

BREAKAWAY: A LOOK AT THE INTEGRATION OF AERIAL
REFUELING AND UNMANNED AIRCRAFT SYSTEMS
IN FUTURE OPERATIONS

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ABSTRACT

BREAKAWAY: A LOOK AT THE INTEGRATION OF AERIAL REFUELING AND UNMANNED AIRCRAFT SYSTEMS IN FUTURE OPERATIONS, by Major Robert R. Basom, 93 pages.

Unmanned aircraft are rapidly becoming the platform of choice for military and governmental leaders. In recent years, the United States (US) government has expressed great interest in Unmanned Aircraft Systems for military and other governmental agencies. With an almost insatiable appetite to gain information immediately, commanders want a persistent, responsive platform at their beck and call. However, the demand greatly outnumbers the availability of platforms, so leaders are looking at the possibility of air refueling unmanned platforms that will prolong their loiter time. Because of the senior leader pressure to get a persistent presence of unmanned aircraft through air refueling, they might have waived the “sanity check” for this, or overlooked a better way to achieve the goal. The future force of 2025 will undoubtedly include many unmanned aircraft and manned aircraft. This thesis investigates how aerial refueling and unmanned aircraft will interact in the future. The author concludes the tanker modified with multiple drogue refueling points, flying in an anchor orbit or track refueling best augments future unmanned aircraft operations.

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ACRONYMS

C2	Command and Control
DARPA	Defense Advanced Research Projects Agency
DoD	Department of Defense
FAA	Federal Aviation Administration
FCS	Future Combat System
GCS	Ground Control Station
ISR	Intelligence, Surveillance and Reconnaissance
JETCD	Joint Experiment, Transformation and Concepts Division
JUCAS	Joint Unmanned Combat Air System
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
QDR	Quadrennial Defense Review
RFP	Request for Proposals
SAC	Strategic Air Command
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
US	United States
USAF	United States Air Force

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CHAPTER 1

INTRODUCTION

I will give up a tank battalion for a UAV company.¹

Major General Paul Kern
Commander 4th Infantry Division

The evolution of unmanned aviation from cheap programmed drones to multimillion dollar aircraft has led a discussion of what exactly is an unmanned aerial vehicle (UAV). Mr. Dyke Weatherington, Deputy Director of the Department of Defense's Unmanned Aircraft Systems Planning Task Force, went before Congress in February 2006, and stated:

The term "UAV" puts emphasis on the air platform, ignoring the other essential components of an effective system--like the ground control station, the sensors and payloads, the communication links, and the data distribution infrastructure. We believe the term "unmanned aircraft systems" better captures the maturing nature of systems taken as a whole and have begun using this term, most notably in our update of the technology roadmap. This terminology encompasses the combination of components in the system, rather than focusing on a single element. It also properly identifies the airborne component as an *aircraft*, which is consistent with the Federal Aviation Administration's (FAA) view of these platforms. In addition to the hardware components of UA systems, many other elements are essential to order our thinking, guide our engineering, and enable us to safely operate these systems. They include a systems architecture that allows data to be moved for a variety of uses, either a few miles or thousands of miles away. This architecture includes adequate spectrum and bandwidth for communication, airspace management and deconfliction, common data standards and formats to allow sharing and data fusion, deliberate contingency mission planning to deal with signal loss, common operating systems, and system interoperability.

For the purpose of this thesis, Mr. Weatherington's definition of unmanned aircraft systems (UAS) is used for ground and air components, and the term unmanned aircraft (UA) is solely referring to the aircraft platform.

Thesis Intent and Primary Research Question

This thesis examines the expected missions the UA platforms will perform in 2025 and explores the optimal aerial refueling techniques that will enable the UAS missions. This research paper is built around the primary question, During future operations, what will the role of air refueling and unmanned aerial vehicles be? This thesis does this by examining future UAS and their expected missions. Furthermore, it examines tanker platforms and their current and future capabilities in order to see how they would complement UA platforms. Specific methods for research and analysis will be covered in chapters 3 and 4, respectively. The most difficult part of this research was determining what the UAS and tanker force will look like in 2025. The best way to forecast nearly twenty years into the future is to look at governmental and military leaders' vision of UAS and tankers. This thesis examines those operations and missions that unmanned platforms and tankers are performing currently. Furthermore, the thesis investigates current procurement contracts for both UAS and tanker platforms in search of answers to the desired capabilities of future assets.

Significance

With the expansion of UAS use in the current operational environment and no evidence of UAS use diminishing, it is important to maximize their effectiveness. As J. R Wilson jokingly wrote in *Aerospace America*, “[Unmanned aircraft] are the *vampires* of military acquisition--rising up every few years since WWII, only to be buried until the next decade brings them a new shot at life.”² This time, however, the “vampire” is here to stay. Undoubtedly, UAS technology will be an important element of future US conflicts. The UAS may even dominate the skies and space by 2025. This is shown when, in 2003,

Mr. Weatherington delivered a briefing to senior Pentagon officials stating, “The Pentagon plans heavy investment in UAS development. The UAS Roadmap provides those high-priority investments necessary to move UAS technology to the mainstream. The potential value UA systems offer ranges across virtually every mission area and capability of interest.”³ Due to the wide proliferation of UAS platforms, it is in the US military’s best interest to determine the role of future UA and investigate the viability of air refueling UA. This thesis is intended to have an impact on future tanker platforms the US government purchases and how best to complement the expanding UAS role.

The Unmanned Aircraft System

To better understand the capabilities and limitations of the UAS, consider the MQ-1 Predator as an example. For the Predator aircraft “system” to successfully launch, fly a mission, and recover it requires the combined capabilities of multiple subsystems. The main components of the system are: the aircraft, a Ground Control Station (GCS), and a Launch and Recovery Element. The pilot in the GCS controls the Predator remotely via Ku-band SATCOM and receives the sensor products via the same link.⁴ An advantage of remote operation is it can be controlled from wherever the GCS is located. Presently, there are Predators flying missions over Iraq and Afghanistan being controlled by a GCS in Nevada. A few advantages of remote control stations are the reduced military footprint in theater and that the GCS are in a secure, stable environment. This is just one example of an UAS. The US Army, Air Force, Navy, and Marines are intrigued and spending millions of dollars for mission specific unmanned systems. This proliferation of UAS is requiring large amounts of communication bandwidth from

limited bandwidth satellites and causing airspace congestion. The UAS proliferation “firestorm” needs oversight before it grows out of control.

Multiple Services--Multiple Unmanned Aircraft Systems

The evolution from “stove-piped” services (Army, Navy, Air Force, and Marines) to a joint military vision is an on-going process and has not been without difficulty. Changing doctrine has influenced the evolution of multiple UAS missions. The UAS proven ability to penetrate into enemy territory and gather intelligence or even to engage enemy targets has led to further development. Furthermore, given the numerous capabilities of UAS, they are no longer serving a single user or even a single Service, so interoperability becomes increasingly important.

The military has been infatuated with new UAS technology and has modified the UAS from a strictly intelligence, surveillance and reconnaissance (ISR) platform, to an interdiction and possibly even a close air support platform. Military leaders, strategists, and high level government officials constantly weigh the cost versus benefits of this new unmanned technology to determine whether a new platform will be effective against the current threats and more importantly, against future threats. Given the current capabilities and future promise of UAS, one may ask whether the US military is using the UAS platform in the most effective manner? Would extended loiter time offered by in-flight refueling enhance the UAS capabilities, or are there hidden problems, such as maintenance or rearming requirements or likelihood of midair collisions? Currently, Air Force engineers are testing the technological feasibility of aerial refueling of unmanned platforms. If given enough money and time, the technological hurdles can be overcome, but is this a smart investment of time and resources? Furthermore, if an existing energy

source or new energy source is discovered in the near future, enabling UA to stay aloft for an infinite amount of time, would that cause aerial refueling of UA systems to become obsolete?

What Are the Advantages of an Unmanned Aircraft System That is Capable of Being Refueled in the Air?

