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THESIS

**UNMANNED AIRCRAFT SYSTEMS: A LOGICAL
CHOICE FOR HOMELAND SECURITY SUPPORT**

by

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December 2011

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CHOICE FOR HOMELAND SECURITY SUPPORT**

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ABSTRACT

Unmanned aircraft systems (UAS) have been part of aviation from the beginnings of manned aviation and have become a vital tool of our overseas military and national security operations. Public and private sector interest continues to grow for UAS to be used in a variety of domestic missions, such as border patrol, law enforcement, and search and rescue. With growing concerns over issues, such as border security and critical infrastructure protection, it would seem that UAS would be a logical choice for increased homeland security support, and yet they remain only in limited use. This thesis examined why UAS are not widely used domestically for homeland security support and found that their sluggish integration into the National Airspace System stems from a perceived flight safety risk. However, UAS operations have improved; systems, such as the Predator have flight safety trends equivalent to that of some manned aircraft. Nevertheless, government, private industry, academia, and other UAS stakeholders should continue to work together to further UAS safety. Specifically, they should collaborate to improve UAS component reliability, develop aviation regulations and standards to account for peculiar UAS characteristics, and improve public perception.

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LIST OF ACRONYMS AND ABBREVIATIONS

ATC	Air Traffic Control
CAA	Civil Aeronautics Administration
CAB	Civil Aeronautics Board
CBP	Customs and Border Protection
CBRNE	Chemical, Biological, Radiological, Nuclear, and Explosives
CFR	Code of Federal Regulation
CIA	Central Intelligence Agency
DHS	Department of Homeland Security
DoD	Department of Defense
DOT	Department of Transportation
ELOS	Equivalent Level of Safety
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FLIR	Forward Looking Infrared Radar
GAO	Government Accountability Office
GPS	Global Positioning System
IFR	Instrument Flight Rule
ISR	Intelligence, Surveillance, and Reconnaissance
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NextGen	Next Generation Air Transportation System
ROA	Remotely Operated Aircraft
RPA	Remotely Piloted Aircraft
RPV	Remotely Piloted Vehicle
TCAS	Terrain Collision and Avoidance System
U.S.	United States
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicle
VFR	Visual Flight Rule

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION

This thesis will examine the question, why is it that, even though Unmanned Aircraft Systems (UAS) have become a vital tool of our overseas military and national security operations, they are not widely used domestically for homeland security support? Unmanned aircraft systems have been part of aviation from the beginnings of manned aviation and have become a vital tool of our overseas military and national security operations. With growing concerns over issues, such as border security and illegal immigration, it would seem that UAS would be a logical choice for increased homeland security support, and yet they remain only in limited use.

The United States (U.S.) continues to advance UAS technology toward making routine domestic UAS integration a possibility. For example, lessons learned in the battlefields of Iraq and Afghanistan have enabled industry to advance electro-optical and infrared sensor technology, navigation systems, communication systems, and command and control systems. Nevertheless, safety is at the heart of the UAS integration issue. According to the Government Accountability Office (GAO), UAS pose challenges that prevent their ability to operate safely and routinely in the National Airspace System (NAS) thereby delaying anticipation of routine integration. In addition, the Federal Aviation Administration (FAA) asserts that UAS flight activity must be conducted at an “acceptable level of safety.”¹ According to UAS industry analysts, the UAS

¹ U.S. Department of Transportation Federal Aviation Administration, “Unmanned Aircraft Operations in the National Airspace System,” March 28, 2011, <http://www.faa.gov/documentlibrary/media/notice/N7210.766.pdf>.

community is in agreement with making safety the first priority for UAS operations. However, the challenge has been defining what safe UAS operations entail.²

This thesis will explore the challenges facing routine UAS integration into the NAS. Through this examination, I will review the various literatures and offer recommendations to address the question of safety as a hindrance to routine integration in hopes of providing a useful contribution to the increased integration of UAS in the NAS. The specific questions I will consider in this thesis are: 1) why have UAS not been more effectively integrated into the NAS; and 2) if safety is an issue, are those concerns warranted, and how can UAS be integrated better?

B. IMPORTANCE

Unmanned aircraft systems can provide new ways for public and private agencies to increase operational effectiveness, decrease operating costs, and even save lives. Hence, public and private sector interest continues to grow for UAS use in a variety of domestic missions, such as law enforcement, search and rescue, border patrol, and scientific research to name a few. Some members of Congress have even called for an increased use of UAS to improve border defense, public safety, and emergency response systems.³ Unmanned aircraft are also big business: the Teal Group predicts \$94 billion will be spent on UAS research, development, and production over the next 10 years, with the U.S. government accounting for 77 percent of the research and development spending and 69 percent of the procurement spending worldwide.⁴ However, it

² 2010 Association for Unmanned Vehicle Systems International, "Unmanned Aircraft System Integration into the United States National Airspace System: An Assessment of the Impact on Job Creation in the U.S. Aerospace Industry," <http://www.mckee.house.gov/pdf/0510jobsreport.pdf>, 9.

³ Congressman Michael McCaul Website, "Texas Congressmen Call for Increased UAV Coverage of Texas-Mexico Border," April 27, 2011, <http://mccaull.house.gov/index.cfm?sectionid=29&parentid=7§iontree=7&itemid=1171>.

⁴ The Teal Group Corporation, "Teal Group Predicts Worldwide UAV Market Will Total Just Over \$94 Billion," March 1, 2011, http://tealgroup.com/index.php?option=com_content&view=article&id=74:teal-group-predicts-worldwide-uav-market-will-total-just-over-94-billion-&catid=3&Itemid=16.

appears that the operational and economic utility that UAS are capable of providing is being overshadowed by a sense that they present a flight safety risk, underscoring the importance of further research on this topic.

C. PROBLEMS AND HYPOTHESES

Although the market for UAS is heating up, domestic deployment and use of these aircraft has taken a long time to come into effect. My hypothesis is that UAS have not been used as much as they could be because of FAA cautions about the integration of UAS into the NAS. These cautions stem from concerns over what safe UAS operations entail and they have affected the ability of UAS to be fully integrated into routine flying operations within the NAS. As an interim solution aimed to facilitate safe domestic UAS operations, the FAA employed a safety analysis and certification process (known as a Certification of Authorization) that must be accomplished prior to approving UAS flights. However, according to critics, this process is restrictive and ineffective, and increases the time it takes to obtain approval for routine UAS operations. In addition, it reduces flexibility that public agencies, namely the Department of Homeland Security (DHS) and Department of Defense (DoD), need in order to fulfill their domestic roles of securing and defending our nation.

Furthermore, according to a 2008 GAO report, “UAS pose technological, regulatory, workload, and coordination challenges that affect their ability to operate safely and routinely in the national airspace system.”⁵ Since this report, the government and industry have been aggressively collaborating to improve UAS operations. Despite these attempts, some entities still question their safe and effective operation in the NAS.

⁵ U.S. Government Accountability Office, *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System*, (GAO-08-511), Washington, DC: GPO, May 2008, <http://www.gao.gov/new.items/d08511.pdf>.

D. LITERATURE REVIEW

Literature suggests there is a growing need for UAS domestically. But many aviation experts also argue that UAS present safety or other concerns that make them difficult to integrate into the NAS. This section will first review the literature that sees a need for domestic UAS use, and then examine the arguments of critics.

Just as unmanned aircraft have proven their usefulness for overseas national security operations in Iraq and Afghanistan, they have also demonstrated their utility domestically. According to analysts, government and private entities have recognized their capabilities in various domestic operations (i.e., law enforcement, weather research, and pipeline surveillance, etc.) and have put pressure on the FAA to facilitate increased domestic UAS operations. Customs and Border Protection (CBP) officials have reported that “Predator B [UAS] has contributed to the seizure of more than 15,000 pounds of marijuana and the apprehension of more than 4,000 undocumented people.”⁶ Also, CBP will increase the number of UAS across the country and along the border by 2015.⁷ This has contributed to Texas officials (e.g., governor, senators and representatives) “leaning on the FAA to approve requests to use unmanned aircraft along the Texas-Mexico border.”⁸ In addition, H.R. 658, the FAA Air Transportation Modernization and Safety Improvement Act, recognizes the value of UAS for homeland security, law enforcement, and scientific research and has introduced steps to advance their integration domestically.⁹

⁶ Tim Eaton, “Unmanned Planes Could Begin Flying Over Texas in a Matter of Months,” *The Associated Press*, May 11, 2010, <http://www.statesman.com/news/texas-politics/unmanned-planes-could-begin-flying-over-texas-in-681019.html>.

⁷ Ibid.

⁸ Joan Lowy, “Pressure Builds for Use of Drones in Home Skies,” *Philadelphia Inquirer*, June 15, 2010, <http://ebird.osd.mil/ebfiles/e20100615758060.html>.

⁹ Congressional Unmanned Systems Caucus, “Federal Aviation Administration Re-Authorization Bill,” <http://uavc.mckee.house.gov/2011/04/federal-aviation-administration-re-authorization-bill.htm>.

Although government and private entities are calling for a greater use of UAS domestically, the FAA has been slow to approve greater integration of UAS into the NAS, which has resulted in a low level of domestic UAS activity. Four primary arguments by critics have led to the sluggish integration of UAS domestically.

First, critics claim that the accident rate of UAS is many times higher than that of manned aircraft. One report claims that “CBP UAS have an accident rate seven times higher than that of general aviation and 353 times higher than commercial aviation.”¹⁰ However, it appears that data regarding UAS accidents may not be as reliable as critics perceive it to be. The FAA has indicated problems in obtaining adequate data on UAS operations in order to assess safety and acknowledge that the safety data they do have may not be a representative sampling of UAS operations.¹¹ In addition, safety data on military UAS operations is pulled from DoD sources and is based on UAS operations in Iraq and Afghanistan, where UAS are typically flown in harsh, high stress environments. Even manned aircraft frequently experience “close calls” with other manned aircraft on a daily basis in these types of flying environments. Other work indicates that systems, such as Predator and Global Hawk were often being flown before completion of their development programs. A 2001 report by the Pentagon concluded that the Predator UAS was not “operationally effective or

¹⁰ Sharon Weinberger, “Border Drones Plagued by Mishaps, Pilot Shortage,” *Aol News*, July 16, 2010, <http://www.aolnews.com/2010/07/16/border-drones-plagued-by-mishaps-pilot-shortge/>.

¹¹ *Statement of Nancy Kalinowski, Vice President for System Operations Services. Testimony before the House of Representatives, Committee on Homeland Security, Subcommittee on Border, Maritime, and Global Counterterrorism on the Role of Unmanned Aerial Systems on Border Security*, July 15, 2010, http://www.faa.gov/news/testimony/news_story.cfm?newsid+11599.

suitable” because it had not completed testing.¹² Despite this claim, the system was one of the first sent to Afghanistan following the September 11, 2001 terrorist attacks.¹³

Supporters of UAS operations, on the other hand, argue that the UAS accident rate might be lower if the Predator and Global Hawk programs had been allowed to fully mature under their development programs. Other UAS proponents claim that “when a military UAS fails to return from a mission it can be impossible to tell whether it was shot down, or crashed because of a systems or communications failure.”¹⁴ Also, according to a UAS researcher from NASA’s Dryden Research Center “the chance of a lost communications link between ground pilot and UAS happening during takeoff and landing is minuscule.”¹⁵ Given the diverging opinions on whether UAS can operate safely in civil airspace, there is the potential for safety mishap statistics to be misleading.

A second reason why UAS have been slow to be used domestically concerns whether UAS technology is advanced enough to allow safe routine UAS operations. Analysts have pointed out that research, development, and testing of certain aviation technology had not produced a suitable technology that would provide UAS with the capability to meet specific FAA requirements to operate safely in the NAS.¹⁶ For example, because UAS do not have a pilot on-board critics claim they cannot directly scan the sky to “see and avoid”¹⁷ other aircraft as required by FAA regulations. The principle of see and avoid allows a

¹² U.S. Library of Congress, Congressional Research Service, *Unmanned Aerial Vehicles: Background and Issues for Congress*, by Elizabeth Bone, CRS Report RL31872 (Washington, DC: Office of Congressional Information and Publishing, April 25, 2003), 24.

¹³ Ibid.

¹⁴ D. Graham-Rowe, “Safety Fears Over Unmanned Planes—Pilotless Aircraft May Soon Fly Alongside Your Holiday Jet,” *New Scientist* 178, no. 2401 (2003): 4–5.

¹⁵ Ibid.

¹⁶ U.S. Government Accountability Office, *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System*, 17.

¹⁷ Department of Transportation, Federal Aviation Administration, 14 CFR Part 91.113, General Operating and Flight Rules, June 2, 2011, http://edocket.access.gpo.gov/cfr_2011/janqtr/pdf/14cfr91.113.pdf.

pilot to operate an aircraft in weather conditions generally clear enough to allow the pilot to see where the aircraft is going and to avoid obstacles and other aircraft. Some analysts claim that UAS platforms themselves cannot be equipped with proper see and avoid technology, such as terrain collision and avoidance systems (TCAS). However, according to one *Aerospace Science and Technology* article, “the separation of two aircraft flying under VFR [visual flight rules] rely on the see and avoid principle but sometimes fails for reasons like closing-in speed or pilot lack of vigilance.”¹⁸ This suggests that even manned aircraft are not always observant of one another under VFR. According to the article, a TCAS can operate to the same level, at which a visual pilot can, thus enabling the requirement for see and avoid. This suggests there may be alternative technologies that could be used to meet see and avoid requirements for UAS.

A third claim of critics is that federal regulations and standards limit domestic use of UAS. Analysts wrote in the *Journal of Applied Remote Sensing*, for example, that the use of UAS can be safer than manned aircraft given certain flight profiles (i.e., flying low to the ground); however, the “main limitation for UAS integration was the institutional regulations of FAA are cumbersome.”¹⁹ In 2009, Embry Riddle Aeronautical University conducted an FAA-sponsored review of the applicability of UAS to Title 14 Code of Federal Regulations (CFRs). Title 14 governs aeronautics and space policy in the U.S. The goal of the study was to examine the relevant regulations, policies, orders, etc., to identify the known problems resulting from UAS integration into the NAS, among other things. The review concluded that the “FAA’s current regulatory system has not evolved to include UAS in the NAS and that the unique technological challenges presented by UAS and the growing demands and needs of the UAS community call for an

¹⁸ C. Le Tallec, “VFR General Aviation Aircraft and UAV Flights Deconfliction,” *Aerospace Science and Technology* 9 (October 2005): 495–503.

