66.

[80]Ibid.

[81]Norton Schwartz, "The Future of Unmanned Systems" (Chief of Staff of the US Air Force speech given to the UAS "Beta Test" Graduation, September 25, 2009), http://www.airforcetimes.com/article/20120724/NEWS/207240327/Schwartz-AF-needs-manned-aircraft-despite-UAVs (accessed March 2, 2014), 3.

restrictions the final number of orbits have been capped at 2012 levels of 60 orbits. Military pilots training in US national airspace along with the burst in public desire to own and operate UASs only congests the skies further. The FAA's delineation of airspace for military and other government organizations' UASs is only in its infancy. Additionally, only a few civilian UAS organizations (like remote controlled hobbyists) have initiated airspace guides for their members and their adherence to guidelines is only suggestive and not mandatory.

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* highlights the DoD's need to integrate UAS into mainstream aviation; however, the FAA has not resolved regulatory issues to allow UAS NAS integration. Considering technology shortfalls in UAS sense-and-avoid technology, UASs are not deemed safe to operate within the NAS therefore commercial companies are not fully engaging in UAS development. Without further testing and a deeper understanding of how UAS integration may affect commercial and civilian air travel, the impacts to integrating UASs into the NAS will not be accomplished by late 2015. The DoD itself is not working aggressively enough to resolve sense-and-avoid issues because the additional redundant systems that must be engineered into the UAS add additional weight and limit the military utility of DoD UASs. Additionally, without sense-and-avoid improvements to UAS's the DoD will continue to rely on segregated airspace to employ UASs in NAS and international air spaces. Ultimately, the FAA's failure to keep pace with FAA Modernization and Reform Act timeline slows UAS integration into the NAS and UAS integration will not be completed by September 2015 as planned. A contributing issue to the FAA's slow pace to airspace integration is a result UAS's reliance on continual ground to aircraft control communications systems. Communications is further expanded on in the "communication" section.

Communications

Airspace command and control in the combat zone is becoming more complex due to the proliferation of unmanned aircraft. DoD's desire is to operate unmanned systems in theater or within the United States and its possessions so that communication constraints do not adversely affect successful mission execution.[82] Overcoming limited bandwidth availability is costly and continues to challenge military planners.

The most significant limitation associated with UASs involves the unique requirement of UASs to be controlled through a data link. "Through most of the last decade," said Vice Admiral William Burke, the Deputy Chief of Naval Operations for Warfare Systems, "drones have been able to operate in a permissive environment, neither congested nor contested. [In the future], frequently the environment will be physically and electronically contested."[83] In contested airspace, the bandwidth available for UASs will not be as large as in later phases of an operation. Most UAS can fly pre-programmed missions; they still require some form of data link for aircraft systems/mission monitoring

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[82]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 60.

[83]Sydney J. Freedberg Jr., "Drones Need Secure Datalinks To Survive Vs. Iran, China," *Breaking Defense*, August 10, 2012, http://breakingdefense.com/2012/08/drones-need-secure-datalinks-to-survive-vs-iran-china/ (accessed October 27, 2013).

and manual flight control. Interruption or loss of the controlling data link could result in degraded mission effectiveness; mission failure; and, in extreme cases, loss of the UA.[84]

The C-band frequencies in particular prove to be problematic in expeditionary environments. For example, to counter the explosive hazard threat in Operation Iraqi Freedom, radio frequency jammers that operate in the C-band often interfere with full motion video and UAS operations.[85] Specifically they are vulnerable to electromagnetic interference; distance and power strength of the signal; and physical obstructions to the signal resulting in "lost link" which cause the UAS to return to home base or pre-programmed location. The current theater of operation has proved to be nearly void of electronic and control interference. UAS communication links are generally more critical than those required for manned systems. Due to the widespread proliferation of UAS, it is reasonable to believe that many peer like adversaries possess comparable unmanned systems technology. It would only then be reasonable to believe that those adversaries would have the technology and know how to conduct jamming or spoofing on the unmanned aerial vehicle system signals. The signal could be either a video frequency, or control frequency with the intent to make the UAS crash or prevent its use. A proven vulnerability of current United States UAS's is an adversary could tap into UAS video, telemetry, or control frequencies. This capability already exists; U.S. forces admitted that

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[84]Department of Defense, *Joint Concept of Operations for Unmanned Aircraft Systems* (Washington, DC: Government Printing Office, November 2008), I-4.

[85]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 69.

insurgents viewed UAS video feeds, but not telemetry or control, in Iraq.[86] In the most daunting scenario a capable adversary could take control of a UAS and land it to access cytological information. Iran apparently managed this feat in late 2011. The exact outcome and details are not publicly available knowledge. But it is clear that UAS's are constrained by their need to be in constant communication with controlling stations. UAS's do possess various communication avenues but each communication method has its own vulnerability.

The UASs are constrained by data links whether conducting line of sight (LOS) or beyond line of sight operations. LOS operating distances are affected by UAS equipment, terrain, and atmospheric conditions. Beyond Line Of Sight operations are sensitive to any anomalies in a complex communications relay structure.[87] Data link range is a function of antenna configuration and transmitter power, while the curvature of the earth restricts data link range due to the "radio line of sight." Today's operational level unmanned aircraft rely mostly on satellite communications (SATCOM) for communications. A large bandwidth is required to allow two-way communications for vehicle control and data exchange. Full Motion Video transmissions typically consume large amounts of bandwidth. The bandwidth must be robust enough to transmit two avenues of communication, the uplink and downlink. Uplink transmits command and control information from the ground station to the UAS while the downlink provides health and

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[86]Thomas Ricks, "Sharing Drone Feeds with the Enemy," *Foreign Policy*, December 18, 2009, http://ricks.foreignpolicy.com/posts/2009/12/18/ sharing_drone_feeds_with_the_enemy (accessed January 2, 2014).

[87]US, Department of Defense, *Joint Concept of Operations for Unmanned Aircraft Systems*, I-4.

status information from the UA to the operator.[88] For tactical UASs, a limitation exists in the fact that the range of the UAS must remain within LOS of the control set. A UAS cannot be controlled beyond the LOS of an Ultrahigh-Frequency radio link. SATCOM eliminates this problem, but the bandwidths available for SATCOM are not always available in all theaters due to satellite orbits. To overcome SATCOM limitations the DoD is forced to contract satellite capabilities with foreign companies to perform ISR mission.

A communications path must be provided to transfer critical ISR products throughout the joint operating area.[89] For strategic UASs, the only means of communication is through SATCOM. If the SATCOM bandwidth is not available, then the strategic UAS cannot fly in that theater. High capacity SATCOM is an essential element of ISR operations, currently the UASs primary mission. Today, much of our ISR information is passed over commercial satellite systems based on legacy equipment because the cost to transition to military satellite systems is high.

Given the current reliance on SATCOM, GPS navigation capability becomes critical in situations where SATCOM is degraded or not available. Also harsh electronic warfare (EW) environments may not have GPS available for timing and position data. The GPS receivers are located on the aircraft and only receive correction signals when LOS of the Differential GPS (DGPS) navigation aids at the launch and recovery location. Once outside of the range of the LOS link at the launch and recover area, reliance on

[88]Muraru, "An Overview on the Concept of UAV Survivability," 3.

[89]Department of the Air Force, *Air Force Aerial Layer Networking Enabling Concept*, 33.

satellite GPS is a must for two reasons: (1) GPS position data is needed for aircraft guidance, and (2) GPS position data provides target position data needed for exploitation of ISR data.[90] In a GPS jamming scenario, the UAS could potentially lose its ability to determine its location, altitude, and the direction in which it is traveling. Low cost devices that jam GPS signals are prevalent. According to one industry expert, GPS jamming would become a larger problem if GPS is the only method for navigating a UAS.[91] In the event of lost communications, a manned aircraft will typically press with the mission or return safely to a home base or alternate field.[92] Few instances of UASs interference are caused by accidental, malicious actions have caused UASs to crash or to be redirected.

The latest threats to unnamed aerial systems are not lethal systems but based on electronic warfare or information warfare techniques, that affect they electronic systems and subsystems such as communications, data links, and GPS systems.[93] In 2000 a team of US Air Force laboratory engineers put together a satellite jammer for $7,500; the engineers lashed together a mobile Ultrahigh-frequency high-power noise source that they could use to jam satellite antennas or military Ultrahigh-frequency receivers.[94] The

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[90]Ibid.

[91]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 15.

[92]Joint Chiefs of Staff, JP 3-52, *Joint Air Space Control*, III-11.

[93]Muraru, “An Overview on the Concept of UAV Survivability,” 2.