The first most obvious answer is loiter time. Primary aircraft, such as Airborne Warning and Control System, F-15s, and EC-130s, are air refuelable to increase time on station performing their primary mission. By increasing the UA's loiter time, one UA could perform two or three missions per sortie. An air refuelable UAS would drastically reduce the number of sorties a non air refuelable UAS would require to do those missions. As a secondary effect, it would reduce the overall number of UA required in the operational area. The end result could be a reduced footprint of American presence, a decrease in production and maintenance costs, and a reduction in logistics support.

Secondly, the UAS has the ability to perform the dirty and dangerous missions that put the aircrews of manned aircraft at risk. Commanders are more apt to send an unmanned platform into dirty and dangerous missions because they know there is no risk of loss of life or possible aircrew capture. Simply re-rolling a UA already airborne to aerial refuel and perform a dirty or dangerous mission would save a sortie and allows a quicker response time. In the larger picture, UA also reduce the number of combat search and rescue units required. Furthermore, in today's casualty adverse society, even more pressure is placed on a commander to complete the mission with the absolute minimum number of casualties--UA are rapidly becoming the solution.

Lastly, by not having humans in the aircraft, operational planners are not confined by physiological endurance constraints; the length of the mission becomes a mechanical constraint. Furthermore, the unmanned platform does not require life support equipment, such as oxygen supply systems, ejection systems, and combat survival gear which collectively weighs thousands of pounds. The savings in weight reduction could be directly transferred to fuel load, weapons payload, or sensor payload.

Brief History of Aerial Refueling

In 1917, a pilot in the Imperial Russian Navy Alexander P. de Seversky proposed increasing the range of combat aircraft by refueling them in flight. In 1918, de Seversky came to the United States (US) as a naval attaché to the Russian Embassy and later became an engineer in the War Department, where he applied for and received the first patent for air-to-air refueling in 1921.⁵

On 12 November 1921, wing walker Wesley May climbed from a Lincoln Standard to a Curtiss JN-4 airplane with a can of fuel strapped to his back. When he reached the JN-4, he poured the fuel into its gas tank! This amazing aerial stunt would remain merely a stunt until technology proved viable and the military recognized the need. Aerial refueling remained a dormant capability, with few exceptions throughout most of the 1920s, 1930s, and early 1940s. However, in the “jet-era” of the late 1940s, the leadership of the newly formed United States Air Force (USAF), recognized the Warsaw Pact countries outnumbered the North Atlantic Treaty Organization troops nearly three to one, so a “massive retaliation” concept was adopted. Deterrence of Soviet invasion was anchored around the *nuclear triad*--strategic bombers, intercontinental ballistic missiles, and ballistic missile submarines. General Curtis LeMay became head of

the Strategic Air Command (SAC), parent command of the bomber force, and made aerial refueling a major goal for his new command. He realized that the jet-powered bombers then entering service consumed far more fuel than piston engines and also needed to fly farther--from the US to targets deep in the Soviet Union and back. The increasing demands of the SAC bombers led to the procurement of the Boeing KC-135, a dedicated tanker aircraft that was similar (but not identical) to the commercial Boeing 707 airliner. During the 1950s, under General LeMay's leadership, SAC built up a large (over 500 airplanes) KC-135 tanker fleet to support its B-52 bombers, which could not attack targets inside the Soviet Union without aerial refueling. General LeMay was such a staunch proponent of air refueling that he stated:

If you gave us money for jet airplanes, I would buy tankers, not airplanes for MATS [Military Air Transport Service, ancestor of Air Mobility Command]. . . . I think we would increase our combat capability more in that manner.⁶

Although B-52s, aided by KC-135s, never attacked the targets deep inside Russia, the KC-135 enjoyed huge combat success over the jungles of Vietnam. From 1964 to 1974, the KC-135 flew an amazing 194,687 sorties performing 813,873 aerial refuelings.⁷ However, the KC-135 tanker, designed and built just for refueling the SAC bombers was not able to air refuel US Navy or Marine aircraft, unless a drogue basket was attached to the tanker's boom, prior to launch. This process required, and still requires, nearly three hours to attach. As a result, during the mid-1970s the US began looking at another air refueling platform to accommodate the increasing requirement for the global mobilization of airpower. In an effort to save money, Air Force leadership modified the existing civilian transport McDonnell Douglas DC-10 aircraft to deliver fuel. Designers of the re-designated KC-10 developed a system capable of delivering fuel to "boom" and

“drogue”-type receivers (see figures 1 and 2). This modification allowed greater flexibility to not only Air Force, Navy, and Marine aircraft, but to allied aircraft as well. In 1977, the Air Force procured fifty-nine of the new KC-10A, and they have enjoyed a huge success since their first delivery to SAC in 1981.



Figure 1. Boom-type Refueling

Source: US Air Force, Website; available from <http://www.af.mil/photos/index.asp?galleryID=36&page=5>; Internet; accessed on 20 January 2007.



Figure 2. Drogue-type Refueling

Source: Answers.com, Aerial Refueling; available from <http://www.answers.com/topic/aerial-refueling>; Internet; accessed on 20 January 2007.

In 2001, the US government was on the verge of acquiring a new tanker via a Boeing lease program; however, senior Pentagon acquisitions employee, Darleen Druyun was caught in a serious ethics violation. She admitted to giving Boeing preferential treatment for multimillion dollar Department of Defense (DoD) acquisition contracts in exchange for a future lucrative, senior-level position on the Boeing staff. The new tanker acquisition came to a grinding halt, a federal investigation began, and the “tanker deal” quickly became a “black eye” to many senior defense officials. The dishonesty by senior Pentagon and Boeing officials delayed procurement of a new tanker for over five years. Today, the high operations tempo of the current tanker fleet has highlighted the necessity for a modern, multicable, dependable refueling platform. Acting Secretary of the Air Force, Peter B. Teets, testified before the Senate Armed Services Committee on 2 March 2005 stating:

The Air Force's No. 1 challenge is to recapitalize our aging systems. Our aircraft fleet averages 23 years old--ranging from fairly young F-117 (Nighthawks) and B-2 (Spirits), to venerable B-52 (Stratofortresses) and KC-135 (Stratotankers). Flightline and depot maintenance crews work magic to keep many of our legacy aircraft flying, but we cannot fly those planes forever.⁸

Most Pentagon correspondents believe the “future tanker” front-runners are the Boeing 767 and Airbus 330. The Air Force would modify it, much like they did to the DC-10, and have a new air refueling platform. A brief synopsis of the projected refueling capabilities of each is discussed in chapter 4.

Brief History of Unmanned Aerial Vehicles

To begin with, there are two different types of UAVs: drones and remotely piloted vehicles. Both drones and remotely piloted vehicles are pilotless, but drones are programmed for autonomous flight, meaning the aircraft flies a designated route from point-to-point without ground operator inputs. Remotely piloted vehicles are actively flown--remotely--by a ground control operator.

The history of the UAVs began with the drone. These were used both to train antiaircraft gunners and to fly one-way attack missions. They were little more than full-sized remote controlled airplanes. The turning point in UA employment came in the early 1982 as Israel successfully deployed a number of different unmanned systems in the Bekaa Valley in Lebanon. In a carefully planned and coordinated operation, Israeli forces used the Mastiff and Scout unmanned systems to provide ISR and to activate Syrian air defense systems. The surface-to-air radars were activated and the surface-to-air missile sites launched all their missiles at the UAVs. The ruse proved successful and Israeli manned aircraft shortly thereafter flew into Syrian territory and destroyed the now impotent air defenses.⁹ This tactical success proved that unmanned platforms could

perform other missions in addition to its normal drone ISR mission. The UAV became a tactical, force-multiplying asset, which military leaders were eager to exploit.