¹⁹ Albert Rango and Andrea S. Laliberte, “Impact of Flight Regulations on Effective Use of Unmanned Aircraft Systems for Natural Resources Applications,” *Journal of Applied Remote Sensing* 4 (October 2010).

appropriate response to implement regulatory change.”²⁰ This supports the claim that insufficient regulation is an area that is impacting safety and restricting routine integration of UAS operations into the NAS. The author of the study recommended that the FAA consider developing regulations that may be “applied or revised, and against which new regulations may be developed to provide for a safe integration of UAS operations into the NAS.”²¹ The FAA estimates that completing UAS safety regulations will take at least 10 years. To reduce FAA workload and expedite the process, some have suggested that the FAA get help in writing future federal regulations for UAS operations.

Other literature suggests that many of the regulations associated with the Certificate of Authorization (COA) process are adapted from the manned aircraft program and may not be directly pertinent to UAS characteristics and capabilities, thus increasing the time to process and approve (or deny) requests to operate UAS. According to testimony given by an FAA official before the House of Representatives in 2010, “the FAA is working to better standardize the review process and increase communication and transparency between agency and applicants.”²²

In addition, an article from *Aerospace Sciences* attempts to address the highly debated issue of equivalent level of safety (ELOS), which has become the FAA’s underlying principle for any future UAS regulation. The principle of ELOS states that before UAS can be routinely integrated into the NAS, the FAA must ensure the safety of the public to a level equivalent to that of manned aircraft. According to the article, the current standards developed and regulations enforced by the FAA to ensure an ELOS may not apply to UAS. The approach

²⁰ U.S. Department of Transportation, Federal Aviation Administration, *Unmanned Aircraft System Regulation Review*, by L. Kirk, D. Marshall, B. Trapnell, and G. Frushour, (Federal Aviation Administration Report AR-09/7), September 2009, 17.

²¹ Ibid.

²² *Statement of Nancy Kalinowski, Vice President for System Operations Services. Testimony before the House of Representatives, Committee on Homeland Security, Subcommittee on Border, Maritime, and Global Counterterrorism on the Role of Unmanned Aerial Systems on Border Security.*

used to prove ELOS for UAS has been questioned because of the wide range of UAS sizes and characteristics, leading some analysts to believe that “this approach is not readily applicable to define an ELOS for UAS.”²³

Fourth, there is a public education aspect to UAS integration that analysts claim requires attention. The literature suggests that lack of cultural acceptance regarding UAS integration is a problem. Unmanned aircraft systems are portrayed by critics as “flying robots used as sentries or snipers that track down and kill their intended targets.”²⁴ One article associates U.S. drone patrols in Pakistan to a “robot proxy war” while another quotes the British Ministry of Defence as saying, “unmanned aircraft are moving us towards a terminator-like world.”²⁵ This rhetoric instills fear in the public, according to UAS analysts, and poses a challenge to UAS integration in the NAS.²⁶

E. METHODS AND SOURCES

For this thesis, I first examine U.S. government policies and regulations concerning the domestic use and safety of UAS, and other work found in government records and aviation journals, such as *Aviation Week and Space Technology*. As described above, this review indicates that most of the objections and barriers to routine, domestic, UAS operations are related to safety issues.

Next, I review UAS safety data. As the military is the largest user of UAS today, a significant amount of all safety data is pulled from DoD sources and is based on UAS operations in Iraq and Afghanistan where they are flown in harsh,

²³ Konstantinos Dalamagkidis, Kimon P. Valavanis, and Les A. Piegl, “Progress in Aerospace Sciences: On Unmanned Aircraft Systems Issues, Challenges, and Operational Restrictions Preventing Integration into the National Airspace System,” *Aerospace Sciences* 44 (October 2008): 510.

²⁴ Peter Goodspeed, “When Robots Kill—Urgent Questions Over Drone Warfare,” *National Post*, April 30, 2011, <http://fullcomment.nationalpost.com/2011/04/30/goodspeed-when-robots-kill-%e2%80%94urgent-questions-over-drone-warfare/>.

²⁵ William Saletan, “The Machines Aren’t Rising Quite Yet,” *National Post*, May 2, 2011, <http://www.nationalpost.com/news/machines+aren+rising+quite/4707797/story.html>.

²⁶ Association for Unmanned Vehicle Systems International, “Unmanned Aircraft System Integration into the United States National Airspace System: An Assessment of the Impact on Job Creation in the U.S. Aerospace Industry,” 2010, 9.

high stress environments, presumably under high stress conditions, and operating in weather conditions as required by mission urgency. Therefore, I will conduct an examination of UAS safety records to attempt to determine whether the safety statistics cited by critics and by impartial observers, such as the GAO actually pertain to the type of domestic operations that homeland security requirements will require. This information is usually available in DoD and FAA safety reports. I will attempt to identify reasons for mishaps and if needed for clarity, I will assign categories to factors that contribute to the causes of UAS safety mishaps. Categories will include human, material, environmental, or undetermined.

F. THESIS OVERVIEW

This thesis is organized into five chapters. Chapter I provides the introduction. Chapter II includes a historical background of what UAS is and how they have evolved. Chapter III examines the evolution of the NAS and the legal framework that governs aircraft certification and operations. Chapter IV analyzes safety aspects of domestic UAS operations and includes findings from UAS safety records. In Chapter V, I discuss the national strategy for protecting the homeland and highlight UAS as an alternative capability to helping to fulfill this strategy. Chapter VI concludes my thesis and provides recommendations for routine UAS integration domestically.

II. UNMANNED AIRCRAFT SYSTEMS BACKGROUND

Although unmanned aircraft have been part of aviation from the beginning, predating manned aviation, their nomenclature has certainly evolved. In addition, their slowed development has drifted with the ebb and flow of financial and political support since their first use. Yet, towards the end of the 20th century, their utility was rediscovered in performing the 3Ds; dull, dirty and dangerous operations,²⁷ as the U.S. increased its military presence in the Middle East. As advancement in technologies increased during the 21st century, their proliferation has left gaps in how to best integrate them into the NAS for routine domestic operations. To address the integration of unmanned aircraft into the NAS, it is important to understand how they developed over the years. Therefore, this chapter will briefly explore what UAS are and how they have evolved.

A. UAS DEFINED

The nomenclature that describes unmanned aircraft is diverse and has evolved with time. Some of the most common names associated with them include: balloons, drone, unmanned aerial vehicle (UAV), and remotely piloted vehicle (RPV).²⁸ Other terms used to describe them include remotely operated aircraft (ROA) and remotely piloted aircraft (RPA). The DoD recognizes most of these terms and captures them in Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms*. No matter what their nomenclature, each term portrays a common lineage that an unmanned aircraft is “an aircraft operated without the possibility or direct human intervention from within or on the aircraft.”²⁹

²⁷ Dull, dirty, and dangerous operations is a common description given to aircraft that fly long duration flights, sampling hazardous materials and are exposed to hostile action.

²⁸ Department of Defense, *DoD Dictionary of Military and Associated Terms*, Joint Publication 1-02, June 13, 2007, <http://wsti.ac.alionscience.com/pdf/dodmilitarydictionary.pdf>.

²⁹ Department of Transportation, Federal Aviation Administration, *Unmanned Aircraft Operations in the National Airspace System*, NJO 7210.766, March 28, 2011.

Unmanned aircraft have diverse shapes, sizes, uses, and means of control. They range in size from small radio-controlled model airplanes with wingspans as small as six inches to large jet aircraft with wingspans reaching 117 feet (similar to a Boeing 737 aircraft). Some are controlled manually via a ground control system, while others may be controlled autonomously through use of an on-board computer, communication links and any additional equipment required for safe flight. To account for the diversity in unmanned aircraft, the FAA has adopted the term unmanned aircraft system (or UAS), which appears to be a more common lexicon among aviation enthusiasts today. This term recognizes that UAS are systems that include not only the airframe, but other components and personnel required to control them.³⁰ Each of the terms mentioned above are common nomenclature for UAS and can be found in the various literatures that discuss aviation and unmanned flight. However, for this thesis I will use the FAA's "UAS" nomenclature to describe the vast population of remotely piloted, operated and/or monitored aircraft that are capable of flying within NAS.

B. EVOLUTION

The use of UAS by the military dates back to World War I with the U.S. Navy and U.S. Army. In 1917, Elmer Sperry received the first military contract to develop an unmanned flight system for the U.S. Navy.³¹ This early form of UAS was designed to be a flying bomb but was cancelled in 1922 due to technical problems and a lack of continued funding. However, the U.S. Army was successful in its early UAS research program. In 1918, Charles Kettering built a prototype UAS known as the "Kettering Bug," which was also a type of flying

³⁰ Department of Transportation, Federal Aviation Administration, *Unmanned Aircraft Operations in the National Airspace System*.

³¹ John Blom, "Unmanned Aerial Systems: A Historical Perspective," *Combat Studies Institute Press* (September 2010): 45.

bomb. Although the Bug successfully demonstrated its utility as a weapon system and was purchased by the U.S. Army for military operations, it was not used in combat due to the war ending in late 1918.³²

Unmanned aircraft system programs would not receive the same level of attention again until nearly a decade later when the U.S. Navy and U.S. Army launched the Anvil and Aphrodite projects during World War II. The two projects pursued testing and purchase of bomber aircraft that were taken out of service to be used as radio-controlled drones for kamikaze-like and conventional bomber attacks on Japanese targets. Although these “assault drones” were somewhat ineffective, they proved to be invaluable in avoiding the losses sustained by manned aircraft flying over heavily defended targets.³³ These early programs helped to validate unmanned flight, which later proved invaluable throughout the 20th century.

At the end of World War II, General Henry “Hap” Arnold predicted, “the next war may be fought by airplanes with no men in them....”³⁴ General Arnold’s vision would become reality in the years to come as military aviation took on a diverse dimension with the birth of another branch of service, the U.S. Air Force, on September 18, 1947. Following World War II until the Vietnam War, UAS design and technology development progressed. A newly independent U.S. Air Force recognized the operational potential for UAS as a platform for conducting reconnaissance flights over areas deemed too dangerous or politically unacceptable for manned aircraft.³⁵ In 1952, the first jet-powered UAS, named the Q2C, was produced for the U.S. Air Force and helped pave the way as a useful system for fast, high-flying aerial reconnaissance.³⁶ This need was realized even more when in 1960 a U-2 spy plane flown by Gary Powers was

³² Blom, “Unmanned Aerial Systems: A Historical Perspective,” 46.

³³ John Degaspari, “Look, Ma, No Pilot,” *Mechanical Engineering* (November 2003): 43.

³⁴ Lawrence Spinetta, “The Rise of Unmanned Aircraft,” *Aviation History* (November 10, 2010).

³⁵ Ibid.

³⁶ Degaspari, “Look, Ma, No Pilot,” 43.

shot down flying over the Soviet Union. Following this tragic event throughout the Vietnam War, the Air Force and Navy drastically increased the use of UAS in a support role. Between 1962 to 1975 UAS flew more than 3,000 support missions over Southeast Asia consisting of photo reconnaissance, decoy, radar jamming, and other missions.³⁷

Improvements in computers and telecommunications technology along with the military's growing need to obtain and transmit real-time data during reconnaissance operations were key to distinguishing improvements in UAS design during the last two decades of the 20th century.³⁸ Although their use was somewhat limited during the Persian Gulf War, the increasing use of and later installation of Global Positioning System (GPS) receivers significantly enabled UAS to be flown on reconnaissance and targeting missions with greater accuracy. Systems, such as the RQ-1 Predator and RQ-4 Global Hawk validated this capability when they proved their utility in intelligence gathering during air operations over Kosovo during 1999. The operational success rate during this timeframe proved even more the concept and value of UAS operations. This provided the inertia for increased UAS funding and development as the U.S. entered the 21st century.

The operational conditions and necessities of war in Iraq and Afghanistan at the start of the 21st century perpetuated increased development and procurement of UAS. Their most common user today is the DoD with a total inventory surpassing 6,000 systems.³⁹ Since the 2001 terrorist attacks, the amount spent on UAS has increased approximately 23 percent annually.⁴⁰ According to the Congressional Budget Office, the DoD will need \$36.8 billion for UAS it plans to purchase through 2020.⁴¹ This estimate is based on: 1) the Air

³⁷ P. W. Singer, "Drones Don't Die," *Military History* 28, no. 2 (July 2011): 69.

³⁸ Degaspari, "Look, Ma, No Pilot," 44.

³⁹ Ibid.

⁴⁰ Ibid., 69.

⁴¹ Congressional Budget Office, "Policy Options for Unmanned Aircraft Systems," Publication Number 4083, June 2011.

Force's plan to purchase over 300 Reaper and Global Hawk UAS; 2) the Army's plan to purchase 127 Shadow and Predator (Grey Eagle) UAS and 3) the Navy and Marine Corps plan to purchase 97 Broad Area Maritime Surveillance and MQ-8B Firescout UAS.⁴²

The flying bombs and target drones used by our armed forces during the early 20th century seem far removed from the UAS flown today in Iraq, Afghanistan, or along our borders. Yet, their missions remain almost identical; they perform strategic and tactical support operations without putting American men and women in immediate danger. Overseas, in the war zone, UAS are not only used for surveillance missions, but frequently to fly attack missions. A Predator UAS equipped with advanced sensors and hellfire missiles can circle in position over hostile targets for many hours waiting for the opportunity to attack them. Along our borders, UAS can assist border patrol agents detect and continuously track critical targets with their state-of-the-art electro-optical and infrared cameras. Nevertheless, traditional UAS military intelligence, surveillance, reconnaissance, and if required, attack missions, are no longer seen as the only contributing role for UAS in supporting national security. A new UAS industry is being driven by other public and private agencies as their technology improves and is being adapted to civil use.⁴³

Despite these domestic uses, however, UAS are still not being used within the U.S. at a rate that is being called for by political leaders and homeland security experts. Government, private industry, academia, and other UAS stakeholders have addressed some of the challenges mentioned thus far, albeit from a micro perspective. A GAO study concluded that ensuring UAS operate safely in the NAS is a new and complex challenge for the FAA, but the NAS

⁴² Congressional Budget Office, "Policy Options for Unmanned Aircraft Systems."

⁴³ 2010 Association for Unmanned Vehicle Systems International, "Unmanned Aircraft System Integration into the United States National Airspace System: An Assessment of the Impact on Job Creation in the U.S. Aerospace Industry," 3.

should be prepared to accommodate them.⁴⁴ Doing so requires agencies to better understand the airspace system as a whole, its complexities, rules, and challenges. To assist readers with understanding our nation's airspace system, the next chapter will examine its infrastructure and operating procedures.

⁴⁴ U.S. Government Accountability Office, *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System*, 42.