[94]Science News, “Space and Astronomy, Backyard Satellite Jammers Concern US Air Force,” April 25, 2000, last updated 2008, http://www.abc.net.au/science/news/space/SpaceRepublish_120537.htm abc.net.au (accessed April 15, 2014).

engineers built their home-made jammer using a gasoline-driven electricity generator, wood, plastic piping and copper tubing. The amplification and noise-generation electronics were obtained at an electronics enthusiast's swap meet. Of more concern is that this theory is being disseminated through the internet. A website found during research found a posting on "Before Its News", an unknown author provides the basics of "How to Kill UASs". As this article accurately points out, GPS is a secondary navigation system for most UASs. The site presents a concept that appears logical and plausible. The document explains:

> The UASs have two alternative systems for communication. Line of sight radio: In the military C-Band 500–1000 MHz that can be jammed with simple spark-gap radio. Satellite communication: In the Ku-Band between 10.95–14.5 GHz, and the satellite can be jammed. The Uplink-Band to the satellite is 13.75–14.5 GHz. The Downlink-Band from the satellite is 10.95–12.75 GHz. And you should jam the Uplink frequencies with a jammer directed at the satellite. Every military base has their own UASs that must be operated through the C-band radio. C-band radio is also reported to be used for takeoff and landing. Which means that the C-band radio is your primary target. The C-band radio is also easier to jam.[95]

The document also explains the concept graphically. If this concept could be executed to successfully "kill" a UAS, it presents a complex obstacle for current UASs and daunting challenge autonomous operations.

With this knowledge available to anyone with internet access, the question is now becoming what frequency band or bands to use for UAS communications? The lack of protected radio-frequency spectrum for UAS operations heightens the possibility that a

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[95]Before Its News, "How To Kill A Drone: Since Drones Can Kill Americans, Americans Can Kill Drones, Here's How," February 5, 2013, htttml://www.before itsnews.com (accessed April 15, 2014).

pilot could lose command and control of a UAS.[96] While the Office of the Secretary of Defense has mandated the use of Ku-band Common Data Links for Group 2 and Group 3 UASs. To date, not all UASs have not made this transition, mainly because of the technical challenge of using Ku-band on an aircraft that demands minimal size, weight and power consumption.[97] Many smaller unmanned systems utilize various radios and split data, control, and voice. As unmanned systems become more sophisticated, the required network infrastructure and bandwidth that enables their capabilities must also evolve. Bandwidth is limited and demand is growing exponentially. The DoD continues to match unmanned system needs with commercially available SATCOM bandwidth where possible. This alone will not satisfy unmanned communication needs especially when other nations are competing with the U.S. for SATCOM bandwidth in the commercial arena.

The inclusion of communications into the *Unmanned Systems Integrated Roadmap FY2011-FY2036* has not driven the DoD to completely overcome UAS communications limitations, however, the DoD has improved the ability to reduce the impact of LOS, SATCOM, and GPS jamming by employing a variety of UASs with different communications capabilities. Pre-programmed responses to lost link scenarios prevent total loss of UASs. Additionally, the use of higher frequency wavelengths that expand bandwidth and provide more jamming protection improve UAS communication

[96]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 14.

[97]Steve Gardner, "Trends in Communication Systems for ISR UAVs," *Milsat Magazine*, January 2009, html;//www.milsatmagazine.com (accessed October 13, 2013).

reliability. Another long standing issue to UAS integration is the training of UAS operators, which is discussed in the following section.

Training

The DoD can acquire and deliver the most technologically advanced piece of machinery, but if the operators, maintainers, and support personnel are not properly trained, there is no war fighting capability.[98] In the August 2010 edition of *Air Force Magazine*, John Tirpak reported that by the coming decade, USAF will have expanded the UAS fleet from 200 UASs to around 1,100. While this is an issue identified for unmanned systems, it really is a standing concept in all areas of the military. The military aviation community has always recognized that they must have adequately training and combat proficient pilots. Pilots must not only be proficient technicians, they must also be acutely aware of the environment in which they operate aircraft. If the DoD hopes to fully man UASs they will demand more time and greater volumes of airspace to train with increasing capabilities of unmanned vehicles and their sensor suites to can and maintain minimum qualifications.

The DoD has historically been slow to initiate formal training venues for UAS operators in part due to the nature of UAS historical employment. One must consider the traditional uses of UASs as a limitation to pilot training. UAS mission traditionally have been that of clandestine and covert nature. The initial planned use of the UAS was to collect photographs of unsuspecting countries in which the US hoped to gain intelligence while having the ability to deny their actions. This was proven hard to do when U2s

[98]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 72.

containing humans were shot down over other countries. Unmanned aircraft, quieter and smaller, could be unmarked and virtually unnoticeable and easily destroyed if needed with little to no evidence the aircraft was there. These covert specialties are not standard in the DoD task list. They are, however, specialties of other US organizations such as the Central Intelligence Agency. Therefore, it is understandable that only small groups of specialists with special access were trained to operate the UASs, limiting the US's ability to "grow" UAS operators. Not until UASs were proven in limited operations did the US military begin employing them on a large enough scale to warrant a full training schedule. Nineteen ninety five was a historic year for UASs, because the Air Force formed the 11th Reconnaissance Squadron at Creech Air Force Base, Nevada. This was the service's first-ever UAS squadron.[99] Since then, every service has stood up official training schools for UAS operations.

The Army, Navy, and Marines have arguably had a much smaller hurdle within their organizations. Warrant Officers, an extension of the enlisted corps, have flown aircraft for the Army for many years. Their role is one of a technically proficient operator that is not burdened by the additional duties of command and the need to professionally progress outside of their weapons system. Whereas Air Force UAS pilots fall into the same category as manned pilots and until recently were managed as holistic group of pilots, pitting manned and unmanned aviators in the same category for promotion. The Air Force has addressed that by creating a direct UAS pilot course that provides limited "traditional' aviation training and more system specific training in their respective UAS platforms.

[99]John A. Tirpak, "UAVs With Bite," *Air Force Magazine* (January 2007): 1.

Colonel Bradley T. Hoagland's monograph as a senior fellow at the Brooking Institute reports in *Manning the Next Unmanned Air Force Developing RPA Pilots of the Future* that in regard to pilot accession quotas, the Air Force requirement in FY12 was to train 1,129 traditional pilots and 150 Remotely Piloted Aircraft (RPA) pilots. However, the Air Force was not able to meet its RPA training requirements since there were not enough volunteers. Only 82 percent of the Undergraduate Remotely Piloted Training slots were filled Air Force-wide in FY12 while 100 percent of Undergraduate Pilot Training slots were filled. As the Air Force looks into FY13 requirements, it appears a similar anomaly exists. As of January 2013, the United States Air Force Academy only had 12 volunteers for 40 Undergraduate Remotely Piloted Training slots after round one of their assignment process. His research has prompted the United States Air Force to take steps to reform the RPA career field for its UAS pilots.[100]

It should be highlighted that once the RPA candidates graduate from Rated Flight School (RFS), there is a 100 percent graduation rate from follow-on training at Undergraduate Remotely Piloted Training and the Formal Training Unit. Obviously this indicates that the RFS program is adequately training these pilots for follow-on training in the RPA pipeline, but it is still inefficient and unacceptable for attrition rates at RFS to exceed Initial Flight Screening at three times the rate.[101] One contributing factor may be

[100]Caitlin Lee, "USAF Studying Low RPA Pilot Accession Rates," *IHS Jane's Defense Weekly* (August 23, 2013), htttml://janes.com (accessed December 8 2013).

[101]Bradley T. Hoagland, "Manning the Next Unmanned Air Force Developing RPA Pilots of the Future," Brooking Institute, August 6, 2013, http://www.brookings.edu/~/media/Research/Files/Papers/2013/08/06%20Air%20Force%20Drone%20Pilot%20Development%20Hoagland/Manning%20Unmanned%20Force_FINAL_08052013.pdf (accessed March 10, 2014), 11.

the respect in which commanders have for UASs. For example the Air Force permits those "washing-out", or not finishing Undergraduate Pilot Training, to volunteer for the Undergraduate RPA Training track. This contributes to an RPA culture that is comprised of pilots in the bottom of their class and/or perceived as "not good enough" for Undergraduate Pilot Training. The DoD clearly recognizes the need to train additional UAS operators; the DoD had fallen well short of solving the problem. A result of the RPA surge in the 2008 to 2009 timeframe during which pilots were cross-flowed into the RPA career field from almost every other major weapon system in the Air Force was very few, if any, traditional pilots actually volunteered for the RPA community, most commanders generally sent captains that were in the bottom half of the pool of eligible pilots.[102] The Air Force continues to fight UAS stigma, but the Air Force is in the mix of overcoming the "white scarf syndrome," as described by Carl Builder in his book *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the US Air Force*, which refers to the Air Force's institutional preference for manned aircraft versus alternative weapon systems, such as UASs.[103]

Additionally, the DoD may be simply selecting the wrong type of person for the job. The 711th Human Performance Wing (711 HPW) at Wright Patterson Air Force Base has conducted human factors integration research and reported that there are cognitive and multi-tasking differences between traditional and UAS pilots. The study concluded by stating that "advances in automation are decreasing the need for UAS pilots

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[102]Ibid., 13.