During the 1991 Persian Gulf War, the Pioneer UAV flew over 330 ISR sorties. However there remained reconnaissance gaps that senior officials wanted filled¹⁰. This led to the development of the propeller driven Predator UAV, which completed over 350 missions during Operation Joint Endeavor in Bosnia. The ability to see enemy positions “over the horizon” greatly enhanced ground commanders’ situational awareness and took the element of surprise from the enemy.¹¹ The UA’s ability to locate enemy positions and track enemy personnel greatly improved past ISR collection efforts. The images were beamed directly to the Combined Air Operations Center and quickly processed. Leadership then reassigned airborne aircraft to new targets (a process called “flex targeting”).¹²

Following the many successes of the Predator UAV in Bosnia, the military leadership continued developing a jet propelled UAV, capable of flying at high altitudes and equipped with advanced ISR equipment. The RQ-4, Global Hawk, was born. It has been used extensively in Operations Iraqi Freedom and Enduring Freedom. Despite only flying 5 percent of the Operation Iraqi Freedom high altitude sorties, the Global Hawk accounted for over 55 percent of the time-sensitive targeting against enemy air defense assets. The Global Hawk received high praise from General Tommy Franks, Commander, US Central Command, when he said on 27 February 2002:

Global Hawk unmanned aerial vehicles have been proven to be invaluable in providing long dwell surveillance, tracking, positive identification, and collateral and strike damage assessment. Global Hawk, for example, flew sorties approaching 30 hours in duration and imaged over 600 targets during a single mission over Afghanistan.¹³

Lately, with the maturing and miniaturization of applicable technologies, interest in such aircraft has grown within the higher echelons of the US military, as they offer the possibility of cheaper, more capable fighting machines that can be used without risk to aircrews. Initial generations of UA were primarily used for surveillance, but some have already been fitted with air-to-ground missiles. The military envisions that more and more roles will be performed by UA, initially bombing and ground attack, with air-to-air combat as the last domain of the in-cockpit fighter pilot. As figure 3 illustrates, the flight hours have nearly doubled each year among large UAS.

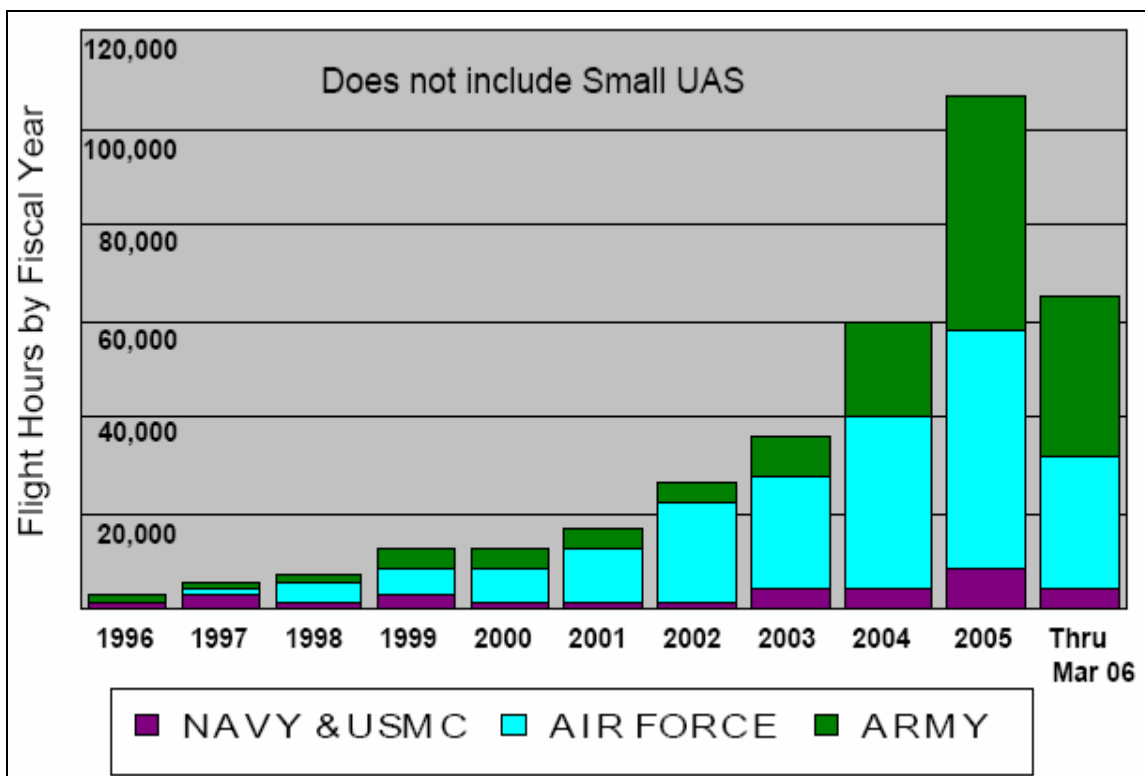


Figure 3. Flight Hours by Fiscal Year and Military Service

Source: Department of Defense, Unmanned Combat Air Systems; available from http://www.dtic.mil/ndia/2006psa_peo/weatherington.pdf; Internet; accessed on 7 January 2007.

The US Government Accountability Office performed a report of the management and fielding of UAS in 2004, and recommended that rather than have each armed service conduct separate research and development of UAS platforms that will not be interoperable, it would be more economical and efficient to look at desired capabilities and build a joint UAS platform.¹⁴ This recommendation was welcomed by some services and met with skepticism by others. Joint programs have proven viable, such as the F-35 Joint Strike Fighter; however, many believe the service mission requirements are too varied to mesh together. As an example, the Army and Marines desire small, tactical, easily portable UAS that are able to see “around the corner,” whereas Navy and Air Force desire a high-endurance aircraft capable of large-scale intelligence, surveillance, and reconnaissance. The UAS task force was founded to consolidate requirements from the different services and determine if a joint UA platform would satisfy all service requirements, reducing costs and increasing interoperability.

Research Method Overview

The research method used to answer the thesis question and the different sub-questions will be developed in three steps. Questions are answered with logical explanation and are screened for feasibility, acceptability, and suitability criteria. The specifics of this research method will be discussed in chapter 3.

In the first step, a literature review of strategic documents will enable a forecast the future tanker and UAS force of 2025. Examining many different articles and monographs provides many viewpoints and helps determine the vision of senior civilian and military leaders. Examining numerous strategic documents provides insight into the

civilian DoD leadership and the service chief's vision of UAS roles and their possible impact by air refueling.

The second step addresses the limitations of UAS. Are there limitations to air refueling due to the UAS' remote control operation? For instance, if the UAS radio frequency was jammed or satellite signal lost during in-flight refueling, is there a way to mitigate the risk to tanker crews? Most of the answers to this question will come from interviews with UAS operators and scientists at Creech Air Force Base, Nevada, and Air Force Research Laboratories located at Wright Patterson Air Force Base, Ohio. Furthermore, what are the limitations of UAS after they have deployed their weapons? Can they be refueled as an ISR asset, or will they need a postflight inspection? The answer to this question comes from UAS operators and sensor technicians and internet research articles. Furthermore, examining strategic documents, such as the Defense Secretary's *National Defense Strategy* will help determine the future operations environment and the roles of the tanker and UAS force by 2025. The Office of the Secretary of Defense's *UAV Roadmap 2005-2030* shows current UA platforms and what senior leadership envisions UAS missions to be. The overall goal of the roadmap is to provide clear direction to the many DoD agencies for a logical systematic migration of mission capabilities. In chapter 2, a review of the *The Air Refueling Roadmap* discusses what capabilities the Air Force's leadership deems future tanker platforms must be able to perform. The research of UAS and tanker future capabilities provides the framework for how they will mesh together in future operations.

The third step investigates the employment procedures of air refueling platforms and UA systems currently in service and projects force composition in 2025. This

information will be drawn from talking to tanker and UA operators, other service component aviators, research technicians, and contractors that are developing the future tanker and UA systems.

Delimitations

This research project will not go into excruciating detail regarding the technical aspects of UA and air refueling. This thesis provides a compilation and analysis of data to estimate what lies ahead for UAS and how air refueling will augment them in future full spectrum operations. Secondly, this thesis forecasts major trends in aerospace forces for 2025. Prognosticating much further than 2025 becomes exponentially speculative. Lastly, this thesis does not discuss drone aircraft in depth, but deals with remotely piloted vehicles and the UA's employment.