III. NATIONAL AIRSPACE SYSTEM INFRASTRUCTURE

Despite what some people may see as an unlimited resource, the airspace environment in which aircraft fly—manned, as well as unmanned--has steadily become complex, congested, and more restricted. This airspace environment, known in the U.S. as the NAS, is a “network of airspace; air navigational facilities, equipment, and services; airports or landing areas; aeronautical charts, information, and services; rules, regulations, and procedures; technical information, manpower, and material.”⁴⁵

The NAS is regulated and operated by the FAA and is one of the most advanced and efficient aviation systems in the world. It supports commercial, general, and military aviation operations, ensuring the timely and efficient flow of goods, services, and support. Also, as part of the National Infrastructure Protection Plan, the NAS is considered “critical infrastructure”⁴⁶ for the U.S. economy and our national security, sustaining a global aviation industry estimated at roughly \$3 trillion a year: 8 percent of the world’s gross domestic product.⁴⁷

The NAS consists of approximately 4,500 air navigation facilities, 18,000 airports or landing areas, 750 air traffic control facilities, and over 48,000 FAA employees who ensure the network is safe, efficient, and robust 24 hours a day, 7 days a week.⁴⁸ The capacity and complexity of the NAS is expected to expand

⁴⁵ Federal Aviation Administration, *Aeronautical Information Manual: Official Guide to Basic Flight Information and ATC Procedures*, February 11, 2010.

⁴⁶ Department of Homeland Security, “Transportation Systems Critical Infrastructure Sector-Specific Plan,” May 2007, <http://www.dhs.gov/xlibrary/assets/nipp-ssp-transportation.pdf>.

⁴⁷ Clinton Oster and John Strong, *Managing the Skies: Public Policy, Organization and Financing of Air Traffic Management* (Ashgate Publishing, 2007), 5.

⁴⁸ FAA Instrument Procedures Handbook, *IFR Operations in the National Airspace System*, (n.d.), http://www.faa.gov/library/manuals/aviation/instrument_procedures_handbook/media/ch-01.pdf.

in order to support an estimated 50 percent increase in air traffic by 2025.⁴⁹ This estimate does not account for UAS operations. Yet, one of the issues facing UAS integration into the NAS is the ability of UAS to fly alongside general and commercial aviation aircraft. Only in limited circumstances does this occur today. Most UAS operations today operate in special use airspace, such as restricted and prohibited areas, where commercial airliners and private pilots do not fly. Yet, introducing routine UAS operations into a dynamic and complex airspace system poses immediate challenges to integration; these were highlighted in Chapter I. This chapter will examine the evolution of the NAS and the legal framework that governs aircraft certification and operation. This background will provide readers insight on the complexity of the NAS and how it impacts integrating UAS with manned aircraft.

A. NAS EVOLUTION

In 1926, the U.S. Congress passed the Air Commerce Act, charging the Secretary of Commerce with “fostering air commerce, issuing and enforcing air traffic rules, licensing pilots, certifying aircraft, establishing airways, and operating and maintaining aids to air navigation.”⁵⁰ The Aeronautic Branch within the Department of Commerce, later called Bureau of Air Commerce, was responsible for implementing and enforcing these responsibilities. As commercial flying increased, air traffic control (ATC) facilities were set up along airways to provide flight advisory and separation services.

In 1938, the Civil Aeronautics Act transferred federal responsibilities from the Bureau of Air Commerce to the Civil Aeronautics Authority. This authority was responsible for ATC, airman and aircraft certification, safety enforcement,

⁴⁹ Federal Aviation Administration, Next Generation Air Transportation System Video, “FAA Aerospace Forecast Fiscal Years 2011–2031,” http://faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2011-2031/media/review%20of%202010.pdf.

⁵⁰ Arnold Briddon, Ellmore Champie, and Peter Marraine, *Federal Aviation Administration Historical Fact Book: A Chronology 1926 to 1971* (Washington, DC: U.S. Government Printing Office, 1974), 9.

and airway development.⁵¹ Later, in 1940, the CAA was split into the Civil Aeronautics Administration (CAA) and the Civil Aeronautics Board (CAB). The newly formed CAA was responsible for ATC, safety programs, and airway development. The CAB, which functioned independently, was delegated responsibility for safety rulemaking, accident investigation, and economic regulation of commercial aviation.⁵²

The introduction of jet aircraft and increase in air traffic, followed by a series of major air disasters, prompted the U.S. government's passage of the Federal Aviation Act of 1958, which transferred CAA functions to the Federal Aviation Agency.⁵³ The FAA Act assigned safety rulemaking and responsibility for ensuring the safe and efficient use of airspace by civil and military aircraft operators to the FAA. Also, the act provided for the regulation and promotion of civil aviation in a manner that would best promote its development and safety. In 1967, the FAA was changed from an independent agency to an operating administration, known today as the Federal Aviation Administration, under the newly established Department of Transportation (DOT).⁵⁴

Over the next decade, NAS infrastructure was transformed to meet the rising demands of the aviation community. To accommodate the expected growth in aviation traffic major improvements were required in terminal airspace capacity, assuring aircraft separation, and reducing costs of ATC services. The ATC Advisory Committee formed during this era believed that midair collision problems could be overcome in airspace using radar surveillance.⁵⁵ By the mid-1970s, the FAA had implemented automated ATC radar systems at some of its busiest airports, enabling air traffic controllers to provide more effective aircraft

⁵¹ Briddon, Champie, and Marraine, *Federal Aviation Administration Historical Fact Book: A Chronology 1926 to 197*, 34–35.

⁵² *Ibid.*, 39–40.

⁵³ *Ibid.*, 84.

⁵⁴ *Ibid.*, 165, 170.

⁵⁵ *Ibid.*, 203.

separation services. Yet, business and the general traveling public's increased reliance on air transport pushed the FAA to seek improved methods to keep up with demand.

During the last two decades of the 20th century, the FAA implemented several plans that invested heavily in improving NAS infrastructure. In 1982, the FAA released a NAS Plan to modernize the nation's airspace system by consolidating air route traffic control centers and improving advanced automated ATC equipment, surveillance, and communications technology.⁵⁶ Also, new flight procedures were established that facilitated reduced aircraft separation. In February 1991, the FAA replaced the NAS Plan with the Capital Investment Plan, which is a 5-year plan that describes NAS modernization projects and associated funding levels.

One of the projects discussed in the Capital Investment Plan that evolved early this century is the Next Generation Air Transportation System (NextGen) program. According to the NextGen Concept of Operations, its goals are to "significantly increase the safety, security, and capacity of air transportation operations...."⁵⁷ The FAA asserts NextGen will completely transform the NAS and will contribute to the effort of safely incorporating UAS into the NAS.⁵⁸ These benefits are being achieved through advances in technology, as well as new procedures and standards.

⁵⁶ Oster and Strong, *Managing the Skies: Public Policy, Organization and Financing of Air Traffic Management*, 123.

⁵⁷ Joint Planning and Development Office, "Concept of Operations for the Next Generation Air Transportation System," Version 2.0, June 13, 2007, http://www.jpdo.gov/library/NextGen_v2.0.pdf.

⁵⁸ Federal Aviation Administration, "NextGen Implementation Plan," March 2011, [http://www.faa.gov/next en/media/ng2011_implementation_plan.pdf](http://www.faa.gov/next%20en/media/ng2011_implementation_plan.pdf).

B. NAS AIRSPACE

Some have likened the airspace above the U.S. to a soap opera plot due to its complexity and elaborate structure.⁵⁹ However, understanding its configuration and the requirements for flying in each type of airspace can facilitate a better understanding of it. There are two categories of airspace in the NAS, regulatory and nonregulatory. Within these two types of airspace, there is controlled, uncontrolled, special use, and other airspace. According to the FAA's *Aeronautical Information Manual*, the categories and types of airspace are dictated by "the complexity or density of aircraft movements, the nature of the operations conducted within the airspace, the level of safety required, and the national and public interest."⁶⁰

Regulatory airspace is categorized as either Class A, B, C, D, or E airspace. It also includes restricted and prohibited areas. Regulatory airspace is controlled airspace in which ATC has the authority to control air traffic and is generally located in the vicinity of busier airports. Unless otherwise authorized, aircraft are required to comply with ATC clearances and are separated from other aircraft. Nonregulatory airspace is categorized as military operations areas, warning areas, alert areas, and controlled firing areas. This airspace is considered special use airspace because the activities occurring within it must be confined or may impose limitations upon other aircraft not taking part in the activities. Class G airspace is neither regulatory nor nonregulatory and is considered uncontrolled, or airspace in which ATC is not necessary for controlling air traffic or cannot be provided and generally includes aircraft flying in visual flight rule (VFR) conditions. Other airspace areas include military training

⁵⁹ Bruce Landsberg et al., "Airspace for Everyone," *Aircraft Owners and Pilot Association Air Safety Foundation*, no. 38002, Edition 5, June 2009, <http://www.aopa.org/asf/publications/sa02.pdf>.

⁶⁰ Federal Aviation Administration, *Aeronautical Information Manual Official Guide to Basic Flight Information and ATC Procedures*, February 11, 2010.

routes, terminal radar service areas, national security areas, and more. These classifications of airspace and the requirements for flying in each are further described in Table 1.

Regulatory Airspace	
Class A (controlled airspace)	Generally, that airspace from 18,000 feet mean sea level (MSL) up to and including flight level 600, including the airspace overlying the waters within 12 nautical miles (NM) of the coast of the 48 contiguous states and Alaska; and designated international airspace beyond 12 NM of the coast of the 48 contiguous states and Alaska within areas of domestic radio navigational signal or ATC radar coverage, and which domestic procedures are applied.
Class B (controlled airspace)	Generally, that airspace from the surface to 10,000 feet MSL surrounding the nation's busiest airports in terms of instrument flight rule (IFR) operations or passenger enplanements. The configuration of each Class B airspace area is individually tailored and consists of a surface area and two or more layers (some Class B airspace areas resemble upside-down wedding cakes), and is designed to contain all published instrument procedures once an aircraft enters the airspace. An ATC clearance is required for all aircraft to operate in the area, and all aircraft that are cleared receive separation services within the airspace. The cloud clearance requirement for visual flight rule (VFR) operations is "clear of clouds."
Class C (controlled airspace)	Generally, that airspace from the surface to 4,000 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower, are serviced by a radar approach control, and that have a certain number of IFR operations or passenger enplanements. Although the configuration of each Class C airspace area is individually tailored, the airspace usually consists of a 5 NM radius core surface area that extends from the surface up to 4,000 feet above the airport elevation, and a 10 NM radius shelf area that extends no lower than 1,200 feet up to 4,000 feet above the airport elevation.
Class D (controlled airspace)	Generally, that airspace from the surface to 2,500 feet above the airport elevation (charted in MSL) surrounding those airports that have an operational control tower. The configuration of each Class D airspace area is individually tailored and when instrument procedures are published, the airspace will normally be designed to contain the procedures.
Class E (controlled airspace)	Generally, if the airspace is not Class A, Class B, Class C, or Class D, and it is controlled airspace, it is Class E airspace.
Class G (uncontrolled airspace)	Class G airspace is that portion of airspace that has not been designated as Class A, Class B, Class C, Class D, or Class E airspace.
Restricted Area (special use airspace)	Contains airspace identified by an area on the surface of the earth within which the flight of aircraft, while not wholly prohibited, is subject to restrictions. Activities within these areas must be confined because of their nature or limitations imposed upon aircraft operations that are not a part of those activities or both.
Prohibited Area (special use airspace)	Contain airspace of defined dimensions identified by an area on the surface of the earth within which the flight of aircraft is prohibited. These areas are established for security or other reasons associated with national welfare.

Nonregulatory Airspace	
Military Operations Area (special use airspace)	Consist of airspace of defined vertical and lateral limits established for the purpose of separating certain military training activities from IFR traffic. Air combat tactics and low altitude tactics are a few examples of activities conducted in military operations areas (MOAs).
Warning Area (special use airspace)	Airspace of defined dimensions that extend from 3 NM outward from the coast of the U.S. that contains activity that may be hazardous to nonparticipating aircraft.
Alert Area (special use airspace)	An area that contains a high volume of pilot training or an unusual type of aerial activity.
Controlled Firing Area (special use airspace)	An area that could be hazardous to nonparticipating aircraft and similar to other nonregulated airspace except that activities occurring within them are suspended immediately when there are indications that other aircraft might be approaching the area.
Source: FAA Aeronautical Information Manual	

Table 1. Airspace Classifications

C. RULES FOR UAS CERTIFICATION AND OPERATION

The legal framework that oversees UAS certification and operation within the U.S. is vast and complex and designed to accommodate mostly manned aircraft. It consists of regulations, procedures, orders, standards, handbooks, etc. This framework is intended to provide some level of assurance that aircraft will operate safely, posing minimal risk to persons and property. Specifically, Title 14 CFR, also known as Federal Aviation Regulation (FAR), prescribes the rules for aviation in the U.S. These rules are separated into numerous sections called parts. These parts include airworthiness certification, maintenance, aircraft registration, pilot training and certification, airspace, air traffic and general operating rules, and many others. Although there are many parts to FAR, the ones most applicable to UAS that will be discussed in this thesis are Parts 91 and 61.

Federal Aviation Regulation Part 91 prescribes rules for operating aircraft other than moored balloons, kites, unmanned rockets, unmanned free balloons, and ultra-light vehicles. It prescribes that for any aircraft to fly legally in the U.S. it must be certified airworthy by the FAA. To be certified as airworthy, an aircraft “must conform to its type design” and “must be in a condition for safe

operation.”⁶¹ Safe operation refers to the “condition of an aircraft relative to wear and deterioration.”⁶² An aircraft has attained conformity to its type design when “its configuration and the engine, propeller, and articles installed are consistent with the drawings, specifications, and other data that are part of the type certified aircraft.”⁶³ An aircraft will not be considered airworthy if one or both of these conditions is not met.

Besides standard airworthiness certification, there are six special airworthiness certificates available for aircraft that do not meet the requirements for a standard certificate but are capable of safe flight. These certificates are often specified for experimental and special purpose aircraft and include primary, restricted, limited, light-sport aircraft, experimental, and special flight permits. Civil operators of UAS in the NAS (e.g., private industry) are required to obtain operational approval under the special airworthiness certificate, experimental category, and are issued only for the purpose of research and development, crew training, and market surveys.⁶⁴ Public operators of UAS (e.g., DoD, CBP) are required to follow the COA process highlighted in paragraph D of this chapter.

In addition to standard and special airworthiness certificates that allow aircraft to enter the NAS, there are certain types of aerial vehicles that have many of the requirements, procedures, and regulations waived. These vehicles include moored balloons, unmanned rockets, unmanned balloons, and ultra-light aircraft. Although these aerial vehicles may proceed with waivers, they only do so with specific restrictions to facilitate their safe operation.