[103]Carl Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the US Air Force* (New Brunswick, NJ: Transaction Publishers, 1994), 35.

to have traditional pilot skills and instead emphasize monitoring and collaborative decision making skills.[104]

UAS pilot career field hovered around the 50-person level in the late 1990s but now exceeds 1,300 and is growing to approximately 1,650 by FY17.[105] The high operations tempo resulted in the inability of UAS pilots to participate in educational, training, and staff officer opportunities on par with their peers, even though the Air Force realizes it must still deliberately identify and professionally develop these aviators that have unique RPA backgrounds and skill sets.[106] The Army is overcoming this phenomenon by utilizing its enlisted and warrant officer corps to pilot small tactical UASs.

To help attract more RPA pilots and, more significantly, formally recognize the importance of those that operate unmanned aircraft, the AF created the 18X AF specialty code (AFSC) in 2010, with the long-term goal of building a cradle-to-grave training pipeline for RPA pilots.[107] The birth of this career field is intended to end the system that has forced a large number of traditional pilots to cross-flow to RPA for one tour before heading back to their original weapon system. One notable initiative is to attract civilian UAS hobbyist into the UAS profession. The USAF is trying to attract more volunteers into the UAS programs in order to improve the initial UAS trainee skill, ultimately

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[104]Anthony Tvaryanas, "Human Systems Integration in Remotely Piloted Aircraft Operations," *Aviation, Space, and Environmental Medicine* 77, no. 12 (December 2006).

[105]Hoagland, *Manning the Next Unmanned Air Force Developing RPA Pilots of the Future*, iv.

[106]Ibid., 7.

[107]Ibid., 4.

increasing training output. An initiative underway is to stand up a small UAS cadet club, similar to the aero club that currently exists at United States Air Force Academy and many other Air Force bases. Within this club, cadets would receive initial training at Hurlburt Field, Florida, on the Raven and Wasp “small” UASs, then would upgrade to instructor and eventually conduct the hands-on initial training at United States Air Force Academy.[108] While the Air Force has restructured its training programs to enhance officer UAS training the Army has had to improve UAS training for its enlisted corps.

The Army’s UAS program came to fruition in 1991 when the Pioneer UAS successfully flew over 300 combat missions during Operations Desert Shield/Storm. The *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035* concludes that more than 328 Army UASs deployed Iraq and Afghanistan theaters, which have flown in excess of one million hours in support of combat operations. To keep pace with the prolific UAS growth, the Army will train more than 2,100 UAS operators, maintainers, and leaders in fiscal year 2012, which is an 800 percent increased compared to the fiscal year 2003 training quota.[109] The Army’s UAS maintainer training base has struggled to meet training demands due to sharing their maintainer corps with OH-58D maintainers. Soldiers were required to attend initial training at Fort Eustis with follow-on UAS training at Fort Huachuca. In early 2010 a standalone UAS maintainer specialty was created, allowing direct accessions of non-prior service soldiers into UAS maintenance,

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[108]Ibid., 12.

[109]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 1.

reducing average training time from 35 weeks to 17 weeks.[110] Because the US Army has embedded UAS equipment and operators within their echelons, they are able to conduct more integrated UAS training with organic force. Unlike the Air Force which has segregated its UAS fleet from training with other aircraft. Due to the Air Force's UAS fleet being a high demand low density platform its high operations tempo does not allow for integrated training on a large scale with other weapons system. Instead, as automation technology advances, the role of the UAS operator will continue shifting towards mission management of several different UASs, with demands for far more decision making, course of action planning, collaborative planning, and resource management than for stick-and-rudder piloting skills.[111]

Both the Navy and the Marines have recognized that UAS require a new kind of UAS operator to control their UAs fleet. Traditional manned aircraft pilot training and proficiency with complex video games are simply not enough to prepare tomorrow's UAS pilots. Replicating the manned aviation select-train-equip approach is an inefficient solution at best and a potentially disastrous one at worst.[112]

That said, the DoD has only recently begun to understand the value of the training in the joint realm. Goldwater-Nichols Act of 1986 restructured the U.S. military to increase joint cooperation, training and integration between DoD services; however, unmanned systems have traditionally been developed by each service to meet service

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[110]Ibid.

[111]John Keller, "Navy Asks For Industry Help to Establish Effective Screening and Training for UAS Pilots," August 9, 2012, Militaryaerospace.com (accessed April 15, 2014).

[112]Ibid.

needs. Each service is authorized to organize, train, and equip its respective UAS forces. The Air Force and Navy recently signed an agreement to seek common training and support functions for the Global Hawk and Broad Area Maritime Surveillance aircraft, toward reduction manpower and lowering costs.[113]

In the earliest stages of UAS development, civilian contractors were predominately responsible for providing the new equipment training during system fielding. UAS's are now so wide-spread in their use that the military must now take full ownership of UAS training to operate the fleet. The Army has made great strides in UAS training and has developed a formalized UAS training strategy to align with the Army's UAS roadmap vision.[114] The UAS training battalion located at Fort Huachuca conducts initial entry and MOS producing training for operators, maintainers, and leaders on Group Three and above UAS. Additionally the training battalion supports the joint community by training a large portion of the Marine Corp and Navy UAS personnel.[115] Enlisted Soldiers, Sailors, and Marines attend a UAS Operator Common Core course prior to attending a MOS qualification course or a UAS transition course for Shadow and Hunter systems. Officer courses consist of either the UAS Warrant Technician Course or the USMC Mission Commanders Course.[116] Additionally, the 2nd Battalion, 29th Infantry Regiment, 197th Infantry Training Brigade at Fort Benning, Georgia

[113]Tirpak, "The RPA Boom," 42.

[114]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 36.

[115]Ibid., 37.

[116]Ibid.

accomplishes Raven UAS training. They also conduct mobile training teams to that significantly increase the annual throughput. The US Army has initiated a program at Fort Benning, Georgia to train a selected group of tactical UAS operators. Calling them "master trainers", the Army is certifying UAS operators to return to their units and they have the authority to qualify new soldiers on Raven and Puma UASs at their home stations.[117] The separation of pilot and aircraft creates a number of issues, including loss of sensory cues valuable for flight control, delays in control and communications loops, and difficulty in scanning the visual environment surrounding the unmanned aircraft. A limitation within the Army and Joint community, with respect to Groups One, Two, and Three, is the inability to the UAS GCS to process, prepare, and disseminate Full Motion Video and metadata information from missions.[118] The Department of the Army is working to develop universal ground control stations, which would allow UAS pilots to fly different types of UASs without having to be trained on multiple configurations of a ground control station.[119]

The DoD now understands that not only training of unmanned aircraft controllers is imperative to successful unmanned aerial vehicle operations but additionally training joint staffs how to utilize unmanned systems is critical to their successful employment. The DoD's strategy will leverage the skills and expertise of each organization and build

[117]Zach Rosenberg, "Army Rethinks UAV Training," *Flight*, November 26, 2012, html://flightglobal.com (accessed December 8, 2013).

[118]Department of the Army, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035*, 17.

[119]Government Accountability Office, GAO-13-346T, *Unmanned Aircraft Systems Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development*, 16.

on foundational efforts already completed or underway within the Services.[120] Lt Gen. David A. Deptula the Air Force's Chief of Staff for intelligence-surveillance-reconnaissance (ISR) office, stated in *Air Force Magazine* there's nothing unmanned about them. It can take as many as 170 persons to launch, fly, and maintain such an aircraft as well as to process and disseminate its ISR products.[121] UAS need to be habitually integrated into the kill chain in training scenarios. Commanders must be educated on the use of UAS as combat resources, and learn how to train with these relatively new assets.[122]

It is critical that UASs be incorporated into current operational war plans and Time-Phased Force Deployment Data (TPFDD), which state what types of units will deploy to a particular theater and when. Moreover, these UASs should be integrated into various training exercises such as Red Flag Exercises so that weapon systems may practice with all the assets that they will employ with in combat. Red Flag Exercises are Air Force administered exercises that attempts to simulate the first 10 days of air warfare. The exercise's goal is to give a new aviator the experience and awareness of large force air operations. The axiom "train the way you intend to fight" has been repeatedly proven true and should also be applied to UAS integration. In order to enhance UAS training they must be integrated into large force exercises to validate the concept and train with the warfighters that they will operate with in combat. Currently, UASs are not

[120]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 74.