Limitations

This thesis only uses unclassified sources. Secondly, this thesis addresses only military UA and unmanned combat aerial vehicles that will be capable of being air refueled. There are dozens of miniature, tactical UA platforms used in military operations right now; however, this thesis will be limited to large UA platforms. These larger platforms are variants of the 26-foot-long Predator and 45-foot-long Global Hawk, see figures 4 and 5, respectively.



Figure 4. MQ-1 Predator

Source: US Air Force, Website; available from <http://www.af.mil/shared/media/photodb/photos/040120-F-9629J-109.jpg>; Internet; accessed on 9 April 2007.



Figure 5. RQ-4 Global Hawk

Source: US Air Force, Website; available from <http://www.af.mil/shared/media/photodb/photos/030808-F-9999X-001.jpg>; Internet; accessed on 9 April 2007.

¹Major General Paul Kern, Commander 4th Infantry Division, to General Reimer, CSA, March 1997; available from <http://www.fas.org/irp/agency/daro/uav97/page7-8.html>; Internet; accessed on 8 May 2007.

²J. R. Wilson, "A New Generation of Unmanned Aircraft," *Aerospace America* (January 2007): 28.

³Sergeant First Class Doug Sample, USA, "Pentagon Plans Heavy Investment in UAV Development," *American Forces Press Service*, 18 March 2003, 1-2; available from <http://www.defenselink.mil/news/newsarticle.aspx?id=29279>; Internet; accessed on 12 May 2007.

⁴Office of the Secretary of Defense, *Unmanned Aircraft Systems Roadmap 2005-2030* (Washington, DC: Government Printing Office, 2005), C-2.

⁵US Centennial of Flight Commission, Aerial Refueling; available from http://www.centennialofflight.gov/essay/Evolution_of_Technology/refueling/Tech22.htm; Internet; accessed on 21 November 2006.

⁶David M. Cohen, *The Vital Link: The Tankers Role in Winning America's Wars* (Maxwell Air Force Base, AL: Air University Press, 2001), 3; available from http://www.au.af.mil/au/aupress/fairchild_papers/Cohen/Cohen.pdf; Internet; accessed on 28 January 2007.

⁷Alwyn T. Lloyd, "The Boeing KC-135 Stratotanker at 50," *American Aviation Historical Society Journal* 51, no.4 (winter 2006): 251.

⁸Staff Sergeant C. Todd Lopez, "Teets Discusses Recapitalization, Death Benefit, Core Values," Air Force Print News; available from <http://www.af.mil/news/story.asp?storyID=123009953>; Internet; accessed on 19 November 2006.

⁹Steven M. Kosiak, and Elizabeth E. Heeter, Unmanned Aerial Vehicles--Plans and Prospects for the Future, 11 July 1997, 2; available from http://www.csbaonline.org/4Publications/Archive/B.19970711.Unmanned_Aerial_Ve/B.19970711.Unmanned_Aerial_Ve.htm; Internet; accessed on 3 December 2006.

¹⁰Bruce W. Carmichael, Troy E. Devine, Robert J. Kaufman, Patrick E. Pence, and Richard S. Wilcox, *Strikestar 2025* (Maxwell Air Force Base, AL: Air University Press, 1996), 6.

¹¹Pat McKenna, "Eyes of the Warrior," *Airman Magazine* 42, no. 7 (July 1998): 28.

¹²Department of Defense, Kosovo/Operation ALLIED FORCE After-Action Report to Congress, January 2000; available from <http://www.defenselink.mil/pubs/kaar02072000.pdf>; Internet; accessed on 27 November 2006.

¹³Department of the Air Force, *The U.S. Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle Strategic Vision 2005* (Washington, DC: Government Printing Office, 2005), 2.

¹⁴House of Representatives, Committee on Armed Services, *Unmanned Aerial Vehicles, Major Management Issues Facing DoD's Development and Fielding Efforts*, Testimony before the Subcommittee on Tactical Air and Land Forces, Statement of Neal P Curtin, Director Defense Capabilities and Management, and Paul L. Francis, Director Acquisition and Sourcing Management, 17 March 2004, 18; available from <http://www.gao.gov/new.items/d04530t.pdf>; Internet; accessed on 23 February 2007.

CHAPTER 2

LITERATURE REVIEW

Overview

Replacing manned aircraft with UA is not a new concept. Since the early 1920s military thinkers dreamed of projecting airpower and air surveillance through extended aerial refueling. Both the US military and private sector have conducted extensive research into expanding the capabilities of UAS platforms and how to maximize their capabilities. This thesis includes the capabilities requirements, expected costs, and procurement of UAS platforms and the KC-X tanker platform. Information on this subject is found throughout many government documents, professional journals, and on-line articles. This chapter reviews literature from contemporary writers, leaders, and governmental agencies and their visions of future unmanned aircraft missions. This chapter divides the literature into four sections.

The first part of this chapter explores some facts related to the past, current, and future of aerial refueling and UAS. It also discusses the future of UAS in other governmental operations, such as law enforcement and border security. The increased federal spending on unmanned surveillance technology has flooded the DoD UAS research agencies with more work than they are able to handle, opening the flood gates for private industry. The numerous companies offering different unmanned systems are expanding the missions and employment of the UAS. This chapter introduces a few of the leading UAS lobbyists and DoD research agencies impacting the future of the UA.

The second part of this chapter reviews the expanding UAS operations in the joint service arena and the strategic vision of tankers in future operations. This part

investigates strategic documents, such as the *United States Air Force UAV Strategic Vision 2005*, *Vision-Presence-Power--A Program Guide to the US Navy 2004*, the 2006 *Quadrennial Defense Review (QDR)*, and the Joint Experiment, Transformation, and Concepts Division (JETCD)--the DoD Future Joint Warfare Department). A review of these documents and JETCD discloses redundancy of UAS concepts and overlapping capability requirements that may eliminate or justify UAS and tanker procurement. This establishes the purpose and direction of joint operations in regards to UAS integration and gives insight to future air refueling requirements.

The third part of this chapter concentrates on the statements and vision of key DoD leadership and acquisitions personnel regarding UAS and tanker platforms. This helps determine the roles of UA platforms and the KC-X tanker integration into the future operating environment.

The fourth part of this chapter focuses on the Office of the Secretary of Defense, *UAS Roadmap 2005-2030*, and *The US Air Force Roadmap 2006-2025*. These provide excellent insight to the expected roles UAS platforms will perform.

A review of these documents provides the basic framework for answering the primary research question: During future operations, what will the role of air refueling and unmanned aerial vehicles be?

Part One

Current events that have altered the US' view on threats and the government's vision for future military operations needs to be researched. The attacks on 11 September 2001, drastically changed the face of DoD and the nation. Eleven terrorists on visas entered the US and attacked the World Trade Center in Manhattan, the Pentagon and the

American public's sense of security. In the ensuing months, the US government reviewed the procedures for legally entering the US. During this process, the US government recognized the vulnerability of the US, due to the porous, although patrolled, US borders. The border could be breached by motivated individuals with minimal planning and reconnaissance. There was a need for a persistent surveillance solution to protect Americans from another attack. President Bush created The Department of Homeland Security in October 2001, to "Secure the United States from terrorist threats or attacks."¹ US Border Patrol manning was increased to improve the border security. However, increased foot and vehicular patrols by Border Patrol Agents took their toll on the US Border Patrol's limited resources. An aerial ISR platform capable of covering large areas and alerting patrol agents to possible illegal crossers would enhance ground patrol effectiveness. The Department of Homeland Security was interested in UAS capabilities to provide a continuous presence flying over the US borders with Mexico and Canada. In early 2003, Gordon England the Deputy Director for Homeland Security stated, "The issue of terrorism is not transitory. We fought communism for 40 years until the wall came down. The war on terrorism is going to be a long-term effort. In the UAV we have the technology needed in homeland security to monitor and protect our borders."²