Furthermore, FAR Part 91 requires that “when weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an

⁶¹ Federal Aviation Administration, *Airworthiness Certification of Aircraft and Related Products*, FAAO 8130.2G, August 31, 2010.

⁶² *Ibid.*

⁶³ *Ibid.*, 2–1.

⁶⁴ *Ibid.*, 3–4.

aircraft so as to see and avoid other aircraft.”⁶⁵ The “see and avoid” requirement of this regulation is one of the FAA’s primary safety concerns limiting UAS operations. Hence, alternate methods of compliance are required to achieve the see and avoid function in order for UAS to be granted approval to operate. In addition, a pilot flying under VFR is required to maintain certain horizontal and vertical distances from clouds.

Just as manned aircraft are to be certified airworthy, unless waived, the pilot in command also has to meet certain requirements to legally fly aircraft. Part 61 of the FAR states “no person may serve as a required pilot or flight crewmember of a civil aircraft of the United States, unless that person has a pilot certificate....”⁶⁶ Each pilot certificate further specifies the aircraft category, class, and type that may be operated by the pilot.

D. CURRENT UAS GUIDANCE

As mentioned above, Title 14 CFR prescribes the rules that govern the certification and operation of aircraft in the NAS, albeit mostly intended for manned aircraft. In response to the growing demand for UAS operations, the FAA has issued interim operational approval guidance, which highlight two methods for seeking approval to operate in the NAS—airworthiness certificate and COA.

First, the airworthiness certificate was discussed in the previous section and mostly applies to aircraft operating as civil aircraft (aircraft used by commercial or private operators). According to the FAA, only special airworthiness certificates in the experimental category are being issued for UAS

⁶⁵ Federal Aviation Regulation Part 91.113, *Right of Way Rules: Except Water Operations*, September 1, 2004, <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=3fa5b4e2e33c94f0b1450dcb7a81d7e5&rgn=div8&view=text&node=14:2.0.1.3.10.2.4.7&idno=14>.

⁶⁶ Federal Aviation Regulation Part 61.3, *Certification: Pilots, Flight Instructors, and Ground Instructors*, October 20, 2009, <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=3fa5b4e2e33c94f0b1450dcb7a81d7e5&rgn=div8&view=text&node=14:2.0.1.1.2.1.1.3&idno=14>.

operating as civil aircraft with accompanying operational restrictions.⁶⁷ These have mostly been issued for the purposes of research and development, UAS flight crew training, market surveys, and manned aircraft integrated with UAS technology.

The second method for UAS operators to seek approval to operate within the NAS is the COA. The COA applies to UAS operating as public aircraft: aircraft used by DoD, CBP, or other public institution. The FAA's Interim Approval Guidance Notice 08-01, *Unmanned Aircraft Systems Operations in the U.S. National Airspace System*, prescribes the procedures for UAS operators to follow when seeking approval to operate. Because UAS operations must be conducted at an acceptable level of safety (see next chapter for further details), operators are required to establish airworthiness by demonstrating that a collision with another aircraft or other airspace user is extremely improbable, as well as comply with appropriate cloud and terrain clearances as described in Title 14 Part 91. Also, when operating UAS outside of restricted areas and warning areas, the COA applicant must submit his/her request at least 60 days prior to the proposed UAS operational date. According to the FAA, a formal response is provided to the individual requesting the COA within 60 days, and once issued, a COA is valid for up to one year.

Federal Aviation Regulations do not specifically mention UAS, hence current aviation regulations have been assumed to apply equally to all aircraft categories, including UAS. But, applying current aviation regulations that are tailored mostly for manned aircraft to UAS has posed constraints. To better understand these constraints, Chapter IV will evaluate flight safety by examining the FAA's principle of equivalent level of safety, UAS safety performance, and public perception.

⁶⁷ Federal Aviation Administration Notice, "Unmanned Aircraft Operations in the National Airspace System," Docket No. FAA-2006-25714, http://www.faa.gov/about/initiatives/uas/reg/media/frnotice_uas.pdf.

IV. FLIGHT SAFETY

Inability to meet FAA safety requirements, high accident rates, fear, and lack of public support are common themes proliferated throughout the literature regarding UAS integration. Aviation safety campaigners have even claimed “[UAS] operations would risk the safety of other planes, passengers on the ground, and people living near airports.”⁶⁸ As a result, the FAA has put in place procedures for limited approval of UAS operations, following a case-by-case safety review through the COA or special airworthiness certificate process (discussed in Chapter III). These procedures help “to avoid any situations in which a UAS would endanger other users of the NAS or compromise the safety of persons or property on the ground.”⁶⁹

However, are UAS as unsafe as some have claimed and, if so, are these claims warranted? This chapter will attempt to answer these questions by providing an assessment of three areas found in the literature covering UAS flight safety. These areas are equivalent level of safety (ELOS), reliability of safety performance data, and public perception.

A. EQUIVALENT LEVEL OF SAFETY

According to the FAA, safe integration of UAS in the NAS requires assurances that they can operate at a safety level equivalent to that of manned aircraft. Because unmanned aircraft systems operate differently from manned aircraft, some have questioned whether they should be held to the same level of safety. Not surprising, defining ELOS in terms of requirements and standards has

⁶⁸ Duncan Graham-Duncan, “Safety Fears Over Unmanned Planes,” *New Scientist* 178, no. 2401 (June 28, 2003): 4.

⁶⁹ *Statement of Nancy Kalinowski, Vice President for System Operations Services. Testimony before the House of Representatives, Committee on Homeland Security, Subcommittee on Border, Maritime, and Global Counterterrorism on the Role of Unmanned Aerial Systems on Border Security.*

been a challenge for operators, manufacturers, and regulators. Nevertheless, safety risks are inescapable in the operations of any complex system, and UAS are no exception.

The ELOS standard for see and avoid has become a salient fixture for UAS operations. The fear of a UAS colliding with another aircraft (or other obstacle) in flight or on the ground has become a pressing safety concern that has often become the main point of discussion among aviation stakeholders. With regards to collision avoidance, aviation regulations stipulate that all aircraft be vigilant in maintaining safety, in visual or instrument conditions, regardless of type of aircraft.⁷⁰ This requires pilots to be able to see other aircraft and obstacles and to safely steer clear of them. For aircraft with an on-board pilot, this appears to be an easy feat, as they can visually scan outside the cockpit window for other aircraft and obstacles. For UAS, this requires sensors that can detect aircraft whose presence may not be observable from other sources, such as radar or collision avoidance systems.

To ensure on-board pilots have adequate field of view outside their cockpit windows, aviation standards stipulate cockpit field of view requirements (both horizontally and vertically) according to airframe design. However, these standards do not always guarantee that pilots can see other aircraft (although most are equipped with collision avoidance systems). According to some analysts on the topic, pilots of manned aircraft are poor at identifying potential collisions, even during flight operations occurring in clear daylight.⁷¹ Not all pilots have the same visual acuity and depth perception, nor do they spend equal time and follow proper technique looking out of the cockpit window.⁷²

⁷⁰ Federal Aviation Advisory Circular 90-48C, "Pilot's Role in Collision Avoidance," March 18, 1983.

⁷¹ Matthew DeGarmo, "Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace," *The MITRE Corporation Center for Advanced Aviation System Development*, MITRE Product 04W0000323, November 2004, 2–4, http://www.mitre.org/work/tech_papers/tech_papers_04/04_1232/04_1232.pdf.

⁷² Ibid.

If research indicates that humans looking out of the cockpit window are not always vigilant at detecting other air traffic and obstacles, it appears not to be prudent to apply the same see and avoid standard to UAS. Unmanned aircraft systems are unique and should not be held to the exact standards as manned aircraft. Sensor technologies, such as ground based [and airborne] detect, sense, and avoid can prevent mid-air collisions between UAS and other aircraft.⁷³ This technology includes transponders, electro-optical, infrared radar, and synthetic aperture radar. Although each type of technology has advantages and constraints (i.e., weight, cost, size, etc.), UAS can be equipped with sensor technology that is most suited for its designed mission and operating characteristics. A 2007 study conducted by Carnegie Mellon University on the integration of UAS into the NAS concluded that “sense and avoid technology is important only in airspace with significant traffic density.”⁷⁴ The study also compared a UAS used for weather reconnaissance to a WC-130J Hercules manned aircraft. It noted that currently available sense and avoid technology for the UAS cause significant decrease in cost effectiveness, but does not cause it to be more expensive than the WC-130J. Further noting that UAS is not only operationally viable, but affordable.

Requiring that UAS safety be equivalent to that of manned aircraft may not always be the best course of action.⁷⁵ The level of safety needed for UAS must be considered according to form, fit, and function and their mission profile, as there are many variations being produced today.

⁷³ Graham Warwick, “UAV Collision Bolsters Sense and Avoid Systems,” *Aviation Week* (August 18, 2011), <http://www.aviationweek.com/aw/generic/story.jsp?id=news/asd/2011/08/18/01.xml&channel=defense>.

⁷⁴ Carnegie Mellon University, *Review Panel Presentation for Project on Integration of Unmanned Aircraft into the National Airspace System*, Department of Engineering and Public Policy and Department of Social and Decision Sciences, May 1, 2007, http://www.andrew.cmu.edu/course/19-451/CMU_UAS_Final_Presentation.

⁷⁵ Ibid.

B. UAS SAFETY PERFORMANCE

The Predator B UAS, which is manufactured by General Atomics and CBP's UAS of choice, "has a reliability record that exceeds that of manned aircraft."⁷⁶ Nevertheless, safety activists are quick to claim that UAS accident rates are much higher than manned aircraft accident rates. In truth, there have been few UAS accidents within the continental U.S., so safety concerns are largely based on data derived from overseas military use. But when analyzed, the data regarding UAS accidents may not be as dependable as critics perceive it to be. The FAA has recognized this consistency problem and acknowledges that operational and safety data is limited and may not be a representative sampling of UAS operations.⁷⁷ An FAA report underscores this notion.

In 2004, the FAA completed a report that reviewed and analyzed UAS accident data in hopes of identifying factors related to their use.⁷⁸ As the U.S. armed forces is by far the largest user of UAS today, the FAA obtained accident data from Army, Navy, and Air Force Safety Centers. Accident data from 1980 to 2004 was provided for the Army's Hunter and Shadow UAS, from 1986 to 2002 for the Navy's Pioneer UAS, and from 1999 to 2003 for the Air Force's Predator and Global Hawk UAS. The data reported for each type of UAS indicated that the two biggest problems were system reliability and human factors. System reliability problems entailed failures of electrical and mechanical components in the airframe. Human factors problems associated with UAS included display design deficiencies located in UAS ground control stations, procedural errors, flight crew skills errors, and other human factors issues.⁷⁹ The most critical reason cited for these problems was cost savings, which are inclined to occur in areas, such as component reliability and system redundancy.

⁷⁶ DeGarmo, "Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace," 2–12.

⁷⁷ Ibid.

⁷⁸ Kevin Williams, *A Summary of Unmanned Aircraft Accident and Incident Data: Human Factors Implications*, Federal Aviation Administration Technical Report, December 2004.

⁷⁹ Ibid., 12.

Although this report does highlight some problems, the data collected on each UAS was not as detailed as that found for manned aircraft accidents. There are two possible reasons: decreased level of analysis and UAS classification. First, because most UAS are less expensive than manned aircraft, researchers assert they do not warrant the same level of analysis.⁸⁰ In addition, since a majority of UAS safety data is collected by the military, as it is the largest user overseas and domestic operations are limited, it is difficult to obtain safety statistics regarding their operation. Second, as described in Chapter II, the nomenclature for unmanned aircraft has been diverse and evolving. Until recently, they were classified as anything other than aircraft. The Army and Navy have traditionally classified them as vehicles, meaning that any accident involving them were treated in the same fashion as a ground vehicle, further distorting UAS safety data.

Additionally, the potential misleading character of safety data for UAS can also be attributed to fielding UAS that have not completed their acquisition development programs and comparing them to manned aircraft based on a unit of measure per 100,000 flying hours. First, the DoD noted in a 2004 Defense Science Board study that “many early systems [UAS] were not developed or procured under standard acquisition program rules and that such specifications on system reliability were often absent.”⁸¹ Because their ISR capabilities were in such high demand by the DoD and CIA during the late 20th century, UAS flew missions while still under development. Second, accident rates for manned and unmanned aircraft are calculated per 100,000 flying hours. When each type of aircraft is compared to the other, these safety statistics can be taken out of context since UAS have significantly less flying time compared to manned aircraft. Also, most manned aircraft have a higher mishap rate in their first 50,000

⁸⁰ Williams, *A Summary of Unmanned Aircraft Accident and Incident Data: Human Factors Implications*, 12.

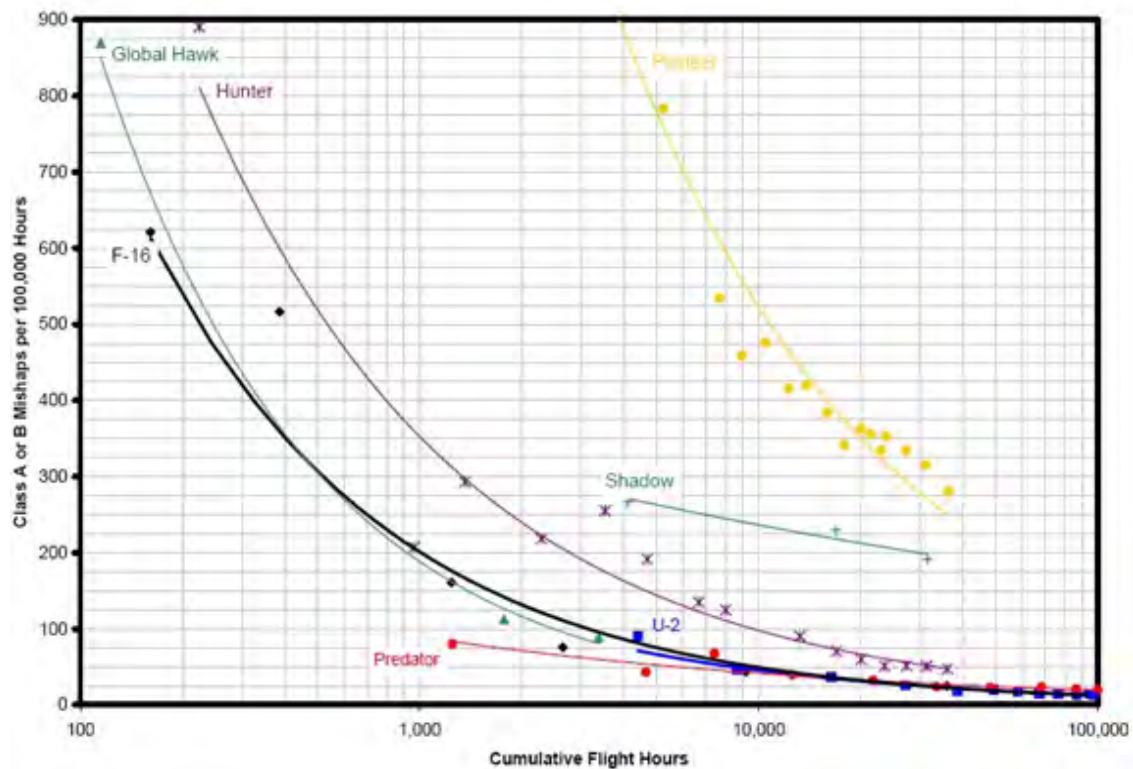
⁸¹ Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, “Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles,” February 2004.

flying hours than their second 50,000 hours inferring that as UAS flight hours increase one could expect the number of accidents to decrease.⁸² Figure 1 depicts this concept best.