[121]Tirpak, "The RPA Boom," 37.

[122]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 74.

incorporated into Red Flag Exercises most likely due to their low density and high demand on platforms and crews.

Training UAS operators and maintainers have improved as a result of the *Unmanned Systems Integrated Roadmap FY2011-FY2036* call to produce better trained members. Historically, UAS training was restricted to only a few operators working in special programs but with the explosion of UAS employment, all services have instituted comprehensive UAS training programs. Additionally, each service has improved their selection process for UAS pilots. Furthermore, the establishment of dedicated UAS job specialties will help to build corporate knowledge within the UAS community.

Manned Unmanned-Teaming

The UASs can play a major role in obtaining dominance over an enemy by filling the current gaps in the capabilities in US weapon systems. By employing UASs to assist in building the air picture, strike and interdiction weapon systems will also gain valuable information necessary to successfully complete their missions. Demand for the capabilities that UASs provide continues to grow in ongoing conflicts. Compared to manned aircraft, the combat UAS can loiter over a target area longer. A fully armed F-16 will most probably be in the target area for 30 minutes before having to air refuel. A Reaper UAS, with a comparable weapon load, could orbit the area for 18 to 20 hours.[123] Incorporating current unmanned systems with manned systems, MUM-T refers to the use of an unmanned, flying sensor which can be used to deliver additional situational awareness beyond the manned platforms organic capabilities. MUM-T is the overarching

[123]Tirpak, "UAVs With Bite," 4.

term used to describe manned and unmanned platform interoperability and shared asset control to achieve a common operational mission objective.[124] The goal of the unmanned vehicles is to provide a force multiplier for the human warfighter that enables the human and the unmanned vehicle to perform tasks more effectively or more safely than a human warfighter can alone.[125] Missions that occur with little reconnaissance prior to take off in a highly dynamic environment can benefit from MUM-T operations. Missions that require quick reaction without fully developing situational awareness of the threat, such as personnel recovery operations can be expedited with effective MUM-T.

The MUM-T concept is not a new use for UASs. The concept of MUM-T has been proven viable on numerous occasions. The US has already proved the concept of providing jamming for a UAS instead of the UAS doing the jamming during Vietnam. A factor which increased the survivability of the drones over high threat areas was electronic jamming of early warning, surveillance, acquisition, and terminal threat radars by Air Force and Marine electronic countermeasures (ECM) aircraft.[126] Additionally, MUM-T was employed in the late 1960s when the USAF flew AQM-34 equipped with Maverick missiles from airborne C-130 aircraft. However, the DoD lost favor with the MUM-T concept after the Vietnam War concluded.

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[124]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 82.

[125]S. Jameson, "Collaborative Autonomy for Manned/Unmanned Teams" (paper presented at 61st annual American Helicopter Society Grapevine, TX, June 1-3, 2005), htttml://www.Atl.lmco.com (accessed April 29, 2014).

[126]Department of the Air Force, *Project CHECO Southeast Asia Report, BUFFALO HUNTER, 1970-1972* (Washington, DC: Government Printing Office, 1973), 22.

The obvious attribute of UASs is that commanders can send them over heavily defended enemy positions where the threat to manned aircraft is inordinately high.[127] The use of UASs as decoys was adopted by the Israeli Air Force, which employed US-made BQM-74 Chukar target drones as decoys for the first time in the 1973 Yom Kippur War as part of a deliberate, phased attack plan designed to suppress missile defenses. The drones (looking like an attacking formation) prompted Egyptian missile radars to emit. Radar homing missiles right behind the drones slammed into the radar sites, blinding them for the manned aircraft strike that dropped deadly ordnance on the missile sites. Israel repeated the trick in the 1982 Bekaa Valley strike using a variety of indigenously produced decoys. In a deliberate reprise of those Israeli tactics, the US Air Force launched 40 Chukar target drones into Baghdad on the first two days of the Gulf War in 1991.[128] Their capabilities have been improved and they have been used more in multi-role capacity, however, they still exhibit vulnerabilities that restrict their employment. The US's use of UASs to suppress enemy air defenses emerged in the first months of OIF. The Air Force attempted to use Predators to destroy Iraqi defense installations. However, the Predator proved too slow and vulnerable for Iraqi MIGs, which quickly shot down several Predators.[129]

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[127]Ibid., 25.

[128]David A. Fulghum, "US Air Force Target Drones Baffled Iraqi Defense Radars," *Aviation Week and Space Technology* 135, no. 6 (August 12, 1991).

[129]Andrew Callam, "Drone Wars: Armed Unmanned Aerial Vehicles," *International Affairs Review Journal* 18, no. 3 (Winter 2010), http://www.iar-gwu.org/node/144 (accessed November 1, 2013).

The concept was reenergized in the early 2000. The *Unmanned Aerial Vehicle 2002* road map called for MUM-T to be planned for and integrated into DoD systems. The term used then was hunter-killer. It was described as the next level of weaponization Concept of Operations intended to mitigate the aforementioned ISR system design limitations, by recognizing that when UASs work in concert with other UASs (or other manned vehicles), one component may be optimized as the sensor/targeting device and the other component may then effectively operate as the weapons delivery vehicle.[130]

The current issue is the practicality of the concept. The DoD is evolving the MUM-T concept using it as a "loyal wingman" to assist in target identification, ISR, and most simply as a decoy to confuse the enemy. Generally, MUM-T requires the unmanned system to be paired with a manned system working in concert. Commanders recognized that they could dramatically reduce sensor-to-shooter times and improve situational awareness of helicopter pilots, while drastically reducing collateral damage and the potential for fratricide.[131] While MUM-T theoretically maximizes commanders resources, in reality it currently limits resources because it still requires a crewmember to fly the manned aircraft while another flies the unmanned aerial vehicle. If the DoD can achieve higher levels of unmanned system autonomy, the MUM-T concept could meet its full potential in the near future.

The Army is already fielding manned and unmanned aviation platforms in the same units. Army scout helicopter squadrons are being paired with General Atomics MQ-

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[130]Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap 2002,* 177.

[131]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 84.

1C Gray Eagle UASs to aid in target acquisition and reconnaissance missions. Kiowa Warrior armed scout helicopters and the Apache Block III are being teamed with Shadows. A fleet that has flown 750,000 hours, 92 percent of which was in combat, the Shadow can beam live video and targeting information directly into the cockpit of either helicopter.[132] Amid broad cuts and a restructure of its aviation assets, the Army has preserved funding for data-link integration of its AH-64 Apache attack helicopters with RQ-7B Shadow UAS that will enable new tactics, techniques, and procedures to compensate in part for the retirement of the AH-58 Kiowa Warrior reconnaissance and armed reconnaissance helicopters.[133]

Another, more controversial component to teaming UASs with manned vehicles is the level of autonomy those unmanned systems are granted. To alleviate human pilots from having to control UAS flights at teaming levels four and five, the unmanned platforms will have to accomplish some tasks on their own.[134]

The U.S. military currently authorizes Joint Force Commanders to use any unmanned aircraft available to them in order to meet the demands of their missions.[135] Joint Publication 3-52, *Doctrine for Joint Airspace Control*, advocates exploiting the

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[132]Dan Parsons, "Teaming Pilots with Drones Hampered by Technology," *National Defense Business and Technology Magazine*, July 20, 2012, html://www.nationaldefensemagazine.org (accessed December 20, 2013).

[133]Brannen, *Sustaining the U.S. Lead in Unmanned Systems Military and Homeland Considerations through 2025*, 9.

[134]Parsons, "Teaming Pilots with Drones Hampered by Technology."