In the summer of 2004, the US Customs and Border Protection Agency conducted a surveillance experiment along the Arizona border using a MQ-9 Predator B. This was the first time that the UAS was used by the US government in a non-military and or clandestine setting. The experiment was so successful that the agency procured another UAS that went into service mid-2005. The Predator B flew 959 hours and contributed to 2,309 arrests and the seizure of 8,267 pounds of marijuana and four vehicles.³ However,

the Customs and Border Patrol UAS program experienced a substantial setback on 24 April 2006, when one of its two Predators crashed into a hillside. Preliminary National Transportation Safety Board reports attribute operator error as the primary cause of this accident. On 26 October 2006, President Bush signed the Secure Fence Act, authorizing the Department of Homeland Security to increase the use of advanced technology like infrared cameras, satellites, and UAVs to reinforce surveillance of the border.⁴ The Secure Fence Act authorized \$95 million for procurement of two more UAS and five additional helicopters.⁵ In 2007, the Customs and Border Patrol is expecting delivery of two more Predator B UAS, equipped with upgraded communications capability. The increased spending and attention from senior leaders is a testament to the versatility of UAS platforms in military and other governmental agencies. For instance, the Massachusetts Institute of Technology is involved in developing Global Positioning Systems and video camera guidance for locating and identifying toxic substances. Additionally, the Department of Energy announced that it would test unmanned platforms outfitted with radiation sensors to detect potential nuclear reactor accidents.⁶

Increased funding has drawn the interest of civilian research and development teams and some have joined together to form lobbying groups for the advancement of UAS platforms. Due to the technological composition of the UAS, there are literally thousands of companies that contribute to the various sub-systems of the UAS. The major UAS defense contractors, such as Boeing, Northrup-Grumman, General Dynamics, General Electric, and General Atomics Aeronautical Systems (developer of the MQ-1 Predator) have robust UAS research and development departments.

Many corporations have gone to an independent research and development strategy, working in concert with Defense Advanced Research Projects Agency (DARPA), which is discussed later, to address the needs of future unmanned systems. Corporations hope that developing improved military capabilities through the company's financially-backed research will win multimillion dollar government contracts in the near future. A few examples of this independent research and development concept are:

Morphing UAV: An unmanned combat aerial vehicle that uses in-flight shape changes to expand its flight envelope and provide long loiter, intelligence, surveillance, reconnaissance, and attack against time-critical targets.

Force Application and Launch from Continental US (FALCON) SLV-1: A hypersonic (Mach 10+) UAS for strategic strike and reconnaissance.⁷ A joint DARPA, National Aeronautics and Space Administration (NASA), and Lockheed Martin endeavor to explore mixed inert fuel and oxygen propulsion for UA systems.

The two major organizations promoting the integration of present and future UAS platforms are the Association for Unmanned Vehicle Systems International (AUVSI) and the UAV National Industry Team. The Association for Unmanned Vehicle Systems International is comprised of over 1,400 member companies and organizations from over 50 countries and is the world's largest non-profit organization devoted exclusively to advancing the unmanned systems community. The Association for Unmanned Vehicle Systems International members range from government organizations to academia, and are all committed to fostering, developing, and promoting unmanned systems and related technologies.⁸ Similarly, UAV National Industry Team is a coalition of leading UAS companies including Aurora Flight Sciences, AeroVironment, The Boeing Company,

General Atomics Aeronautical Systems, Lockheed Martin, and Northrop Grumman dedicated to promoting the routine operation of UA in the National Airspace System (NAS). This organization is a staunch advocate for UAS policy and builds legislative support for UAS regulations. UAV National Industry Team was founded in early 2002 when the six companies put aside competitive differences and formed an alliance. They immediately began working with NASA and the Federal Aviation Administration (FAA) planning to integrate UAS platforms into the NAS.

Operating large UAS platforms in the US airspace system has forced corporate leaders and governmental agencies to investigate rules and regulations for these aircraft. The Aircraft Owners and Pilot Association is a non-profit individual membership association that lobbies to promote the safety, utility, and popularity of flight in general aviation aircraft.⁹ With a membership force of 409,000--equal to two-thirds of US certified pilots--they are a formidable regulatory advocate. Melissa Rudinger, Vice President of Aircraft Owners and Pilot Association mentioned the complexities of incorporating unmanned systems in the NAS. Rudinger asserts, "The problem is the technology has advanced, and there are no regulations that talk about how to certify these aircraft, how to certify the operator, and how to operate in the national airspace system." Rudinger highlights three difficult regulatory obstacles in her statement: certification of aircraft, certification of operator, and integration into the NAS. Another significant concern is how most UA are designed to sip fuel and therefore fly at a much slower airspeed compared to commercial aircraft that would be sharing the same airspace. On 29 March 2006, a hearing was held to discuss the use of UA in the NAS and the authority of the FAA to provide safety oversight and air traffic control over these systems in the

NAS.¹⁰ The FAA hired Lockheed Martin Corporation to develop a “roadmap” for introducing UA into the NAS.

The DoD also has an agency that is its “technological engine,” heavily involved in research and development of unmanned systems: DARPA. DARPA’s mission is to maintain the technological superiority of the US military and prevent technological surprise from harming the national security by sponsoring revolutionary, high-payoff research that bridges the gap between fundamental discoveries and their military use.¹¹ An example of the research done by DARPA is the Stealth technology of the 1980s which the US used with great success during Desert Storm and Iraqi Freedom. The DARPA Director interacts with Secretary and Under Secretaries of Defense, the Chairman of the Joint Chiefs of Staff, the Combatant Commanders, the Service Secretaries, the Service Chiefs, military units, and the staffs at various DoD levels to reach each service’s technological goals. DARPA also conducts tests for the Joint Unmanned Combat Air System (JUCAS) office, which is discussed later.

Part Two

The key to maintaining a lethal military force and be successful in future campaigns is to focus and direct all the services to a common end. Analysis of service documents provides insight to where the service chiefs envision their forces to be in five to twenty years. The Secretary of Defense, through the Joint Chiefs of Staff, ultimately holds the responsibility of ensuring all services are progressing towards the joint vision. The integration of UAS platforms as force multipliers in future battles is discussed in the strategic documents of today.

The US Air Force Remotely Piloted Aircraft and Unmanned Aerial Vehicle

Strategic Vision 2005: This document, specifically section five, deals with integration of remotely piloted vehicles and UAS platforms into Air Force and joint plans, operations, and capabilities for the next twenty to twenty-five years. It states:

Future RPVs [remotely piloted vehicles] and UAVs may be capable of carrying mixed loads of kinetic and non-kinetic weapons. On-board electro-optical cameras, infrared sensors, radars, and other collection systems will provide real-time combat assessments and targeting capabilities on many unmanned platforms. Using a combination of active sensors on unmanned systems and passive sensors on manned systems can help reduce the need to radiate from manned platforms, preserving their relative stealth capabilities.¹²

The Strategic Vision, describes many of the current operations of UA platforms, however, it neglects to discuss the strategic bombing aspect of the UAS. The USAF is investing heavily in a stealth, strategic attack UAS as its global strike platform and hoping to have it operational in 2018. One of the major hurdles of the program is the limited range of the prototype when carrying a weapons load. In order to leverage the strategic attack capability, the conceptual UAS requires aerial refueling to increase its range.

Army Vision 2010: The military has been searching for the best platform to execute weapons delivery while minimizing the risk of fratricide. *Army Vision 2010* outlines this idea.