The data in Figure 1 shows the relationship between Class A and B mishaps⁸³ per 100,000 flight hours and the cumulative flight hours of two manned aircraft, F-16 and U-2, and five UAS, Global Hawk, Hunter, Predator, Shadow, and Pioneer. According to the trend lines in Figure 1, the number of mishaps for each UAS has decreased as the number of flight hours increased. In particular, the safety performance for Global Hawk and Predator UAS indicate a historical trend similar to that of the F-16 aircraft.

⁸² U.S. Library of Congress, Congressional Research Service, *Unmanned Aerial Vehicles: Background and Issues for Congress*, by Harlan Greer and Christopher Bolkcom, CRS Report RL31872 (Washington, DC: Office of Congressional Information and Publishing, November 21, 2005).

⁸³ Class A mishap is defined as an accident in which the resulting total cost of property damage is \$1 million or more, loss of life, injury resulting in permanent total disability, destruction of an Air Force aircraft, and/or property damage/loss exceeding \$1 million. Class B mishap is a total mishap cost of \$200,000 or more but less than \$1 million or a permanent partial disability, or inpatient hospitalization of three or more personnel.



Source: Department of Defense FY2009–2034 UAS Integrated Roadmap

Figure 1. U.S. Military Aircraft and UAS Class A or B Mishap Rates, 1986–2006

Although there is potential for safety data that has been collected, calculated, and depicted to be misleading, UAS operations within the NAS have grown indicating that safety has and will continue to improve. Since 2005, the FAA issued over 78 experimental certificates for 17 different UAS types, and over the last two years over 400 COAs have been issued to 95 users. However, the FAA claims that in order to fully integrate UAS into the NAS, more safety data is needed. Until this occurs, the concern over UAS safety will be influenced by the variations of public perception.

C. PUBLIC PERCEPTION

Safety remains foremost on the minds of UAS manufacturers, operators, airspace users, and regulators. However, in no small part, the concern over UAS

safety is also affected by public perception. Public perception is affected, positively or negatively, by statistical data, emotional and safety persuasions that, in turn, can instill support for or against UAS integration efforts.

In 2003, the American Institute of Aeronautics and Astronautics published a public opinion survey tested whether the public could be persuaded into acceptance of UAS integration by providing each participant UAS statistical data and emotional and safety persuasions.⁸⁴ The survey indicated that UAS use for commercial and humanitarian missions (i.e., fire fighting, crop dusting, meteorology research, etc.) and cargo transportation are perceived as acceptable forms of UAS application by the public. The survey did not indicate that statistical data alone (as opposed to only emotional and safety persuasion data) was enough to persuade acceptance of UAS integration. However, it did indicate that when a combination of statistical data and emotional and safety persuasion data were given, survey participants significantly support the FAA in allowing UAS applications. The survey also highlighted that the FAA is “enormously persuaded by public perception.”⁸⁵ Understanding these types of social behaviors can obviously be a tool, which critics, as well as supporters, can use to garner support for or against UAS integration initiatives.

While much debate over domestic UAS integration focuses on the safety risks posed by UAS, less attention is given to the potential safety benefits. The DoD is the leading contributor for advancing UAS technology and has put safety foremost. Many of the new technologies and procedures being researched, tested, and implemented for UAS improve safety for civilian and military, manned and unmanned aircraft. However, no matter how much time and money is dedicated to improving safety, there is still no guarantee that accidents will not occur. In January 2011, an American Airlines Boeing 777 narrowly missed having

⁸⁴ Sandra MacSween-George, *A Public Opinion Survey: Unmanned Aerial Vehicles for Cargo, Commercial, and Passenger Transportation*, American Institute of Aeronautics and Astronautics Document 2003-6519, September 2003.

⁸⁵ *Ibid.*, 3.

a mid-air collision with two U.S. Air Force C-17 aircraft.⁸⁶ The Boeing 777 and the McDonnell Douglas C-17 are two of the most technologically advanced aircraft flying today, having accumulated several thousand flying hours. Nevertheless, the accident potential of manned aircraft, no matter how advanced, still exists. This same scenario will no doubt apply to UAS as they become more integrated with other aircraft; but only then can regulators, researchers, and manufacturers identify problems so that UAS can continuously be improved.

⁸⁶ Harro Ranter, "NTSB Investigates Near Midair Collision Involving B777 and USAF C-17s," *Aviation Safety Network, Flight Safety Foundation*, February 5, 2011, <http://aviation-safety.net/news/newsitem.php?id=2355>.

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V. NATIONAL STRATEGY AND UAS AS AN ALTERNATIVE CAPABILITY

A. NATIONAL STRATEGY

During the Cold War, adversaries and their weapons of choice were fixed and widely known by the Western world. When communism came to an end during the early 1990s so did an era of constancy. The 1993 attack on the World Trade Center and 1995 bombing of the Alfred Murrah Federal Building in Oklahoma City were signs of the types of threat that would confront the U.S. as it approached the new century. America's wake-up call would not come until September 11, 2001, when four aircraft, hijacked by radical Muslims, were used as weapons to attack the U.S. homeland. Since these tragic actions, a tremendous effort in time and money has been spent transforming America's institutions and reshaping mindsets. Strategy has been the key from which this transformation has occurred. It has been the catalyst for change revolutionizing America's approach to homeland security from a capability-based approach to a threat-based approach using technology as a force enhancer.

This chapter introduces four security strategies that help to form a security framework, which UAS operations can help to support. These strategies are the *National Strategy for Homeland Security*, the *National Security Strategy*, the *National Strategy for Counterterrorism*, and DoD's strategy for homeland defense. The strategies together present a common theme; they rely upon interconnected and complementary systems that ensure America's homeland security objectives are met. Following an introduction to each strategy, the chapter will conclude by describing how UAS can be used as an alternative capability in helping to fulfill America's strategic security objectives.

1. National Strategy for Homeland Security

In July 2002, the first *National Strategy for Homeland Security* was issued, setting in motion America's new framework for securing its homeland. This new

framework was centered almost exclusively around terrorism and the al-Qaeda network. Although its intent in combating terrorism was met with much progress, natural disasters, namely Hurricane Katrina, highlighted more vulnerabilities to America's security shield. Consequently, in October 2007 the *National Strategy for Homeland Security* was revised, to account for an all-hazards approach that was founded upon preventing terrorist attacks at home and strengthening our nation's preparedness for both natural and manmade disasters. The 2007 strategy "provides a common framework by which our entire nation should focus its efforts on four goals: prevent and disrupt terrorist attacks; protect the American people, our critical infrastructure, and key resources; respond to and recover from incidents that do occur; and continue to strengthen the foundation to ensure our long-term success."⁸⁷

a. *Prevent and Disrupt Terrorist Attacks*

The first goal of the 2007 *National Strategy for Homeland Security* is to prevent and disrupt terrorist attacks. This requires denying terrorists, their weapons, and other terror-related materials entry into the U.S. and disrupting terrorists and their capacity to operate.⁸⁸ Hence, the detection, disruption, and interdiction of weapons of mass destruction (WMD) related materials, along with denying terrorists entry into the U.S., is among the most important missions of homeland security.⁸⁹ Fulfilling these missions will require integrating operational and intelligence efforts at all levels of government, the private sector, and international partners.⁹⁰

In addition, the homeland security strategy attempts to deny terrorists' ability to move across and within our borders and requires improving the legal means for entering while disrupting illicit passages into and across the

⁸⁷ The Office of the President of the United States, "National Strategy for Homeland Security," *Homeland Security Council*, October 2007, 1.

⁸⁸ *Ibid.*, 15.

⁸⁹ *Ibid.*

⁹⁰ *Ibid.*, 15–16.

U.S. Hence, an integrated system of people, technology, and tactical infrastructure is needed to detect, identify, and respond to all entry attempts.⁹¹ This dynamic system to enhance integration will require a domain awareness that relies on the collection and sharing of information.

b. Protect the American People, Our Critical Infrastructure, and Key Resources

Preventing and disrupting terrorist attacks so that people, infrastructure, and resources are protected requires deterrence of the threat, mitigation of our nation's vulnerabilities, and reduction of consequences.⁹² Some critics may dismiss deterrence as being a remnant of a Cold War strategy in which superpower confronts superpower, therefore not applicable to terrorists' obscure tactics and networks.⁹³ Others maintain that deterrence can work if the enemy understands that the policy of the U.S. is to eradicate them.⁹⁴ Although this type of strategy may seem more acceptable in a war zone abroad, it is not within the borders of the U.S. Instead, the homeland security strategy calls for a "deterrence through denial" concept. This concept hinges on decreasing the chances that terrorists are likely to achieve their objectives or that the costs of their efforts are too high.⁹⁵ One way to achieve this objective is to deny terrorist actors their ability to move weapons and materials into the U.S. by filling gaps in security coverage within and along our borders.⁹⁶

Mitigating vulnerabilities to acts of terrorism, manmade and natural disasters can also provide protection of Americans and increase confidence and

⁹¹ The Office of the President of the United States, "National Strategy for Homeland Security," 19.

⁹² *Ibid.*, 25.

⁹³ Uri Fisher, "Deterrence, Terrorism, and American Values," *Homeland Security Affairs* III, no. 1 (February 2007), <http://www.hsaj.org/?fullarticle=3.1.4>.

⁹⁴ *Ibid.*, 2.

⁹⁵ The Office of the President of the United States, "National Strategy for Homeland Security," 25.

⁹⁶ *Ibid.*, 26.

support for homeland security objectives. Thus, fortifying critical infrastructure and key resources becomes vital. Critical infrastructure are "systems and assets, whether physical or virtual, so vital to the U.S. that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters."⁹⁷ Despite attempts to mitigate vulnerabilities to public and private critical infrastructure, future terrorist attacks and disasters will occur. Taking this into account, the homeland security strategy underlines the importance of implementing early steps to reduce the consequences. Such steps entail improved notification, alert, and warning systems by leveraging modern technology.⁹⁸

c. *Respond to and Recover From Incidents*

The homeland security strategy calls for a system that can "quickly adapt to the full range of catastrophic scenarios confronting our nation and integrate capabilities and resources from all stakeholders."⁹⁹ Accordingly, the nation will respond to all hazards by quickly and competently assessing the situation and taking action; expanding operational capabilities as needed; commencing short-term recovery actions; and effectively transferring to long-term rebuilding.¹⁰⁰ If quickly and effectively implemented, these activities can help to save lives, mitigate suffering, and protect property.

d. *Strengthen the Foundation to Ensure Long-Term Success*

The last goal depicted in the *National Strategy for Homeland Security* emphasizes the need to strengthen the principles, systems, structures,

⁹⁷ Homeland Security Presidential Directive 7, "Critical Infrastructure Identification, Prioritization, and Protection," December 17, 2003, <http://www.fas.org/irp/offdocs/nspd/hspd-7.html>.

⁹⁸ The Office of the President of the United States, "National Strategy for Homeland Security," 30.

⁹⁹ *Ibid.*, 31.

¹⁰⁰ *Ibid.*, 31–39.

and institutions that join together the homeland security enterprise and support its numerous activities. Of the many elements that will continue to be strengthened, in particular, science and technology and leveraging instruments of national power will become more vital in helping to secure our nation.

First, the proliferation of technology throughout the world has given adversaries greater access to devices that can be used to harm us or thwart our attempts to prevent an attack on the U.S. For that reason, the homeland security strategy underscores the importance of employing technology. Second, leveraging the instruments of national power, especially access to information, becomes even more important. Partnerships among all levels of government, the private sector, and foreign partners are needed to detect, prevent, disrupt, preempt, and mitigate effects of manmade or natural disasters.¹⁰¹ Thus, technology that can rapidly collect and disseminate real-time information will be critical.

2. National Security Strategy

The notion that defeating terrorism at home begins with operations abroad is no longer a sufficient strategy. Although the U.S. must continue to wage a global campaign to defeat terrorism, a strategy to disrupt, dismantle, and defeat terrorists and extremist groups must begin by first securing America's homeland. The *National Security Strategy*, dated May 2010, emphasizes these critical elements to America's security and calls for a partnered approach to strengthening it. To make it work, the plan relies on intelligence, law enforcement, and homeland security capabilities for collecting and sharing information.¹⁰²

In particular, strengthening security at home will require denying hostile actors the ability to operate along and within U.S. borders, and protecting and

¹⁰¹ The Office of the President of the United States, "National Strategy for Homeland Security," 49.

¹⁰² The Office of the President of the United States, "National Security Strategy," May 2010, 20.

reducing vulnerabilities to critical infrastructure. In the unfortunate event that an attack caused by terrorism or other hostile actor or natural disaster does occur at home, America must be able to quickly respond and recover.

3. National Strategy for Counterterrorism

The 2011 *National Strategy for Counterterrorism* articulates America's framework for countering global terrorism. One of the areas of focus in the strategy is to protect the homeland. This requires an offensive and defensive approach to disrupt terrorist plots, prevent terrorists from entering the U.S., or from operating freely inside U.S. borders. Although the strategy primarily focuses on al-Qaida, it underlines the need to examine other potentially violent foreign and domestic groups and individuals. This is especially important in the wake of the November 2009 Fort Hood massacre, in which one of America's own defenders of freedom engaged in terrorist acts of violence.