[135]Department of Defense, Joint Publication (JP) 3-30, *Command and Control of Joint Air Operations* (Washington, DC: Government Printing Office, January 2010), III–34.

endurance of UASs: most larger UA have considerably longer endurance times than comparable manned systems. Planners must exploit this capability when tasking UA assets.[136] The chain of command for the authorization to deploy lethal force from a remotely piloted aircraft involves a combination of “eyes on target” from the pilot in the U.S., a regional area commander, and a local commander on the ground in theater that ultimately authorizes the pilot to fire. Humans are still very engaged in the control loop. UASs currently operate at “level one” integration where the information they gather is interpreted by a remote operator, then communicated to the pilot of a manned aircraft or to troops on the ground. Some operate at “level two,” where the drone’s video feed is directly linked to the flat-panel display of a manned aircraft.[137] Leaders throughout the Defense of Department see the potential in teaming drones with other platforms. For example, they could pair swarms of UASs with the new F-35 Joint Strike Fighter once it comes online, or with helicopters aboard the Littoral Combat Ship. Unmanned mine hunters could operate alongside future attack submarines.[138] But there are significant technological and logistical obstacles that must be overcome before the grand vision of seamless MUM-T is a reality. Those include figuring out how man and machine will interact and in what form information will be delivered to pilots. Helicopter and jet pilots are already inundated with information from sensors on their own aircraft and radio communications, not to mention enemy fire. Introducing another source of information or controls for another platform into the cockpit could be distracting and potentially

[136]Joint Chiefs of Staff, JP 3-52, *Joint Airspace Control*, III–11.

[137]Parsons, “Teaming Pilots with Drones Hampered by Technology.”

[138]Ibid.

disastrous. As technology progresses to level three, pilots or co-pilots of manned aircraft will take control of the drone's sensors. At level four, aircraft pilots will control the drone's flight and firing mechanism. Ultimately, with level-five teaming, manned aircraft crews will take complete control of their partner drones to include takeoff, landing and flight and fire control.[139]

Manned Unmanned-Training, while not an entirely new concept, has proven effective in reducing risk to humans while expanding battlefield situational awareness. To date, the Army is the only service operationally fielding MUM-T. It is unclear if the other services have been slow to field MUM-T because they lack the capability to integrate UAS with current manned systems or, more likely, they have not encountered an air or sea battlefield that will allow for MUM-T operations. Furthermore, with the emphases the *Unmanned Systems Integrated Roadmap FY2011-FY2036* places on MUM-T provides a foundation for the DoD improve UAS autonomy incrementally.

Conclusion

While the *Unmanned Systems Integrated Roadmap FY2011-FY2036* pushes for UAS operations that sound revolutionary to most, the *Unmanned Systems Integrated Roadmap FY2011-FY2036* is lagging behind where it should be. Nearly every focus area of the *Unmanned Systems Integrated Roadmap FY2011-FY2036* has been highlighted for improvement in the past. The *Unmanned Ariel Vehicle Roadmap 2002* noted the need for integration of UASs into US National Airspace structure, both civil and military.[140] Flight

[139]Ibid.

[140]Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap 2002*, 139.

operations standards are those standards required to operate the UAS in the real world airspace occupied by both manned and unmanned aircraft. These include the standards for flight clearance; operations with Air Traffic Control, aircraft certification standards, aircrew training requirements, etc. While many of these standards will parallel those used by manned aircraft, they must also be tailored to the specific environment of the unmanned platform.[141] Dr. Daniel L. Haulman of the Air Force Historical Research Agency identified some of the exact same progression areas in June 2003 in is paper *US Unmanned Aerial Vehicles in Combat, 1991-2003* he asserts **"**Newer UASs under development should have more autonomous control so that they need less pilot correction. This will include automatic collision avoidance. Improved mission control capabilities should allow multiple UASs to fly in a cooperative groups and formations." Furthermore the February 2004 *Defense Science Board Study on UASs and UCAV* identified five areas the US needed to further UAS development. Their findings further reinforce the long standing need for UASs to progress in many of the same areas the *Unmanned Systems Integrated Roadmap FY2011-2036* cites. The Defense Science Board found the DoD needed to address communication bandwidth constraints, to consider approaches to common UAS mission management, work to allow UASs unencumbered access to the National Airspace System (NAS) outside of restricted areas here in the United States and around the world, address selected technology issues, and carefully investigate approaches that could allow UASs to operate with more persistence. A decade later the U.S. remains short of these achievements.

[141]Ibid., 149.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The final chapter of this thesis provides a conclusion to a qualitative study examining the DoD's progress in the areas the *Unmanned Systems Integrated Roadmap FY2011-2036* identified as important focus areas needing development in order achieve future DoD UAS integration. Each focus area was evaluated in the previous chapter to formulate a factual basis to evaluate the DoD's capability. Those findings will be discussed in the following text. First, an overall synopsis is provided, followed by a specific conclusion for each focus area.

The DoD believes unmanned systems will be critical to U.S. operations in all domains across a range of conflicts, both because of capability and performance advantages, and the ability for unmanned systems to take greater risk.[142] UASs have not proved fully capable of shooting down enemy airplanes, airlifting troops or equipment, dropping heavy bombs, or refueling other aircraft, however it is plausible that they soon will. UASs probably will not replace manned aircraft near future, but they will continue to provide commanders with more effective tools to wage war. Simply investing development dollars into unmanned systems that have a direct combat role, such as air-to-air or air-to-ground will not bring the UAS into complete balance within the US military. Affordability is a persistent myth surrounding the UAS issue, but for the sophisticated types pursued by the Air Force, history shows that taking the pilot out of the

[142]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, 13.

cockpit costs money.[143] The idea that UAS are 'unmanned' is a misnomer. While the aircraft itself is not manned, the system is manned. Although UAS are operated with varying degrees of autonomy, they all require some amount of human interface throughout the mission.

The *Unmanned Systems Integration Roadmap FY211-FY2013* achieves its purpose as a forward thinking document that provides guidance for the DoD regarding UAS integration. The document lays out seven areas, six of which have been analyzed throughout this paper. When all areas are evaluated as a group, it is clear that the DoD has selected areas that will enhance UAS employment in future operations. Studied individually, areas such as autonomy and airspace integration are either lacking functionality in practical application, are bogged down by safety and ethical quagmires, or legally require insurmountable attention to see fruition in the near future. The FAAs failure to meet milestones within the congressional mandated timeframe is severely restricting UASs widespread use by civilian and government agencies. As a result, commercial companies are may be shying away from aggressive UAS development that would help improve UAS innovation. DoD UAS development will be enhanced once the FAA sets definitive guidelines for UAS integration into the NAS. A more detailed assessment of each focus area is discussed next.

Interoperability

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* identified interoperability as the most critical area to focus UAS development. The Roadmap

[143] Thomas P. Ehrhard, *Air Force UASs The Secret History* (Washington, DC: Government Printing Office, 2010), 24.

directs that interoperability of UAS systems must be improved so that UASs can operate seamlessly across the domain of air to improve utility and reduce life-cycle costs.[144] The roadmap was correct to identify interoperability as a focus area and the DoD is generally progressing in regards to interoperability of its unmanned systems, but lacks significant progress in the sub-focus area of commonality. Prior to the *Unmanned Systems Integrated Roadmap FY2011-FY2036*, DoD's approach to software and hardware acquisition and development relied on dedicated design for each UAS system to accomplish a specific mission or capability.[145] The publication of the *Unmanned Systems Integrated Roadmap FY2011-FY2036* illustrates that the DoD recognizes that improving interoperability between UAS systems and there components will be critical to ensure UASs are flexible enough to meet mission needs. In this area, the *Unmanned Systems Integrated Roadmap FY2011- FY2036* addresses interoperability and the DoD is actively working to develop interoperability within its UAS fleet.

Research presented during this study shows that focusing on UAS interoperability is a correct focus area for the DoD to develop UASs. Chapter 4 highlighted that interoperability has been a recurring focus area for UASs. Also identified in the previous chapter, was the DoD’s current trend to search out technologies that allow for and enhance a platforms multi-role capability. Though difficult to standardize and implement, OAs foster greater innovation through a freer market for software and hardware solutions and allow smaller companies to compete. Open design will also allow control and

[144]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, V.

[145]Ibid., 32.

integration potentially of multiple platforms simultaneously.[146] Evidence presented in this paper shows that other areas identified in the roadmap are meeting DoD's vision of enhancing UAS integration with mainstream military equipment, concepts, and operations. Universal ground station have been proven effective as a control platforms allowing control of many tactical UAS’s and limited functionality with large UAS such as the Army's Grey Eagle. DoD’s adherence to STANAGs with NATO partners also reinforces the DoD’s continued efforts to gain more interoperability between unmanned aircraft and their controlling stations. Commonality between UAS platforms that will allow for a more plug-and-play utility is reportedly being developed, however, no firm evidence was found that allows us to conclude that the DoD is making significant progress with any foreign militaries in this sub-focus area.

The DoD is making progress perhaps slowly, but progress none the less. Continuing to focus on interoperability in all aspects of UAS employment will be critical if UASs are to be force multipliers in future operations. While this study has shown that interoperability is progressing as the *Unmanned Systems Integrated Roadmap FY2011-FY2036* requires, there is still question as to why it remains to be a focus area? This study identified that interoperability has been a focus area virtually since the first UAS Roadmap was produced. If the past trends of UAS interoperability remain constant the DoD will likely continue to place interoperability on future roadmaps.