Manned and unmanned platforms will contribute to the weave of sensor and weapon capabilities so that the reach of full dimensional protection can extend far beyond the horizon. Significantly more sensors will provide refined information to even more elements at lower echelons, enhancing total force situational understanding, enabling greater dispersion, and minimizing the risk of fratricide.¹³

The Army is spending most of its funds on tactical UAS platforms that can be carried by soldiers and that will integrate with the Future Combat System (FCS). Many UA systems

will supplement the FCS. Each FCS-equipped brigade will have almost 200 unmanned aerial systems.¹⁴ The Army envisions 15 FCS equipped brigades, translating to 3,000 UAS. The number of unmanned sensors will greatly enhance commander's view of their battlespace and feed data to the joint common operating picture. The net-centric capability of the FCS and its expected impact on the common operating picture shows the Army's desire to integrate UAS platforms in its doctrine for future operations. However, the enormous amount of bandwidth required to control multiple unmanned systems becomes a huge operational hurdle.

The *Army Vision 2010* is largely devoted to smaller, tactical UA to provide ISR information to small units, then pieced together via the network at higher echelons to build the common operating picture. The document does not mention UA systems being enabled by aerial refueling because the Army envisions UA platforms carried, launched, employed, and recovered by individuals or small teams. However, in 2005 the Army awarded a multimillion dollar contract to the same company that builds the MQ-1 Predator. The new platform, called the Warrior, is part of the Extended Range Multi-Purpose Army program to replace the smaller I-Gnat and RQ-5 Hunter UA. The Warrior is a derivative of the Predator, with the exception that the Warrior will fly via line of sight communication. However, this platform is designed to operate at 25,000 feet which begins to blur airspace command and control (C2) responsibilities and complicates the deconfliction of manned and unmanned aircraft. As unmanned systems become more and more capable, C2 of battlespace becomes important and coordination at all levels is crucial.

Vision-Presence-Power--A Program Guide to the US Navy 2004: The US Navy's senior leadership is very interested in the growing applications of UAS technologies. The Navy's ability to project military power throughout the globe by exploiting international waters provides a marked advantage over most adversaries. Enabling UAS platforms to launch from expeditionary aircraft carriers or even smaller vessels for ISR, tactical strikes, or monitoring of time-sensitive targets is seen as a force multiplier by leadership. The Chief of Naval Operations vision "Sea Power 21," states how the conceptual broad area maritime surveillance, high altitude UAS can aid the Fleet Commander with maritime surveillance, battle damage assessment, port surveillance, support of homeland security, mine warfare, maritime interdiction, surface warfare, counterdrug operations, and battlespace management.¹⁵ The persistent presence of UAS platforms enables two of the three pillars of "Sea Power 21."

Sea Strike and Sea Shield: The first, Sea Strike, is the power projection of naval forces, and unmanned airpower will be projected through JUCAS, a joint Navy and Air Force venture. Sea Shield is the global defensive assurance produced by extended homeland defense and will be performed by maritime surveillance UAS platforms.

The surveillance and defense of US coasts is an expanding mission and information gained from the broad area maritime surveillance UAS will be disseminated across many federal agencies. Aerial refueling of the conceptual broad area maritime surveillance platform would enhance maritime operations through extended loiter times. Furthermore, aerial refueling would reduce the overall number of unmanned platforms needed to perform the maritime mission.

2006 Quadrennial Defense Review (QDR): In 2001, DoD produced the first *QDR*. This report contains the vision of senior DoD leadership, analysis of progress to date (from 2001), and decisions needed to achieve the vision. The unclassified portion of the document mentions the need for a “persistent surveillance, including systems that can penetrate and loiter in denied or contested areas” and “secure broadband communications into denied or contested areas to support penetrating surveillance and strike systems.”¹⁶ These two requirements point toward the employment of UAS capabilities in future military operations. General Ronald Keys, Commander of Air Combat Command, was correct when he stated, “The outfall of this (*QDR*) is going to reverberate across our force and affect our manning, our missions, our force structure (size and type) and our budget.”

The senior leadership also identified future force characteristics ripe for UAS operations including: “joint ground; special operations forces; joint air; joint maritime; tailored deterrence; combating WMD; joint mobility; ISR and space capabilities; net-centricity; and joint command and control.”¹⁷ The document later states that the DoD’s forces will be reoriented over time to reflect these ten characteristics. The 11 September 2001, attacks have spurred the transformation of the military and highlighted the need for persistent monitoring of possible threats and the force characteristics mentioned above can all be enhanced by UAS assets.

Another portion of the *QDR* deals with joint air capabilities. The air capabilities vision portrayed vehicles that will have far greater range and persistence; larger and more flexible payloads for surveillance or strike; and the ability to penetrate and sustain operations in denied areas. This section further deals with the restructuring of forces and training Guard and Reserve forces for core competencies, now performed only by the

Active Duty forces. The document mentions using the US Reserve Component for UAS operations and ISR reach-back capabilities. For instance, California's Air National Guard, 163rd Air Refueling Wing, which was operating KC-135 tankers, has transitioned to perform the Predator UAS role. The wing has provided not only operators to fly the UAS but also intelligence officers to analyze the ISR products. The unit is stationed at March AFB, California, and became fully operational in October 2006.¹⁸ This is further evidence of the marriage between active, guard, and reserve roles and the replacement of a manned aircraft with an unmanned platform. Enabling Reserve forces to operate at continental US military installations, like Creech AFB, Nevada, or March AFB, California, has reduced the deployment stress across the entire force. This restructuring reduces the strain on the overall force because the operator does not have to physically deploy to area of responsibility, which may be half-way around the world. In the Joint Air Capabilities section, the *QDR* notes that the Air Force believes approximately 45 percent of the future long-range strike force will be unmanned, enabling global conventional strikes against time-sensitive targets. One decision of the *QDR* is to, "Restructure the JUCAS program and develop an unmanned longer-range carrier based aircraft capable of being air refueled to provide greater standoff capability, to expand payload and launch options, and to increase naval reach and persistence."¹⁹ Senior leadership also plans to nearly double the UAS coverage capacity by accelerating the acquisition of the Predator and Global Hawk platforms. UAS platforms will be an integral part of future joint air operations; the key to greater operational effectiveness is to maximize the capabilities of these platforms.

In the Joint Mobility section of the *QDR*, leaders recognized the importance of a newer tanker platform to support the increasingly expeditionary nature of the DoD. The *QDR* specifies, “a future KC-X aircraft that will have defensive systems and provide significant cargo-carrying capacity while supporting its aerial refueling mission.”²⁰ Providing an aerial refueling platform equipped with defensive systems expands the battlespace tankers can operate in and reduces transit time for the receiver aircraft. Ultimately, these capabilities will improve time on station for manned and unmanned aircraft.

2005 National Defense Strategy: This document states how the military instrument of power can be used to achieve national objectives. It is published by the Secretary of Defense and provides guidance in three main areas: objectives, defense policy goals, and force structure. The *National Defense Strategy* emphasizes that there is a changing security environment because adversaries will not challenge the US military in a traditional sense. Instead, adversaries will probably use an array of irregular, disruptive, and catastrophic capabilities to threaten US interests. To implement strategic plans and decision making, the DoD plans to:

1. Rely on an Active, Layered Defense--removing the opponent’s ability to strike first.
2. Continue Transformation--by developing technologies and refocusing capabilities to defeat future challenges.
3. Continue a Capabilities Based Approach--restructuring of US forces to link capabilities across all military services, focusing on “how” adversaries might challenge the US, rather than “who” will challenge the US.

4. Manage Risks--considers the operational objective compared to the financial or personnel cost.

The UAS, with its ability to provide persistent presence and to launch attacks rapidly, is central to all these ideas. The *National Defense Strategy* document provides a broad brush view of how the DoD will perform tasks defined in the *National Security Strategy*. It does not identify specifically what assets the DoD will use to perform specific tasks. ISR is the greatest capability the UAS brings to augment “an active, layered defense posture.” The future combat UAS platforms can find, fix, track, target, and engage threats before opponents can launch an attack. Furthermore, a UAS equipped with certain sensors can track possible threats in the air, over land, on water, and even under water and help protect the US borders and coastlines.