The *National Strategy for Counterterrorism* reinforces what the previous two strategies called for: investing in capabilities that enhance our ability to detect, disrupt, and defeat terrorist plots along our borders. In addition, it requires critical infrastructure protection (CIP), ability to detect illicit use of nuclear, biological, and chemical materials, and relies on access to vital information maintained by federal, state, local, and tribal institutions.¹⁰³

4. Department of Defense Strategy for Homeland Security

Although close examination of the DoD's role in homeland security is beyond the scope of this thesis, it should be noted that it continues its vital role in defending America's homeland through homeland defense missions and support to civil authorities. The U.S. Northern Command (USNORTHCOM) is DoD's operational command established after 9/11 to unify DoD efforts to defend the homeland. USNORTHCOM's mission encompasses "the protection of the United States sovereignty, territory, domestic population, and critical defense

¹⁰³ Office of the President of the United States, "National Strategy for Counterterrorism," June 2011, 11.

infrastructure against external threats and aggression or other threats as directed by the President.”¹⁰⁴ Civil support missions include providing military assistance (personnel and equipment) to non-military entities. These missions include domestic relief operations that occur from natural disasters, counter-drug operations, and consequence management resulting from a WMD threat.¹⁰⁵

This section presented a strategic security framework that focuses on preventing terrorist attacks, reducing America’s vulnerabilities, and minimizing damage and recovering from attacks that do occur within U.S. borders. The next section will describe how UAS can be used as an alternative capability in helping to fulfill the objectives highlighted in America’s security strategies.

B. UAS AS AN ALTERNATIVE CAPABILITY

Despite the countless hours and billions of dollars spent by public and private institutions fortifying the nation’s security and resilience, criminal networks, violent extremist groups, insurgents, as well as mother nature, continue to threaten America’s homeland security. Hence, a capability that is effective, flexible, and affordable is needed to help bolster homeland security requirements. This capability can be found in UAS; specifically for border protection, law enforcement, and critical infrastructure protection.

1. Border Protection

The concern for a more secure border has multiplied since 9/11 as many U.S. citizens fear that terrorists could enter the U.S. from Mexico or Canada.¹⁰⁶ Trafficking illicit drugs along U.S. borders contributes to the threat of terrorist activity by supplying cash, creating instability, supporting corruption, providing a

¹⁰⁴ Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms*, November 8, 2010, 156.

¹⁰⁵ United States Northern Command, “About USNORTHCOM,” <http://www.northcom.mil/about/index.html>.

¹⁰⁶ U.S. Library of Congress, Congressional Research Service, *Securing America’s Borders: The Role of the Intelligence Community*, by Richard A. Best, Jr., CRS Report R41520 (Washington, DC: Office of Congressional Information and Publishing, December 7, 2010).

cover for sustaining infrastructures for illicit activity, and competing for law enforcement and intelligence attention.¹⁰⁷ Demands for drugs and other contraband have grown in recent years boosting the violence in Mexico and along our borders. According to analysts, \$19 to \$29 billion each year flows from the U.S. into Mexico in money and weapons to fuel the violence.¹⁰⁸ For this reason, it is no coincidence Americans are concerned that an increase in drug violence along U.S. borders could potentially lead to terrorist activity.

The *National Strategy for Homeland Security*, the *National Security Strategy*, and the *National Strategy for Counterterrorism* each highlight a need for stronger land and maritime border protection. The U.S. border is a resource-thin environment despite the government's efforts to increase the number of CBP agents and other security devices. The Department of Homeland Security, through CBP and the U.S. Coast Guard, are the primary custodians of border security, responsible for approximately 7,000 miles of land border and over 12,000 miles of maritime border.¹⁰⁹ Filling the gaps in border security to prevent illegal trafficking of people, illegal drugs, weapons, and terrorist activity requires a layered approach. This approach can be realized with the use of UAS, which are well suited for the dull, dirty, and dangerous missions found within border protection and law enforcement.

Customs and Border Protection recognized the utility in UAS for border security and started to experiment with the MQ-9 Predator B UAS along the southwestern border in 2005. The aircraft is an effective, low cost, and adaptable platform with a proven safety and performance record. These aircraft are able to

¹⁰⁷ U.S. Library of Congress, Congressional Research Service, *Illicit Drugs and the Terrorist Threat: Causal Links and Implications for Domestic Drug Control Policy*, by Mark Kleiman, CRS Report RL32334 (Washington, DC: Office of Congressional Information and Publishing, April 20, 2004), summary.

¹⁰⁸ Andrew Selee and Eric Olson, "Steady Advances, Slow Results: U.S.-Mexico Security Cooperation After Two Years of the Obama Administration," *Woodrow Wilson International Center for Scholars*, 3.

¹⁰⁹ Under Secretary of Defense (Acquisition, Technology, and Logistics), *Department of Defense Final Report to Congress on Access to National airspace for Unmanned Aircraft Systems*, October 2010, 11.

conduct missions in areas that are difficult to access, or are considered too high-risk for manned aircraft or personnel on the ground. They help fulfill America's homeland security strategy by performing surveillance coverage along porous sections of America's borders. Their electro-optical sensors can provide precise and real-time imagery to ground control operators who can disseminate information to be used to deploy border patrol agents. Also, the UAS has a prolonged loitering capacity, ranging up to 20 hours without refueling that enables sustained air domain coverage improving border security.¹¹⁰

Not only do UAS offer operational advantages, but cost advantages as well. A UAS costs a fraction of what a manned aircraft costs with similar operational capabilities. A 2004 congressional report identified the unit procurement cost of a Predator B UAS at approximately \$4.5 million in comparison to the unit procurement cost of a P-3 Orion manned aircraft, used by Immigration and Customs Enforcement, which costs \$36 million.¹¹¹ Also, the cost and operational advantages of UAS are significantly better than other manned aircraft, such as Blackhawk helicopters, that are frequently used for border protection support.

The Intelligence Reform and Terrorism Prevention Act (IRTPA) of 2004 has influenced the rapid use of UAS along U.S. borders. This act opened the doors for advanced technologies for border surveillance and law enforcement support along our northern and southwestern borders. Title V, Subtitles A and B of the act, gave the Secretary of Homeland Security authorization to implement a pilot program to test various advanced technologies that could improve border security between ports of entry along the northern and southwestern borders of the U.S.¹¹² Since its enactment, IRPTA enabled DHS to make great strides

¹¹⁰ Department of Homeland Security, Customs and Border Protection, "Unmanned Aircraft System Overview," August 31, 2010, http://www.cbp.gov/xp/cgov/border_security/air_marine/uas_program/uasoverview.xml.

¹¹¹ U.S. Library of Congress, Congressional Research Service, *Border Security and Unmanned Aerial Vehicles*, by Jason Blazakis, CRS Report RS21698 (Washington, DC: Office of Congressional Information and Publishing, January 2, 2004), 3.

¹¹² Intelligence Reform and Terrorism Prevention Act of 2004, Pub L. No. 108-458 (2004).

employing the use of UAS technology for surveillance support along our borders. Federal government funding to operate, support, and purchase Predator UAS for CBP from 2006 to 2010 totaled approximately \$121 million.¹¹³

UAS are as effective as manned aircraft in patrolling U.S. coastal borders. The Fiscal Year 2008 Consolidated Appropriations Act directed DHS to explore the use of UAS for maritime flight operations. Subsequently, DHS appropriated \$15 million for a UAS program resulting in a modified “Guardian” Predator B UAS.¹¹⁴ This system will increase the U.S. Coast Guard’s surveillance capabilities for joint counter-narcotics operations in the southeast coastal border region and along the Great Lakes. These systems can provide a “comprehensive picture of activity in the maritime environment, as well as give law enforcement a more accurate tool to use in sorting illegal from legitimate activity.”¹¹⁵

2. Law Enforcement

UAS are receiving more attention to assist federal, state, and local police officials in protecting the American people. They can be used to help fight crime, monitor crowds and automobile traffic, and conduct search and rescue missions. For example, a UAS patrolling overhead can detect and monitor civil unrest and disturbances, as well as spot cars speeding along interstates and highways. They can also be used to support special weapons and tactics (SWAT) teams. For example, a Texas SWAT team from Austin, Texas, used UAS technology to facilitate the arrest of a man suspected of storing large amounts of drugs and weapons in his home.¹¹⁶ The specialized law enforcement team used a small UAS, known as a Wasp, to conduct an aerial surveillance of the suspect’s

¹¹³ U.S. Library of Congress, Congressional Research Service, *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*, by Chad Haddal and Jeremiah Gertler, CRS Report RS21698 (Washington, DC: Office of Congressional Information and Publishing, July 8, 2010), 3.

¹¹⁴ Ibid.

¹¹⁵ Department of Homeland Security Customs and Border Protection Fact Sheet, “Guardian UAS Maritime Variant Predator B,” <http://www.hsdl.org/?view&did=29270>.

¹¹⁶ Peter Finn, “Domestic Use of Aerial Drones by Law Enforcement Likely to Prompt Privacy Debate,” *Washington Post*, January 23, 2011.

residence in fear that the man inside possessed immediate danger to any law enforcement helicopter flying overhead. The UAS was able to beam live video to agents on the ground, which enabled them to storm the house and arrest the suspect safely.

Unmanned aircraft systems can significantly reduce operating costs, making them feasible for many law enforcement agencies.¹¹⁷ According to a U.S. Justice Department official, “unmanned aircraft are a rapidly emerging technology that has exceptional appeal to law enforcement.”¹¹⁸ Police departments in Houston and Miami have already begun testing small UAS platforms in their policing operations.¹¹⁹ As integration within the NAS becomes more routine, “the law enforcement community could be one of the largest UAS customers following the military.”¹²⁰ The FAA expects small UAS to experience the greatest near-term growth in civil and commercial operations because of their versatility and relatively low initial cost and operating expenses.

3. Critical Infrastructure Protection (CIP)

The 2007 *National Strategy for Homeland Security* identifies 17 critical infrastructures and key resources that must be structurally and operationally resilient to manmade threats and natural disasters. Although many of these infrastructures are interrelated, this section will examine emergency management, transportation, agriculture and food, and energy as the ones UAS are most suitable to support.

¹¹⁷ Ramon Lopez, “Unmanned Aircraft in Demand by Law Enforcement,” *Aviation Today*, July 1, 2008, <http://www.aviationtoday.com/rw/publicservice/police/23075.html>.

¹¹⁸ Ibid.

¹¹⁹ 2010 Association for Unmanned Vehicle Systems International, “Unmanned Aircraft System Integration into the United States National Airspace System: An Assessment of the Impact on Job Creation in the U.S. Aerospace Industry,” 8.

¹²⁰ Ibid.

a. Emergency Management

Within the last decade, the U.S. has faced several large-scale natural disasters. The 2004 hurricane season was estimated at causing over 3,000 deaths and approximately \$50 billion in damages.¹²¹ Hurricane Katrina caused more than 1,330 deaths and impacted nearly 93,000 square miles along the Gulf Coast.¹²² In 2007, there were more than 85,000 wildfires destroying over 9 million acres in the U.S.¹²³ Emergency management is a vital service entailing a comprehensive system that enables response and recovery efforts following the consequences of a manmade attack or natural disaster. It consists of disciplines from emergency management, emergency medical services, fire, hazardous material, law enforcement, bomb squads, tactical operations and special weapons assault teams, and search and rescue.¹²⁴ Unmanned aircraft systems are well suited to provide support to first-responders working in any one of these key emergency management disciplines.

In devastated areas where communications may be degraded or nonexistent, UAS can loiter overhead while providing a temporary bridge for which imagery and communications can be monitored and relayed. This type of support was provided to emergency response teams following the earthquake that flattened Haiti in 2010. A Global Hawk UAS operated over Haiti providing surveillance in the wake of the country's 7.0 magnitude earthquake.¹²⁵ It flew for 14 hours collecting and disseminating real-time imagery that helped determine the level of destruction.

¹²¹ National Weather Service, National Hurricane Center, "Tropical Weather Summary," http://www.nhc.noaa.gov/archive/2004/tws/MIATWSAT_nov.shtml.

¹²² Frances Townsend, *The Federal Response to Hurricane Katrina: Lessons Learned* (Washington, DC: Office of the President of the United States, 2006), <http://library.stmarytx.edu/acadlib/edocs/katrinawh.pdf>.

¹²³ National Oceanic and Atmospheric Administration, "National Climate Data Center, Climate of 2007, Wildfire Season Summary," <http://ncdc.noaa.gov/sotc/fire/2007/13>.

¹²⁴ Department of Homeland Security, "Emergency Services Sector: Critical Infrastructure and Key Resources," http://www.dhs.gov/files/programs/gc_1189094187811.shtm.

¹²⁵ Russell Petcoff, "Global Hawk Collects Reconnaissance Data During Haiti Relief Efforts," *Air Force News*, January 15, 2010, <http://www.af.mil/news/story.asp?id=123185754>.

Unmanned aircraft systems are also uniquely capable of helping to support scientific research in helping to reduce the consequences of emergencies. For example, the National Oceanic and Atmospheric Administration (NOAA) began operating UAS in 2006 as a hurricane hunter. NOAA flies UAS into a hurricane and communicates near-real-time data directly to the National Hurricane Center. These unmanned aircraft fly closer to the water's surface, collecting more accurate barometric pressure and temperature data than can safely be collected by manned aircraft. According to NOAA, "UASs can help meet its mission goals with a more advanced fleet capable of collecting data from areas that are currently inaccessible."¹²⁶

In addition, the video and synthetic aperture radar capabilities on UAS can be used to provide imagery of river basins in support of flood response efforts. In early 2011, a CBP Predator was flown from Corpus Christi, Texas, to North Dakota to support the U.S. Geological Survey and the U.S. Army Corps of Engineers in mapping areas affected by flooding along the Red River Valley.

In places, such as California and Colorado, major forest fires are a common occurrence, destroying thousands of acres of land every year. Hence, the U.S. Forest Service has explored the use of UAS technology in an effort to aid wildfire imaging and mapping capabilities for these parts of the U.S. In 2009, it flew a modified Predator B UAS over a 40,200-acre fire near Palm Springs, California, for 16 hours.¹²⁷ The aircraft circled at 43,000 feet transmitting imagery that enabled the fire management team to pinpoint the perimeter of a dangerous blaze that killed five firefighters. According to fire management experts, UAS capability will "go a long way toward helping the forest service understand the science of these giant fires."¹²⁸

¹²⁶ National Oceanic and Atmospheric Administration, "Bridging the Observations Gap Between Earth and Space," <http://uas.noaa.gov>.

¹²⁷ Jeff Wise, "Civilian UAVs: No Pilot, No Problem," *Popular Mechanics* (October 1, 2009), <http://www.popularmechanics.com/science/space/4213464>.