[146]Brannen, *Sustaining the U.S. Lead in Unmanned Systems Military and Homeland Considerations through 2025*, 6.

Autonomy

Autonomy, as a focus area in the *Unmanned Systems Integrated Roadmap FY2011-FY2036* is a concept that draws close scrutiny for the public and policy makers. To improve UAS autonomy, the *Unmanned Systems Integrated Roadmap FY2011-FY2036* directs the DoD to pursue technologies and policies that introduce a higher degree of autonomy, reduce manpower and reliance on full-time high-speed communications links while reducing decision loop cycle time. At this point in time, focusing on increased autonomy is a prudent decision for the DOD to take. In order to maintain leadership in the UAS community DoD must continue to further develop technology that supports autonomous operations. Technological advances to software allow for faster more robust computing that may lead to full autonomy. For the DoD to disregard this technology could be a major mis-step in US UAS evolution. Other countries are keenly focused on autonomous capabilities that will likely be integrated into their weapons systems. The DoD cannot afford to wait and see what our adversaries can do. Autonomy will be increasingly necessary on the ocean's surface, in the air, and on the ground due to anti-access area denial technologies fielded by adversaries that will compromise communications through the electromagnetic spectrum that currently allow for remote-piloting and near-real-time exchange of information.[147] Breakthroughs in swarm technology may help to catapult autonomy in UASs, but for how the swarm concepts is better applied to MUM-T in order to gain more functionality with manned systems. However, any new introduction of autonomy into the present unmanned

[147]Ibid., 5.

platforms will open new lines of inquiry with respect to governance, accountability, permissible and ethical use of autonomous platforms.[148]

The current Roadmap fails to make this distinction, which allows too much "what if" discussion to slow progress. What must be fully considered is the level of autonomy that the DoD hopes to employ. The most basic current-generation unmanned systems require not only a platform, but sensors, a ground-control station, and human maintainers, operators, and specialists to exploit the information collected. They do not operate autonomously and decisions to use lethal force adhere to the same criteria as they would for any manned platform. Natural progression of UAS development is a UAS capable of truly autonomous operation. Their use will depend on how autonomous the technology of the time can make them and how willingly humans will allow the machines to make lethal decisions on their own.[149] Unless artificial intelligence reaches a point where it can replicate, if not transcend, human cognition and emotion, machines will not be able to act under ethical considerations or to imagine the consequences of action in strategic terms.[150] Technology will someday allow further reduced human control and involvement in the operations of these systems, but not for some time.[151] Until

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[148]John Markoff, "War Machines: Recruiting Robots for Combat," *New York Times*, November 27, 2010, http://www. Nytimes.com/2010/11/28/science/2robot.html (accessed February 4, 2014).

[149]Tirpak, "The RPA Boom," 37.

[150]Cole, "When Drones Decide to Kill on Their Own."

[151]Brannen, *Sustaining the U.S. Lead in Unmanned Systems Military and Homeland Considerations through 2025*, 4.

technology allows full autonomous capabilities, the DoD needs to decide how much autonomy is required to remain a dominant force.

The solution is not to determine regulations that will cover every possible situation in which autonomous UASs might find itself fighting. Rather, a more prudent action is to seek whether the environment exists or can exist where UASs can make strike decisions in keeping with the LOAC while also remaining in compliance with the professional military ethic and the Just War Tradition.[152] The increased use of autonomous platforms might make war itself less destructive and costly, but it might make it easier to rationalize their employment in inter-state conflict and could lead to our nation resorting to war in situations that may be better resolved diplomatically.[153]

Airspace Integration

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* Roadmap requires that DoD work to improve UAS airspace integration. While the guidance to complete this task is vague in the document the *Unmanned Systems Integrated Roadmap FY2011-FY2036* is absolutely correct to focus on airspace integration. The DoD has recognized that without a combat zone like Afghanistan to field new UASs, the UAS community will be confined to the domestic airspace for training. However, the DoD is constrained by the fact that they are only a user of the NAS, not a controlling force. While the DoD has a strong voice to advocate UAS integration, the NAS, specifically the FAA is at the helm

[152]Matthew S. Larkin, "Brave New Warfare: Autonomy in Lethal UASs" (Master's Thesis, Naval Postgraduate School, Monterey, CA, March 2011), 16.

[153]George Lucas, Jr., "Postmodern War," *Journal of Military Ethics* 9, no. 4 (December 2010): 298.

and must weigh integration efforts against commercial and civilian safety. Progress to airspace integration is well behind forecasted schedules and even further behind DoD's need to fly long range UAS in domestic airspace.

The UASs have proven to be a useful tool to service targets both lethal and non-lethally but the DoD has just recently recognized the need to integrate UASs in operations with other aircraft. However is appears the concept of sharing airspace between manned and unmanned aircraft is has not been fully developed. The FAA has involved industry stakeholders and academia in the development of standards and research for UAS operations and created the Unmanned Aircraft Systems Integration Office to facilitate integration of UASs safely and efficiently into the NAS.[154] However, the requirement to link the UA with the control element introduces limitations and vulnerabilities that do not exist with manned aviation. Procedural deconfliction may be a necessity to allow for the sheer number of smaller UAS operating at lower altitudes, but we must develop smaller, lightweight deconflicton technologies.

The DoD has not been aggressive enough in integrating UASs into operational airspaces. Proof of this limited attempt to integrate with other airspace users is simply stated in the guiding joint publication *Joint Airspace Control* as: "Procedural control measures need to be uncomplicated and readily accessible to all forces and disseminated in the ACP, ACO, and special instructions (SPINS) of the air tasking order (ATO). Furthermore, *Joint Forcible Entry Operations 3-18* dated November 27, 2012 has not been updated and only mentions that unmanned systems may be planned for and used,

[154]Department of Transportation, *Integration of Civil Unmanned Aircraft Systems (UAS) in the National Airspace System (NAS) Roadmap*, 4.

but does not address any limitations or priorities for their use. Use of these documents is essential for the planning and integration of manned and unmanned aircraft (UA) operations.[155]

Communications

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* Roadmap asserts that the DoD must address frequency and bandwidth availability, link security, link ranges, and network infrastructure to ensure availability of unmanned systems.[156] The area of communication remains the UASs albatross. It is logical and prudent for the *Unmanned Systems Integration Roadmap FY211-FY2036* to continue to place communications as a focus area. The DoD is working to overcome UAS communication issues, as they are the life line for command and control for the platform. UAS communication has always been the main limiting factor for UASs. In this one area, technology has not been able to keep pace with leaders' desires. Incorporation of GPS has greatly improved UASs ability to operate when ground station communications are interrupted. The addition to GPS has also enhanced targeting and surveillance on the battlefield, but GPS still remains vulnerable to jamming. SATCOM capability and the expansion of bandwidth by using super high and extremely high frequency wavelengths improve UAS communications but are susceptible to atmospheric irregularities that limit when and where UASs can be reliably flown. Additionally, SATCOM can be degraded by heavy vegetation and LOS with satellites. Small group (1,2,3) UAVs continue to rely

[155]Joint Chiefs of Staff, JP 3-52, *Joint Air Space Control*, I-5.

[156]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, vi.

on LOS communications which in some cases are a benefit, such as in a GPS jamming environment, but are a limitation when terrain features or buildings interrupt the control signals. There is no clear unclassified evidence that the DoD has developed the technology to overcome these issues, but the DoD continues to identify and negate the effects of degraded communications through detailed planning at all levels.

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* correctly addresses the need to improve communications capabilities in unmanned systems but the DoD has shown little progress in the area of communications. While the research conducted in strictly unclassified material did not uncover any marketable advancements to communication capability, it is very plausible that the DoD has achieved greater capability but kept the achievements out of public view. The DoD has not displayed any tangible evidence that UASs have been freed from their data link tethers. There are numerous challenges by essentially removing the cockpit from the airframe, most notably the necessity of data links for flight control and monitoring of the aircraft. Progress has been made in obtaining additional dedicated radio-frequency spectrum for UAS operations, but additional dedicated spectrum, including satellite spectrum, is still needed to ensure secure and continuous communications for both small and large UAS operations.