Joint Experiment, Transformation, and Concepts Division (JETCD): This DoD future joint warfare department evolved from *Joint Vision 2020*. JETCD’s mission is to “Support and facilitate the transformation efforts of the Chairman of the Joint Chiefs of Staff by acting as the primary agent for developing and monitoring the implementation plans for joint experimentation and concept development”²¹ The JETCD has adopted a capabilities-based assessment for development and application of technologies. To conduct this assessment, the DoD agencies submit the desired capability to the Joint Force Command, which consolidates all requests with similar desired capabilities to minimize stove-piped research and development. The latest UAS platform the Joint Force Command is working on is the USAF and Navy’s joint-venture called the JUCAS. A common idea throughout the documents is that UAS platforms would perform the missions that are “dull,” “dirty,” or “dangerous.”

The multiservice unmanned project, JUCAS, is a platform initially meant for the “first day of the war” that will augment an initial strike package with the preemptive destruction of enemy integrated air defense systems--a dangerous mission. Throughout the rest of the campaign, the JUCAS would provide constant vigilance in an ISR role--a dull mission. In addition, the JUCAS would be armed and able to attack enemy forces, high value targets (HVT) or time sensitive targets if required--re-tasking from a dull to a dangerous mission as needed. The final mission the JUCAS would be ideal for is operating in a battlespace contaminated biologically, chemically, or by nuclear agents--the dirty mission. There are presently two versions of the JUCAS, the X-45C and X-47B platforms. Figure 6 is an artist’s depiction of both JUCAS platforms.

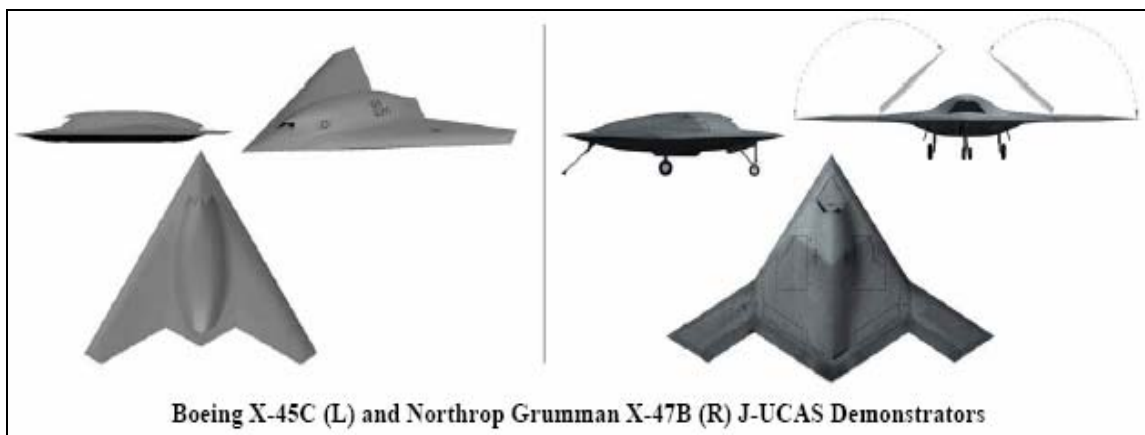


Figure 6. Boeing Joint Unmanned Combat Aircraft Systems
Source: Office of the Secretary of Defense, Unmanned Aircraft Systems Roadmap 2005-2030 (Washington, DC: Government Printing Office, 2005), 11.

Creating a joint concepts division streamlines the acquisitions process and enables senior military leaders to agree on a common vision for future operations. This translates

into a more interoperable system which reduces spending on acquisitions, increases systems knowledge across the services, and reduces logistical and sustainment demands. One problem that JETCD does not address is the competing interests between the services for funding. By agreeing to research and develop a joint system, each service has to divert funding to the concept, reducing the services internal funding. Another problem, not addressed by the JETCD vision is the competition over legacy missions. For instance, the Air Force and Army continually debate over which service should control close air support assets. The Air Force is hesitant to release total control to Brigade-level commands for fear of an asset not used to its full potential across the entire operations area. Conversely, the Army is hesitant to release its medium altitude UAS platforms to the Air Force because the fear of not having that capability right when the Army commander wants it. At upper echelons, senior service leaders do not want to give up missions to another because this would detract from the losing service's budget.

Part Three

Air Force Chief of Staff, General T. Michael Moseley, is a firm believer and proponent of the idea that air and space dominance is a prerequisite to military success on the ground. When asked, "Are we going to see a day when pilots are no longer needed?" General Moseley answered, "Well, we may. Lockheed is talking about an F-35 version that is unmanned. . . . I'm not adverse to it. I love the UAS. I've used a lot of them in combat."²² This is testament to the battle-tested viability of the UAS. General Moseley acted as the Combined Forces Air Component Commander during Operation Iraqi Freedom and is intimately familiar with the application of airpower.

Colonel (Retired) John Warden, a well respected USAF fighter pilot, strategist and theorist, commented in *Aviation Week and Space Technology* that, “[Unmanned aerial systems] are rapidly approaching the point where they will be able to do most things a man can do, other than untangle complicated shoot/no shoot decisions on the spot.” He believes that unmanned platforms will comprise ninety percent of the US combat aircraft by 2020, and maybe before!²³

Regarding the new tanker procurement, General Moseley announced in October 2006, the new tanker is the number one procurement priority for the USAF. This procurement decision enables the replacement of the aging KC-135 Stratotanker fleet. The Air Force Chief stated, “In this global business, the single point of failure of an air bridge, or the single point failure for global intelligence, surveillance and reconnaissance, or global strike is the tanker.”²⁴ Besides becoming the number one procurement priority, a multibillion dollar contract awaits the winning vendor. The winning team, which will be announced in 2007, will be tasked to build 179 new aircraft with the Air Force expecting delivery about 36 months after the contract is awarded. The USAF plans on delivery of 10 to 15 aircraft a year and spending approximately \$3 billion a year.²⁵

According to the draft Request for Proposals (RFP) document, the KC-X aircraft will provide world-wide communication, navigation, surveillance and air traffic management capabilities, day and night, adverse weather, same-sortie boom and drogue with provisions for simultaneous multiple point drogue, aerial refueling to fixed-wing, receiver-capable US, allied, and coalition air vehicles. The KC-X will have the capability to operate in low to medium threat areas with self-defense capability, as well as the capability to operate in a night vision imaging system environment.²⁶

Part Four

UAS proliferation across governmental agencies is a direct result of their success in battle and senior leader intervention. The main benefit of focusing and combining UAS development efforts is the millions of dollars saved in research and development, procurement, maintenance and parts. In an effort to establish strategic guidance and a capabilities analysis, a Joint UAV Planning Task Force was formed in 2001. Through the Joint UAV Planning Task Force, the UAV Roadmap 2002-2027 was born, providing a strategic outlook for DoD unmanned platforms.

Office of the Secretary of Defense, *UAS Roadmap 2005-2030*: The primary focus of this roadmap was to answer three questions for the Office of the Secretary of Defense:

1. What requirements for military capabilities could potentially be filled by UA systems?
2. What processor, communication, platform, and sensor technologies are necessary to provide these capabilities?
3. When could the technologies become available to enable the above capabilities?

Figure 7 depicts a consolidated timeline of the Services' ongoing and planned programs of record for tactical, endurance, and combat UAS platforms.