¹²⁸ *Ibid.*

Furthermore, UAS can be flown into areas designated off limits due to increased chemical, biological, radiological, nuclear, or explosive (CBRNE) threats. They can be equipped with externally mounted CBRNE detection systems and flown at low, medium, or high altitudes to obtain samples while transmitting the detection data to scientists and engineers on the ground. Their ability to quickly respond and provide real-time digital information to emergency response teams awaiting initial assessment and follow-on support is vital.

b. Transportation Infrastructure

Transportation infrastructure is a broad category that consists of aviation, highway, maritime, mass transit, pipeline, and rail systems. Its continuous operation is vital to the movement of people and goods domestically and internationally. Manmade attacks against and natural disasters that affect any one of the transportation infrastructures could significantly disrupt the functioning of government and private entities and produce rippling effects felt within the immediate targeted sector while devastating the nation's economy. Given the flexibility and mobility of UAS, they are well suited to monitor many parts of transportation infrastructure. In particular, UAS can inspect thousands of miles of pipeline that transport oil and gas within and across U.S. borders. With forward looking infrared (FLIR) technology mounted onboard the aircraft, UAS can easily detect oil and gas leaks. If undetected, these leaks can cause fires and explosions damaging land, property, and even loss of life.

c. Agriculture and Food Infrastructure

Agriculture and food infrastructure comprises of production, processing, and delivery systems. A disaster caused by an attack on this infrastructure could disrupt the food supply and pose a serious threat to public health, safety, welfare, or to the national economy.¹²⁹ According to DHS, food and agriculture infrastructure “is almost entirely under private ownership and is

¹²⁹ Food and Agriculture Sector-Specific Plan: An Annex to the National Infrastructure Protection Plan 2010, 1.

composed of an estimated 2.1 million farms, approximately 880,500 firms and over one million facilities.”¹³⁰ It accounts for approximately one-fifth of the nation's economic activity.

The capabilities provided by UAS can facilitate the monitoring of farm and agriculture related features, such as the spread of crop destroying pests, status of crop production, identification of crop varieties, and loss of timber in areas threatened by timber theft. Using UAS for crop spraying and dusting greatly reduces the exposure of people to hazards associated with chemical contamination.

d. Energy

The U.S. energy infrastructure fuels the nation's economy. More than 80 percent of the country's energy infrastructure is owned by the private sector.¹³¹ It consists of three interrelated segments: electricity, petroleum, and natural gas.

The electricity segment consists of a generating element consisting of more than 5,300 power plants and a distribution segment that uses over 211,000 miles of high-voltage transmission lines.¹³² The electricity infrastructure is highly automated and controlled by a regional grid system. Petroleum and natural gas segments consist of exploration, production, storage, transport, and refinement (in the case of oil). There are over 400,000 petroleum and gas wells within the U.S. and within its territorial waters, in addition to hundreds of refineries and processing plants.

These electricity, petroleum, and natural gas areas and installations are difficult to guard. Damage caused by a terrorist attack or natural disaster can lead to enormous ecological damage and revenue losses, such as that

¹³⁰ Department of Homeland Security, “Agriculture and Food Sector: Critical Infrastructure and Key Resources,” http://www.dhs.gov/files/programs/gc_1188565256722.shtm.

¹³¹ Department of Homeland Security National Infrastructure Protection Plan, “Energy Infrastructure,” http://www.dhs.gov/xlibrary/assets/nipp_snapshot_energy.pdf.

¹³² Ibid.

experienced in the Deepwater Horizon oil spill in 2010. This critical infrastructure is dispersed throughout the U.S. and its territorial waters leaving it vulnerable in many locations. Unmanned aircraft systems are a formidable capability that can be used to patrol critical infrastructure on a regular basis. Their FLIR camera can detect the presence of attackers who may be trying to penetrate its vulnerabilities.

The national strategies discussed in this chapter provide America's framework for securing its homeland. Their approach is part of an evolutionary process that changes as the security threat changes. Together, these strategies align common security objectives to a threat environment that is difficult to predict. No matter what the threat is or where it comes from there is emphasis on technology as a means to getting the job done. The technologies needed to support America's changing threats have become harder to anticipate, as we cannot control the time, place, and force manmade or natural disasters will bring upon our nation. Unmanned aircraft systems offer an effective capability, specifically in the areas of border protection, law enforcement, and CIP.

VI. CONCLUSION

A. REVIEW

This thesis examined why UAS are not widely used domestically for homeland security support despite their many benefits. The literature introduced credits their sluggish integration to a poor safety record and technology that has not matured to allow safe routine operations. Other critics have suggested that regulations and standards for the development and operation of UAS are insufficient. Although it is commonly understood that flight safety should be foremost for any type of aircraft, defining what safe UAS operations entail has diverted attention away from defining a clear path forward.

The historical background of UAS evolution indicates that these aircraft are nothing new; evolving since the early 20th century. However, throughout most of the 20th century their advancement varied with financial and political support, thereby reducing their development into a viable and alternative capability for aerial support. Not until the number of U.S. servicemen shot down over Vietnam increased, and later the shoot down of a U-2 spy plane over Soviet Union territory, did UAS receive so much attention. Advancements in computers and telecommunications during the late 20th century helped to further advance UAS as a viable military capability. Yet, the utility of UAS was not fully demonstrated until the start of the 21st century when their usage increased over the skies of Iraq and Afghanistan. Since then, UAS use has proliferated among the armed forces and has gained public and private recognition as a capability for homeland security support.

The airspace operating and regulatory structure (known as the NAS) in which UAS operate, like all aircraft, has and will continue to transform to meet the needs of both public and private flying communities. This structure is a dynamic and complex network of airspace, systems, facilities, information, and people. It is primarily focused on the safe and efficient transit of aircraft operating in

differing levels of complexity and congestion. To meet the growing demands of the aviation community and increase in air traffic, NAS infrastructure has continued to evolve. Some of these changes included deregulation of airline operations, consolidation of airspace, implementation of advanced air traffic control equipment, surveillance, and communications technology, and improvements in flight regulations. Nevertheless, many regulations and standards today do not specifically account for UAS operations, leaving broad interpretations for their application based on manned aircraft.

Safety is the fundamental concern over routine UAS integration. This thesis attempted to satisfy the question of whether the concerns over UAS safety are warranted or not. Due to the challenges and time constraints associated with obtaining empirical UAS safety data, the author examined existing government reports and studies. Specifically, a 2004 FAA sponsored report that summarized UAS accident and incident data and a 2004 Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics sponsored study on UAS development. Together, these documents highlighted three important features: 1) UAS accident data is limited and taken out of context; 2) early versions of UAS were fielded prematurely and not allowed to fully develop under their acquisition programs; and 3) UAS safety has improved as their total flight hours has increased.

No matter how safe any system is (i.e., aircraft, automobile, etc.) public perceptions can be damaged when accidents do occur. This thesis also explored this notion by examining a 2003 report on the public's perception on UAS integration. The report noted that public perception can positively or negatively be affected by statistical data and emotional and safety persuasions. Of particular importance, the report found that the FAA can be persuaded by public perception. There is compelling documentation since some critics in government have suggested that the FAA is not acting fast enough to integrate UAS into the NAS.

While the first four chapters of this thesis provided insight into why UAS are not widely used domestically for homeland security support, Chapter V looked at a security framework, which UAS operations can help to support. The goals of the *National Strategy for Homeland Security* are to prevent and disrupt terrorist attacks, protect the American people, critical infrastructure and key resources, respond to and recover from incidents, and ensure long-term success. The *National Security Strategy* calls for a partnered approach to strengthening security and the *National Strategy for Counterterrorism* articulates America's framework for countering global terrorism. These strategies rely upon an interconnected and complementary system that leverages technology to fortify America's homeland.

B. RECOMMENDATIONS

The author supports arguments of those who claim UAS should be widely used domestically for homeland security support. Their growth has continued to increase and "has been the most dynamic growth sector of the world aerospace industry this decade."¹³³ They are effective and efficient and can significantly reduce the total ownership cost for an aerial support platform of similar capability. There are many organizations throughout state and local government and in private industry that can benefit from domestic UAS operations. Analysts estimate there are approximately "50 companies, universities, and government organizations that are developing and producing some 155 unmanned aircraft designs."¹³⁴ Yet, ensuring UAS operate safely in the NAS is the salient concern.

If history is any indication of what the future holds, UAS safety will progress. This has already been the case, as the safety of UAS operations has improved. Trends in UAS mishaps have decreased as the number of flight hours has grown. Flight experience and improvements in technology are notable

¹³³ The Teal Group Corporation, "Teal Group Predicts Worldwide UAV Market Will Total Just Over \$94 Billion."

¹³⁴ Federal Aviation Administration Fact Sheet, "Unmanned Aircraft Systems," December 1, 2010, http://www.faa.gov/news/fact_sheets/news_storynewsid=6287.

contributions to this success. As of June 2011, CBP's Predator UAS flew more than 1,000 successful missions and 10,000 hours supporting national security roles.¹³⁵ Also, the increase in COAs and Experimental Airworthiness Certificates issued by the FAA to UAS operators is further evidence that UAS are safer and more easily being integrated in the NAS. The U.S. Air Force's Global Hawk UAS was the first UAS to be granted an airworthiness certificate recognizing its ability to safely and routinely fly within the NAS without having to follow the COA process.¹³⁶

Although government, private industry, academia, and other UAS stakeholders have made improvements in addressing the challenges that have constrained UAS operations domestically, there is still more that needs to be done. Specifically, it is necessary to improve UAS reliability, change existing regulations and standards to account for peculiar UAS characteristics, and improve public perception.

There are two ways to improve UAS reliability: 1) improve the integrity of components and systems and/or 2) build in redundancy (backup systems). For manned aircraft, additional costs are paid for multiple backup systems, thus increasing system reliability. However, for UAS, cost, weight, function, and performance considerations have been the primary concern foregoing installation of backup systems.¹³⁷ Instead, aviation engineers and manufacturers should continue to put greater effort into improving the integrity of components. This would eliminate the cost and weight factors associated with designing and installing backup systems, still making UAS an operationally attractive and cost effective capability. Moreover, UAS have not traditionally been given the same

¹³⁵ U.S. Customs and Border Protection Office of Air and Marine, "Expanding UAS Operations in National Security: UAS Action Summit 2011," June 3, 2011.

¹³⁶ Northrop Grumman Aerospace Systems, "High Altitude, Long Endurance Unmanned Aircraft Systems," <http://www.as.northropgrumman.com/products/globalhawk/index.html>.

¹³⁷ Graham Warwick, "UAV Collision Bolsters Sense and Avoid Systems," *Aviation Week* (August 18, 2011), <http://www.aviationweek.com/aw/generic/story.jsp?id=news/asd/2011/08/18/01.xml&channel=defense>.

level of maintenance and operational support as manned aircraft, as these aircraft were often looked at as being expendable. If UAS concept of operations includes expendability, based on its designated mission profile, requiring their safety to be equivalent to manned aircraft may not always be the best course of action. For that reason, the level of safety for UAS should be considered according to form, fit, and function, as there are many variations being produced today.

Also, the government should change existing regulations and standards to account for the peculiar operating characteristics of UAS. The FAA, in coordination with the aviation community, should continue to increase their efforts to find an agreeable solution to automate the capability to see and avoid to an equivalent level of safety that is consistent with UAS form, fit, and function so that pertinent FAA regulations and standards can be developed. The capability to see and avoid other aircraft is the ability for UAS to detect traffic, evaluate flight paths, determine the right of way, and maneuver safely. In essence, avoid a mid-air collision. Sense and avoid (SAA) is a technical solution for UAS to be able to meet the FAA requirement to see and avoid other aircraft. The FAA is currently engaged in SAA workshops to define performance parameters and assessment methodologies to safely implement SAA for UAS operations. However, the challenge with SAA today is not as much technical as it is regulatory.

In addition to defining regulation and standards for see and avoid, the FAA in coordination with other civil aviation authorities, should agree on a proper classification of UAS. The nomenclature "UAS" is a general classification that encompasses their various sizes, shapes, uses, and means of control. To determine how they will integrate in the NAS requires specific classification. The DoD classifies UAS based on operating altitudes and endurance, such as high altitude, long endurance (HALE), medium altitude, long endurance (MALE), etc. Australia's Civil Aviation Safety Authority classifies UAS according to weight. Others have suggested that UAS should be classified according to the

classification of airspace needed for operations and navigational accuracy. No matter how UAS are classified, there needs to be a single solution so that standards and regulations can be developed.

Furthermore, improvements in safety, technology, and regulation and standards mean little when it comes to public perception and political acceptance. The advanced high-resolution surveillance technology and real-time data transmission capability of UAS appears to have instilled fear in many who believe they will be misused and infringe upon their privacy and civil liberties. People fear that if UAS become part of the common homeland security toolset, there will be continuous surveillance of their activities leading some citizens to believe that their Fourth Amendment rights will be violated. For UAS to be accepted, the media and public must be convinced their benefits outweigh costs. The U.S. government must continue to put forth great efforts to ensuring the public that UAS operations will protect, not infringe upon their rights and civil liberties. Courts have been sensitive to this and have responded accordingly by requiring law enforcement officials obtain a warrant before engaging in surveillance activities in accordance with Fourth Amendment protection.

In conclusion, our government's greatest responsibility is the safety and security of the American people, whether it be from flight mishaps, natural disaster, or criminal or terrorist activity. The aviation regulatory structure that governs the NAS is designed to facilitate the safe and efficient operation of all aircraft. Likewise, America's security strategies provide the framework that guides intelligence, security, and law enforcement agencies. Unmanned aircraft systems are an operational and cost-effective capability for homeland security support. They offer advanced technologies for collecting and disseminating intelligence and security information for border protection and law enforcement agents. In addition, the vulnerabilities associated with critical infrastructures, such as emergency management, transportation, agriculture and food, and energy, are significant as they are all interrelated. The disruption or destruction of one will

most likely affect the others. Having an adaptable, first-response capability to patrol these critical and sometimes hostile areas will facilitate America's ability to quickly respond and recover from such calamities.