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* is correct to identify communications as a focus area that the DoD must expand its capability. If the DoD is to achieve additional UAS capability to operate in A2/D2 airspace with multiple unmanned and manned systems, the communications architecture must be more robust than current capabilities allow. The finite bandwidth now available for all military aircraft and future competition for existing bandwidth "may render the expansion of UAS applications infeasible and leave many platforms grounded."[157]

Training

The fifth focus area evaluated from the *Unmanned Systems Integrated Roadmap FY2011-FY2036* was training. The *Unmanned Systems Integrated Roadmap FY2011-FY2036* directs the DoD to ensure recurring UAS operator and joint training requirements are in place while instituting an effective strategy that will improve basing decisions, training standardization, and promote common courses resulting in improved training effectiveness and efficiency.[158] The DoD recognized prior to the roadmaps publication that UASs were becoming a critical part of military operations. They also recognized that the pool of UAS operators would need to expand to meet the growing demand for UASs. Therefore it was a prudent decision to include training as a focus area in the document. The area of training is the DoD's biggest focus area success.

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* is absolutely correct to identify UAS training as a focus area for future UASs development to address. Without adequate training programs the DoD can never hope to meet the growing need for UAS operators. Utilization of a UAS simulation environment capable of facilitating team training, especially in challenging dynamic situations, are important to both the initial and recurrent training of UAS operators.

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[157]Harlan Geer and Christopher Bolkcom, *Unmanned Aerial Vehicles: Background and Issues for Congress* (Washington, DC: Congressional Research Service, 2005), 21.

[158]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, vi.

The UAS requirement grows at a faster pace than the DoD can train personnel to operate these systems, it was apparent that the UAS career field was not properly identifying and professionally developing pilots. There was a significant institutional issue that confronted the UAS community, and those problems were not receiving the level of attention they deserved. The UAS career field was failing to accurately prescreen and access the most appropriate pilots to fly UAS, which is resulting in an attrition rate that is three times higher than traditional pilots.[159] The DoD has now begun initiatives to address training shortfalls but they will likely not fill all the needed UAS operator slots in the near future because the DoD has not yet found a way to standardize training across all services. This is partially due to the unique service requirements of each armed forces component, and partially because of the operator candidates they acquired for their respective programs. Whichever the reason, I agree with Colonel Hoagland's conclusion regarding UAS training and manning in the DoD. He says simply if a rated officer is more qualified to fly unmanned aircraft versus manned aircraft, then they should place them there.[160]

All branches of the DoD have adopted or initiated more comprehensive UAS training methods. Discussed previously, the army has achieved the most improvement in UAS training. The addition of UAS training brigades provide much more than a basic crash course in UAS operations. Their training programs lengths have been extended to ensure hands on training both live and simulation are incorporated with teaching concepts

[159]Hoagland, *Manning the Next Unmanned Air Force Developing RPA Pilots of the Future*, 8.

[160]Ibid., 17.

of operations for UASs. The Navy and Marines now use the Army training at Fort Huachuca to certify most of their operators. The Air Force too has improved their training programs by reducing the requirement to have seasoned aviators at the controls. Allowing operators to enter the UAS training program with basic airmanship qualifications has increased the number of applicants and decreased the non-volunteers. The Navy has begun using Air Force training programs to certify their MALE and HALE UAS operators. Due to the unique responsibilities of each service branch, the DoD will always be limited in their ability to jointly train all UAS operators. Baring those few instances were operations are conducted in a single environment, such as open sea operations, the services have achieved the DoD's vision for UAS joint training described in the 2011 roadmap. Because training is time intensive the DoD must continue to forecast UAS manning needs if they hope to fill all the control and maintenance requirements for future UASs. Furthermore, because decision makers and the American public demand the DoD be prepared to fight as a moment's notice, training will continue to be a UAS integration focus area on future roadmaps. While more UAS training will be required to man the fleet, the MUM-T concept may help to ease some of the burden.

Manned Unmanned Teaming

The *Unmanned Systems Integrated Roadmap FY2011-FY2036* is correct to identify MUM-T as a focus area. MUM-T is the DoD's second most successful focus area from the *Unmanned Systems Integration Roadmap FY211-FY2013* focus area. The *Unmanned Systems Integrated Roadmap FY2011-FY2036* identified MUM-T concept as an evolutionary step in UAS development. Therefore, to achieve full MUM-T potential the DoD must implement technologies and evolve tactics, techniques and procedures

(TTP) that improve the teaming of unmanned systems with the manned force.[161] MUM-T development has the potential to further shrink the tactical gaps between service components. Additionally, MUM-T has been proven to expand aircrews and analysts situational awareness of the battlefield. MUM-T seems to be the most quickly improving focus area. Integration exercises in 2012 and operational deployments in Afghanistan have proven MUM-T a useful progression in UAS development.

Selecting MUM-T as a focus area for the DoD makes it clear that leaders understand the impact UASs have on the battlefield and they are searching out avenues that UASs can be employed to enhance military operations. MUM-T is the rebirth of UAS operations of the past. Technology today, allows for more digital integration that enhances sensor to shooter times and the capability to link several platforms into a single system. Even though the purest MUM-T concept requires UASs to employ fully autonomously for flight and target cueing, MUM-T has not been burdened by the ethical issues that fully autonomous UASs are facing. At this early stage of MUM-T, humans remain very prominently in the loop which appears to be more palatable to the public. Perhaps MUM-T's best attribute is that it reduces manned aircraft exposure to unknown potentially dangerous situations. MUM-T will garner more weight within future roadmaps because MUM-T has already been fielded by army units in Afghanistan. The DoD will continue to us MUM-T as a stepping stone to overcome the public's perceptions that are holding UAS development back. Secondly, by keeping a man in the

[161]Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036*, vi.

loop, it is easily accepted as a minor step in UAS evolution that overcomes some of the communication, integration, and autonomy issues discussed throughout this paper.

Conclusion

The *Unmanned Systems Integrated Roadmap FY2011-2036* identified seven challenges for unmanned systems facing all military Services. Six areas were evaluated to answer the question: Is the DoD advancing UAS development in these areas as identified in *Unmanned Systems Integrated Roadmap FY2011-2036* and are the seven focus areas the correct areas to focus UAS integration efforts? Of the six areas evaluated, autonomy and airspace integration continue to fall short of the DoD's goals, but in both areas there is continued effort to collaborate to enhance UAS autonomy and provide a usable airspace construct for widespread UAS employment within the NAS. Communications remain the most difficult issue for UASs to overcome. UAS, by nature, will continue to be held at the mercy of LOS and jamming no matter where the ground station is in relation to the platform. However, the DoD continues to work aggressively to reduce communications vulnerabilities. Interoperability within data exchange terminals is progressing services, but a common airframe remains to be designed and fielded. The DoD has managed to transform DoD-wide UAS training by focusing training efforts in areas where multiple services can benefit from a joint training sites. Secondly, every service has incorporated UAS operator selection processes and training regiments that maximize UAS operator output. Finally, MUM-T's rebirth into military concepts of operations is working to reduce public distrust with autonomy and improving battlefield situational awareness.

During the course of research for this study the DoD produced its most current Roadmap to date. *Unmanned Systems Integrated Roadmap FY2013-2038* released in December 2013. It further addresses the DoD's vision and strategy for the continued development, production, test, training, operation, and sustainment of unmanned systems technology across DoD for the next 25 years. The new Roadmap continues to envision UASs conducting high-risk, electronic suppression missions deep inside the enemy's airspace. Decoy missions are also planned for the UAS, all in an effort to disable the enemy's ability to track incoming manned packages. What the future holds for UASs is almost the same we once thought about manned aviation. Technologies just need to catch up with ideas and concepts.

Unmanned Aerial Systems are often described publicly and privately by senior Air Force leaders as a key part of wars fought in a virtually uncontested airspace, but not a solution to the challenges the military faces against anti-access area-denial capabilities of potential adversaries that hold at risk U.S. conventional dominance and freedom of operations.[162] Whatever the future military architecture is, it appears clear that unmanned aircraft will not/cannot be a stand-alone magic weapon. Their reliance on external factors is too great. However, it is entirely reasonable to foresee UASs continue to integrate with conventional weapons systems in a complementary role. In a supporting role or as a single platform multi-role aircraft, UASs must become for survivable and affordable. The

[162]Aaron Mehta, "General: DoD Needs ISR Fleet for Contested Environments," *Defense News*, September 18, 2013, http://www.defensenews.com/article/20130918/DEFREG02/309180019/General-DoD-Needs-ISR-Fleet-Contested-Environments (accessed March 2, 2014).

following recommendations bring to light the DoDs need to address UAS survivability and cost as focus areas.