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LIST OF REFERENCES

- 2010 Association for Unmanned Vehicle Systems International. "Unmanned Aircraft System Integration into the United States National Airspace System: An Assessment of the Impact on Job Creation in the U.S. Aerospace Industry." <http://www.mckeeon.house.gov/pdf/0510jobsreport.pdf>.
- Association for Unmanned Vehicle Systems International. "Unmanned Aircraft System Integration into the United States National Airspace System: An Assessment of the Impact on Job Creation in the U.S. Aerospace Industry." 2010.
- Blom, John. "Unmanned Aerial Systems: A Historical Perspective." *Combat Studies Institute Press* (September 2010): 45.
- Briddon, Arnold, Ellmore Champie, and Peter Marraine. *Federal Aviation Administration Historical Fact Book: A Chronology 1926 to 1971*. Washington, DC: U.S. Government Printing Office, 1974.
- Carnegie Mellon University. *Review Panel Presentation for Project on Integration of Unmanned Aircraft into the National Airspace System*. Department of Engineering and Public Policy and Department of Social and Decision Sciences. May 1, 2007. http://www.andrew.cmu.edu/course/19-451/CMU_UAS_Final_Presentation.
- Congressional Budget Office. "Policy Options for Unmanned Aircraft Systems." Publication Number 4083, June 2011.
- Congressional Unmanned Systems Caucus. "Federal Aviation Administration Re-Authorization Bill." <http://uavc.mckeeon.house.gov/2011/04/federal-aviation-administration-re-authorization-bill.htm>.
- Dalamagkidis, Konstantinos, Kimon P. Valavanis, and Les A. Piegl. "Progress in Aerospace Sciences: On Unmanned Aircraft Systems Issues, Challenges, and Operational Restrictions Preventing Integration into the National Airspace System." *Aerospace Sciences* 44 (October 2008): 510.
- DeGarmo, Matthew. "Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace." *The MITRE Corporation Center for Advanced Aviation System Development*. MITRE Product 04W0000323. November 2004. http://www.mitre.org/work/tech_papers/tech_papers_04/04_1232/04_1232.pdf.

- Degaspari, John. "Look, Ma, No Pilot." *Mechanical Engineering* (November 2003): 43.
- Department of Defense. *DoD Dictionary of Military and Associated Terms*. Joint Publication 1-02. June 13, 2007.
<http://wstiac.alionscience.com/pdf/dodmilitarydictionary.pdf>.
- Department of Homeland Security Customs and Border Protection Fact Sheet. "Guardian UAS Maritime Variant Predator B."
<http://www.hSDL.org/?view&did=29270>.
- Department of Homeland Security National Infrastructure Protection Plan. "Energy Infrastructure."
http://www.dhs.gov/xlibrary/assets/nipp_snapshot_energy.pdf.
- Department of Homeland Security. "Agriculture and Food Sector: Critical Infrastructure and Key Resources."
http://www.dhs.gov/files/programs/gc_1188565256722.shtm.
- . "Emergency Services Sector: Critical Infrastructure and Key Resources."
http://www.dhs.gov/files/programs/gc_1189094187811.shtm.
- . "Transportation Systems Critical Infrastructure Sector-Specific Plan." May 2007. <http://www.dhs.gov/xlibrary/assets/nipp-ssp-transportation.pdf>.
- . Customs and Border Protection. "Unmanned Aircraft System Overview." August 31, 2010.
http://www.cbp.gov/xp/cgov/border_security/air_marine/uas_program/uaso_verview.xml.
- Department of Transportation. Federal Aviation Administration. 14 CFR Part 91.113. General Operating and Flight Rules. June 2, 2011.
http://edocket.access.gpo.gov/cfr_2011/janqtr/pdf/14cfr91.113.pdf.
- . Federal Aviation Administration. *Unmanned Aircraft Operations in the National Airspace System*. NJO 7210.766. March 28, 2011.
- Eaton, Tim. "Unmanned Planes Could Begin Flying Over Texas in a Matter of Months." *The Associated Press*, May 11, 2010.
<http://www.statesman.com/news/texas-politics/unmanned-planes-could-begin-flying-over-texas-in-681019.html>.
- FAA Instrument Procedures Handbook. *IFR Operations in the National Airspace System*. (n.d.).
http://www.faa.gov/library/manuals/aviation/instrument_procedures_handbook/media/ch-01.pdf.

- Federal Aviation Administration Fact Sheet. "Unmanned Aircraft Systems." December 1, 2010. http://www.faa.gov/news/fact_sheets/news_storynewsid=6287.
- Federal Aviation Administration Notice. "Unmanned Aircraft Operations in the National Airspace System." Docket No. FAA-2006-25714. http://www.faa.gov/about/initiatives/uas/reg/media/frnotice_uas.pdf.
- Federal Aviation Administration. "NextGen Implementation Plan." March 2011. [http://www.faa.gov/next en/media/ng2011_implementation_plan.pdf](http://www.faa.gov/next%20gen/media/ng2011_implementation_plan.pdf).
- . *Aeronautical Information Manual Official Guide to Basic Flight Information and ATC Procedures*. February 11, 2010.
- . *Airworthiness Certification of Aircraft and Related Products*. FAAO 8130.2G. August 31, 2010.
- . Next Generation Air Transportation System Video. "FAA Aerospace Forecast Fiscal Years 2011–2031." http://faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2011-2031/media/review%20of%202010.pdf.
- Federal Aviation Advisory Circular 90-48C. "Pilot's Role in Collision Avoidance." March 18, 1983.
- Federal Aviation Regulation Part 61.3. *Certification: Pilots, Flight Instructors, and Ground Instructors*. October 20, 2009. <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=3fa5b4e2e33c94f0b1450dcb7a81d7e5&rgn=div8&view=txt&node=14:2.0.1.1.2.1.1.3&idno=14>.
- Federal Aviation Regulation Part 91.113. *Right of Way Rules: Except Water Operations*. September 1, 2004. <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=3fa5b4e2e33c94f0b1450dcb7a81d7e5&rgn=div8&view=txt&node=14:2.0.1.3.10.2.4.7&idno=14>.
- Finn, Peter. "Domestic Use of Aerial Drones by Law Enforcement Likely to Prompt Privacy Debate." *Washington Post*, January 23, 2011.
- Fisher, Uri. "Deterrence, Terrorism, and American Values." *Homeland Security Affairs* III, no. 1 (February 2007). <http://www.hsaj.org/?fullarticle=3.1.4>.
- Food and Agriculture Sector-Specific Plan: An Annex to the National Infrastructure Protection Plan 2010.

- Goodspeed, Peter. "When Robots Kill—Urgent Questions Over Drone Warfare." *National Post*, April 30, 2011.
<http://fullcomment.nationalpost.com/2011/04/30/goodspeed-when-robots-kill-%e2%80%94urgent-questions-over-drone-warfare/>.
- Graham-Duncan, Duncan. "Safety Fears Over Unmanned Planes." *New Scientist* 178, no. 2401 (June 28, 2003): 4.
- Graham-Rowe, D. "Safety Fears Over Unmanned Planes—Pilotless Aircraft May Soon Fly Alongside Your Holiday Jet." *New Scientist* 178, no. 2401 (2003): 4–5.
- Homeland Security Presidential Directive 7. "Critical Infrastructure Identification, Prioritization, and Protection." December 17, 2003.
<http://www.fas.org/irp/offdocs/nspd/hspd-7.html>.
- Intelligence Reform and Terrorism Prevention Act of 2004, Pub L. No. 108–458 (2004).
- Joint Planning and Development Office. "Concept of Operations for the Next Generation Air Transportation System." Version 2.0. June 13, 2007.
http://www.jpdo.gov/library/NextGen_v2.0.pdf.
- Joint Publication 1-02. *Department of Defense Dictionary of Military and Associated Terms*. November 8, 2010.
- Landsberg, Bruce et al. "Airspace for Everyone." *Aircraft Owners and Pilot Association Air Safety Foundation*, no. 38002, Edition 5. June 2009.
<http://www.aopa.org/asf/publications/sa02.pdf>.
- Lopez, Ramon. "Unmanned Aircraft in Demand by Law Enforcement." *Aviation Today*, July 1, 2008.
<http://www.aviationtoday.com/rw/publicservice/police/23075.html>.
- Lowy, Joan. "Pressure Builds for Use of Drones in Home Skies." *Philadelphia Inquirer*, June 15, 2010.
<http://ebird.osd.mil/ebfiles/e20100615758060.html>.
- MacSween-George, Sandra. *A Public Opinion Survey: Unmanned Aerial Vehicles for Cargo, Commercial, and Passenger Transportation*. American Institute of Aeronautics and Astronautics Document 2003-6519. September 2003.
- McCaul, Congressman Michael Website. "Texas Congressmen Call for Increased UAV Coverage of Texas-Mexico Border." April 27, 2011.
<http://mccaul.house.gov/index.cfm?sectionid=29&parentid=7§iontree=7&itemid=1171>.

- National Oceanic and Atmospheric Administration. "Bridging the Observations Gap Between Earth and Space." <http://uas.noaa.gov>.
- . "National Climate Data Center. Climate of 2007. Wildfire Season Summary." <http://ncdc.noaa.gov/sotc/fire/2007/13>.
- National Weather Service. National Hurricane Center. "Tropical Weather Summary." http://www.nhc.noaa.gov/archive/2004/tws/MIATWSAT_nov.shtml.
- Northrop Grumman Aerospace Systems. "High Altitude, Long Endurance Unmanned Aircraft Systems." <http://www.as.northropgrumman.com/products/globalhawk/index.html>.
- Office of the President of the United States. "National Strategy for Counterterrorism." June 2011.
- Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics. "Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles." February 2004.
- Oster, Clinton, and John Strong. *Managing the Skies: Public Policy, Organization and Financing of Air Traffic Management*. Ashgate Publishing, 2007.
- Petcoff, Russell. "Global Hawk Collects Reconnaissance Data During Haiti Relief Efforts." *Air Force News*, January 15, 2010. <http://www.af.mil/news/story.asp?id=123185754>.
- Rango, Albert, and Andrea S. Laliberte. "Impact of Flight Regulations on Effective Use of Unmanned Aircraft Systems for Natural Resources Applications." *Journal of Applied Remote Sensing* 4 (October 2010).
- Ranter, Harro. "NTSB Investigates Near Midair Collision Involving B777 and USAF C-17s." Aviation Safety Network, Flight Safety Foundation. February 5, 2011. <http://aviation-safety.net/news/newsitem.php?id=2355>.
- Saletan, William. "The Machines Aren't Rising Quite Yet." *National Post*, May 2, 2011. <http://www.nationalpost.com/news/machines+aren+rising+quite/4707797/story.html>.
- Selee Andrew, and Eric Olson. "Steady Advances, Slow Results: U.S.-Mexico Security Cooperation After Two Years of the Obama Administration." *Woodrow Wilson International Center for Scholars*.
- Singer, P. W. "Drones Don't Die." *Military History* 28, no. 2 (July 2011): 69.

Spinetta, Lawrence. "The Rise of Unmanned Aircraft." *Aviation History* (November 10, 2010).

Statement of Nancy Kalinowski. Vice President for System Operations Services. Testimony before the House of Representatives, Committee on Homeland Security, Subcommittee on Border, Maritime, and Global Counterterrorism on the Role of Unmanned Aerial Systems on Border Security. July 15, 2010. http://www.faa.gov/news/testimony/news_story.cfm?newsid+11599.

Talleg, C. Le. "VFR General Aviation Aircraft and UAV Flights Deconfliction." *Aerospace Science and Technology* 9 (October 2005): 495–503.

The Office of the President of the United States. "National Security Strategy." May 2010.

———. "National Strategy for Homeland Security." *Homeland Security Council*, October 2007.

The Teal Group Corporation. "Teal Group Predicts Worldwide UAV Market Will Total Just Over \$94 Billion." March 1, 2011. http://tealgroup.com/index.php?option=com_content&view=article&id=74:teal-group-predicts-worldwide-uav-market-will-total-just-over-94-billion-&catid=3&Itemid=16.

Townsend, Frances. *The Federal Response to Hurricane Katrina: Lessons Learned*. Washington, DC: Office of the President of the United States, 2006. <http://library.stmarytx.edu/acadlib/edocs/katrinawh.pdf>.

U.S. Customs and Border Protection Office of Air and Marine. "Expanding UAS Operations in National Security: UAS Action Summit 2011." June 3, 2011.

U.S. Department of Transportation. Federal Aviation Administration. "Unmanned Aircraft Operations in the National Airspace System." March 28, 2011. <http://www.faa.gov/documentlibrary/media/notice/N7210.766.pdf>.

———. *Unmanned Aircraft System Regulation Review* by L. Kirk, D. Marshall, B. Trapnell, and G. Frushour. (Federal Aviation Administration Report AR-09/7). September 2009.

U.S. Government Accountability Office. *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System*. (GAO-08-511). Washington, DC: GPO, May 2008. <http://www.gao.gov/new.items/d08511.pdf>.

- U.S. Library of Congress. Congressional Research Service. *Border Security and Unmanned Aerial Vehicles*, by Jason Blazakis, CRS Report RS21698. Washington, DC: Office of Congressional Information and Publishing, January 2, 2004.
- . *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*, by Chad Haddal and Jeremiah Gertler, CRS Report RS21698. Washington, DC: Office of Congressional Information and Publishing, July 8, 2010.
- . *Illicit Drugs and the Terrorist Threat: Causal Links and Implications for Domestic Drug Control Policy*, by Mark Kleiman, CRS Report RL32334. Washington, DC: Office of Congressional Information and Publishing, April 20, 2004.
- . *Securing America's Borders: The Role of the Intelligence Community*, by Richard A. Best, Jr. CRS Report R41520. Washington, DC: Office of Congressional Information and Publishing, December 7, 2010.
- . *Unmanned Aerial Vehicles: Background and Issues for Congress*, by Elizabeth Bone. CRS Report RL31872. Washington, DC: Office of Congressional Information and Publishing, April 25, 2003.
- . *Unmanned Aerial Vehicles: Background and Issues for Congress*, by Harlan Geer and Christopher Bolkcom. CRS Report RL31872. Washington, DC: Office of Congressional Information and Publishing, November 21, 2005.
- Under Secretary of Defense (Acquisition, Technology, and Logistics). *Department of Defense Final Report to Congress on Access to National airspace for Unmanned Aircraft Systems*, October 2010.
- United States Northern Command. "About USNORTHCOM." <http://www.northcom.mil/about/index.html>.
- Warwick, Graham. "UAV Collision Bolsters Sense and Avoid Systems." *Aviation Week* (August 18, 2011). <http://www.aviationweek.com/aw/generic/story.jsp?id=news/asd/2011/08/18/01.xml&channel=defense>.
- Weinberger, Sharon. "Border Drones Plagued by Mishaps, Pilot Shortage." *Aol News*, July 16, 2010. <http://www.aolnews.com/2010/07/16/border-drones-plagued-by-mishaps-pilot-shortge/>.

Williams, Kevin. *A Summary of Unmanned Aircraft Accident and Incident Data: Human Factors Implications*. Federal Aviation Administration Technical Report. December 2004.

Wise, Jeff. "Civilian UAVs: No Pilot, No Problem." *Popular Mechanics* (October 1, 2009). <http://www.popularmechanics.com/science/space/4213464>.

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