Recommendations

General Martin Dempsey said: “The ability to ensure operational access in the future is being challenged—and may well be the most difficult operational challenge U.S. forces will face over the coming decades.”[163]

The *Unmanned Systems Integration Roadmap FY211-FY2036* focuses the DoDs UASs integration efforts on valid areas; however, the most important area is left out of the document. Survivability of UAS’s is not highlighted as a main focus area. The document indicates that improvements in each listed focus area will increase the potential for UAS survivability. However, the document fails to make survivability an independent focus area for the DoDs action. Instead, the document relies on the implied survivability that will accompany enhancements to the stated focus areas. Curiously, many others have studied the lack of survivability of UASs in current and future operations. Furthermore, there is no shortage of researchers that have identified that the increased reliance on UASs presents unique issues. Research into this subject reinforces Jaysen Yochim’s ascertain that commanders rely upon UASs to increase their situational awareness far-too-much. Without unmanned intelligence products commanders will be reluctant to direct forces as required to achieve mission objectives. Lieutenant Colonel Kevin Murray is a Marine Corps pilot in command of UAS Squadron 1. UASs rule the skies over Afghanistan. But the next war may be a different story. “We’re fighting cavemen that

[163]Department of Defense, *Joint Operational Access Concept (JAOC)*, version 1.0 (Washington, DC: Government Printing Office, 2012), ii.

aren't shooting back," said Murray. "That's not where we're going."[164] Ultimately, for the adversary, denying commanders the ability to effectively use a UAS may represent a tactical victory.[165] Our post-9/11 enemy has either not recognized, or does not have the capability, to directly attack UAS operations outside of the theater of operations, however in the next conflict ground stations used for mission planning, launch and recovery, intelligence gathering, and controlling actual missions may require additional security to protect home based UAS Remote Split Operations.

The UAS operations in contested airspace require platforms with increased integration into airspace management systems and increased survivability. Additional research should be conducted to examine UAS survivability. The DoD could improve the survivability of UASs in a number of ways, such as making them faster, flying them higher, making them more durable, making them more stealthy. UAS trends favor an unmanned force if lower cost and sustained effectiveness can be proven. In 2002 the DoD's estimation of UAS cost expectation as based on the UASs generally smaller size and the mission of those systems needed to support a pilot or aircrew, which can save 3,000 to 5,000 pounds in cockpit weight. Beyond these two measures, however, other cost saving measures to enhance affordability tend to impact reliability.[166] What now

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[164]Freedberg, "Drones Need Secure Datalinks To Survive Vs. Iran, China."

[165]Jaysen A. Yochim, "The Vulnerabilities of Unmanned Aircraft System Common Data Links to Electronic Attack" (Master's Thesis, U.S. Army Command and Staff College, Fort Leavenworth, KS, 2010), 14-41.

[166]Office of the Secretary of Defense, *Unmanned Aerial Vehicle Roadmap 2002*, 185.

appears to be lost in the cost of UASs is the factor of reliability and more specifically the UASs survivability in an access denied theaters.

If future UASs are to be successfully employed across the joint force they must operate within the threat envelope of an enemy's anti-access and area denial capabilities. Passive susceptibility reduction measures, such as visual and acoustic signature reduction, may be the only way to increase the survivability of small aircraft due to their limited size. Larger aircraft can support the introduction of active susceptibility reduction measures such as flares, chaff, other decoys, and/or traditional aircraft vulnerability reduction design concepts.[167] UASs could mitigate some vulnerability through low observable integrated aircraft system design coupled with effective mission planning, air-to-air weapon systems for self-defense, a full suite of countermeasures including active defense systems such as chaff flares and mutual support from other aircraft, both manned and unmanned.

Further research is required to see how the U.S. can advance UAS employment within the military while reducing research and development cost? Additional capability could be relatively quickly and affordably leveraged from the existing unmanned force structure through networking across the air, ground, and maritime domains with other unmanned and manned platforms (including existing platforms). It would be a profound mistake to dismiss current systems as a leftover capability from past wars.[168] Why can the U.S. not retrofit existing manned aircraft to operate as unmanned systems? In lieu of

[167]Muraru, *An Overview on the Concept of UAS Survivability*, 3.

[168]Brannen, *Sustaining the U.S. Lead in Unmanned Systems Military and Homeland Considerations through 2025*, 1.

pursuing new cutting edge technologies to outfit future UASs, why would the DoD not look to its United States Air Force "bone yard" at Davis-Monthan Air Force Base, Arizona to reduce overall UAS costs? Immediately after World War II, the Army's San Antonio Air Technical Service Command established a storage facility for B-29 and C-47 aircraft at Davis-Monthan AFB. Today, this facility is the 309th Aerospace Maintenance and Regeneration Group (309th AMARG), which has grown to include more than 4,400 aircraft and 13 aerospace vehicles from the Air Force, Navy-Marine Corps, Army, Coast Guard, and several federal agencies including NASA.[169] Pulling these combat proven aircraft out of storage and retrofitting them to act a surrogate for new UAS technology and concepts could save developmental dollars.

This final chapter reviewed and presented the findings of six focus areas from the *Unmanned Systems Integration Roadmap FY211-FY2036* evaluating the focus areas to conclude if the DoD is advancing in the selected areas. Furthermore this study evaluated the six focus areas to answer if the DoD has identified the correct focus areas to promote UAS integration. When all areas are evaluated as a group, it is clear that the DoD has selected areas that will enhance UAS employment in future operations. Future roadmaps will likely include many if not all of the same areas, however, the DoD needs to address survivability and UAS cost more specifically in the future. Hoping that survivability and cost savings will be assumed guidance in other focus areas will not be sufficient for the DoD to produce fully integrated UASs in future combat operations.

[169]The Official Website of Davis-Monthan Air Force Base 309th Aerospace Maintenance and Regeneration Group, http://www.dm.af.mil/units/amarc.asp (accessed March 20, 2014).

APPENDIX A

DEPARTMENT OF DEFENSE UAS GROUP CLASSIFICAION

DoD Unmanned Aircraft Systems (As of 1 JULY 2011)

General Groupings	Depiction	Name	(Vehicles/GCS)	Capability/Mission	Command Level
Group 5 • > 1320 lbs • > FL180		•USAF/USN RQ-4A **Global Hawk/BAMS-D** Block 10 •USAF RQ-4B **Global Hawk** Block 20/30 •USAF RQ-4B **Global Hawk** Block 40	•9/3 •20/6 •5/2	•ISR/MDA (USN) •ISR •ISR/BMC	•JFACC/AOC-Theater •JFACC/AOC-Theater •JFACC/AOC-Theater
		•USAF MQ-9 **Reaper**	•73/85* *MQ-1/MQ-9 same GCS	•ISR/RSTA/EW/ STRIKE/FP	•JFACC/AOC- Support Corps, Div, Brig, SOF
Group 4 • > 1320 lbs • < FL180		•USAF MQ-1B **Predator**	•165/85*	•ISR/RSTA/STRIKE/FP	•JFACC/AOC-Support Corps, Div, Brig
		•USA MQ-1 **Warrior**/MQ-1C **Gray Eagle**	•31/11	•(MQ-1C Only-C3/LG)	•NA
		•USN **UCAS**- CVN Demo	•2/0	•Demonstration Only	•NA
		•USN MQ-8B **Fire Scout** VTUAV	•14/8	•ISR/RSTA/ASW/ ASUW/MIW/OMCM/ EOD/FP	•Fleet/Ship
		•SOCOM/DARPA/USA/USMC A160T **Hummingbird**	•8/3	•Demonstration Only	•NA
Group 3 • < 1320 lbs • < FL180 • < 250 knots		•USA MQ-5 **Hunter**	•45/21	•ISR/RSTA/BDA	•Corps, Div, Brig
		•USA/USMC/SOCOM RQ-7 **Shadow**	•368/265	•ISR/RSTA/BDA	•Brigade Combat Team
		•USN/USMC **STUAS**	•0/0	•Demonstration	•Small Unit
Group 2 • 21-55 lbs • < 3500 AGL • < 250 knots		•USN/SOCOM/USMC RQ-21A **ScanEagle**	•122/13	•ISR/RSTA/FORCE PROT	•Small Unit/Ship
Group 1 • 0-20 lbs • < 1200 AGL • < 100 knots		•USA / USN / USMC / SOCOM RQ-11 **Raven**	•5628/3752	•ISR/RSTA	•Small Unit
		•USMC/ SOCOM **Wasp**	•540/270	•ISR/RSTA	•Small Unit
		•SOCOM SUAS AECV **Puma**	•372/124	•ISR/RSTA	•Small Unit
		•USA **gMAV** / USN **T-Hawk**	•270/135	•ISR/RSTA/EOD	•Small Unit

Source: Department of Defense, *Unmanned Systems Integrated Roadmap FY2011-2036* (Washington, DC: Government Printing Office, October 2011), 21.

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