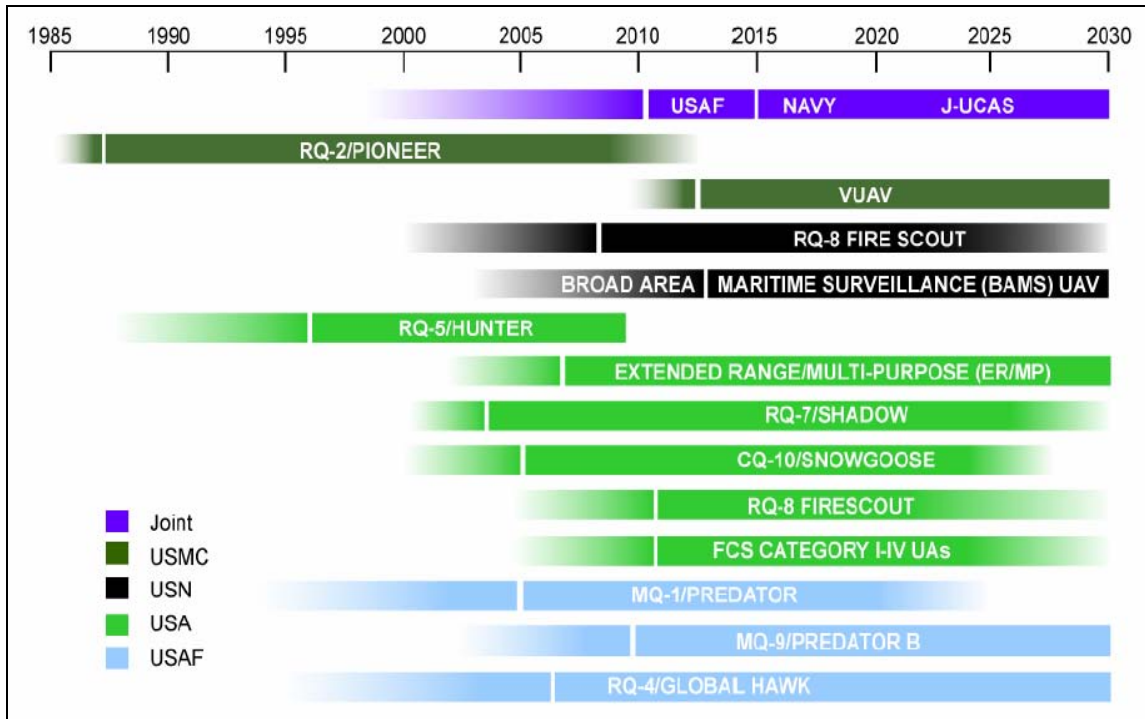


Figure 7. Timeline of Current and Planned Department of Defense Unmanned Aircraft Systems

Source: Office of the Secretary of Defense, *Unmanned Aircraft System Roadmap 2005-2030* (Washington, DC: Government Printing Office, 2005), 3.

The document also discusses the sale of US-manufactured UAS to foreign nations, giving three advantages of this option:

1. Supporting the US industrial base for UAS.
2. Potentially lowering the unit costs of UAS to the Services.
3. Ensuring interoperability by equipping allied forces with mutually compatible systems.

The last advantage seems to be most in-line with strategic defense goals. In today's global environment, the US has opted to form coalitions to achieve its diplomatic objectives. Despite the advantages of selling UAS to foreign nations, the DoD's UAS

roadmap brings up two possible problems with the sale: The possible transfer of critical technology and the possibility that other parties would arm the UAS. The transfer of UAS technology can quickly become a double-edged sword, bolstering today's coalition efforts while becoming a possible future threat.

The roadmap also covers the various combatant commanders' mission prioritization for operational and theater UA systems. Generally, the top three mission areas were: (1) reconnaissance; (2) precision target location and designation; and (3) signals intelligence. The difference between combat UAS and ISR platforms is the weaponization and strike instead of signals intelligence.²⁷

The next applicable section dealt with UAS technologies and illustrated the total UAS funding, broken down by service (see figure 8).

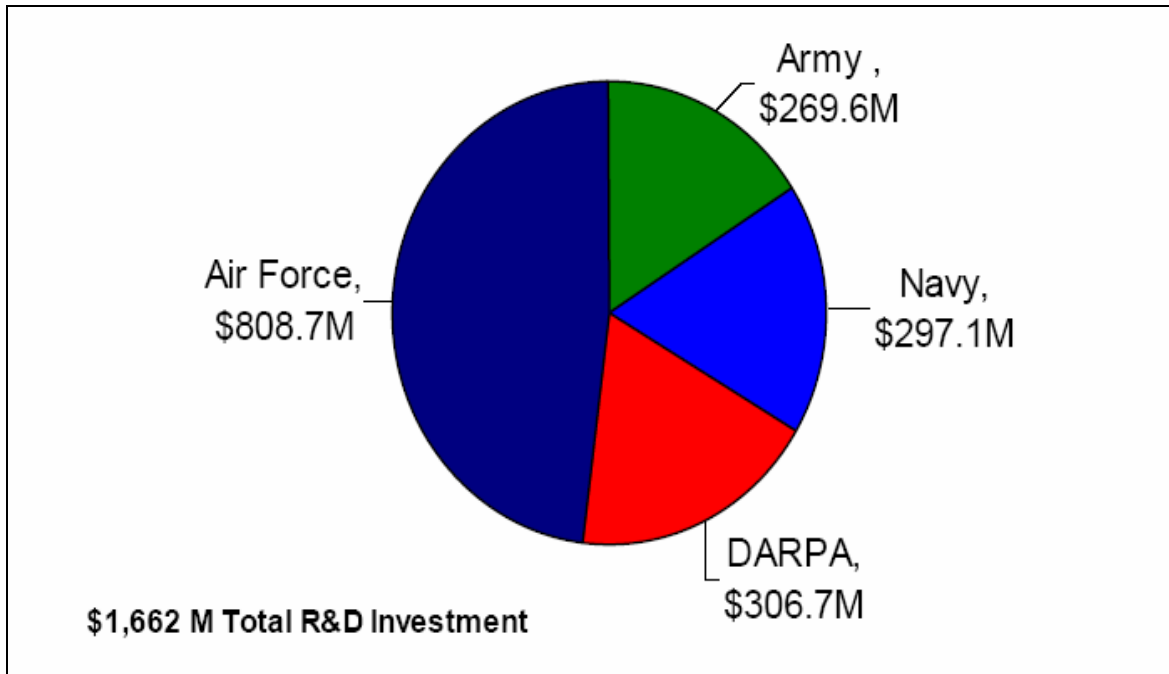


Figure 8. Department of Defense Investment In Unmanned Aircraft System Research and Development, Fiscal Years 2005-2009

Source: Office of the Secretary of Defense, *Unmanned Aircraft System Roadmap, 2005-2030* (Washington, DC: Government Printing Office, 2005), 47.

The Air Force Roadmap 2006-2025: The Air Force Roadmap is a capability-based force structure plan that conveys the planned recapitalization and modernization of the Air Force through 2025. The document organizes current and future force structure under six distinctive capabilities: air and space superiority, information superiority, global attack, precision engagement, rapid global mobility, and agile combat support. The Air Force emphasizes the integration of UAS and tanker platforms in five of the six distinctive capabilities--all but air superiority. This omission contradicts the OSD UAS Roadmap which prognosticates unmanned air superiority (counterair) platforms in the 2020-2025 time frame. This is possibly due to the parochialism of senior leadership, which is nearly all pilots, not being receptive of an unmanned aircraft.

In the Special Operations section, the Predator and Hunter UAS platforms are expected to be two-thirds of the ISR and information operations (IO) force structure by 2017, enabling ISR with decreased sensor-to-shooter time. In the final section of the document, the Roadmap expounds on the capabilities that will allow an effects-based approach to the transformation of forces. The AF Roadmap plans to shift present forces from single mission capabilities to multi-role forces, and aggressively divest itself of legacy systems. The transformation will result in a smaller, more capable force “allowing the Air Force to commit more resources to networked and integrated joint enablers.”

Automated Aerial Refuel Technologies and Challenges: This presentation, from Air Force Research Laboratory and Boeing Phantom Works, discusses the background of automated aerial refueling, the development process, conceptual designs, simulation development, and automated aerial refueling’s future.

It is an Air Force-centric presentation with the JUCAS contractor, Boeing, adding key developmental insight. The presentation did a decent job of presenting the significance of air refueling to the Air Force, but it did not discuss the costs associated with research and development of automated aerial refueling. Furthermore, the document did not discuss automated aerial refueling in adverse weather operations. Air refueling during poor weather is challenging for heavier, manned aircraft and given the light weight of UA platforms compared to the tanker, this becomes infinitely more difficult. The presentation did address three overarching user requirements: (1) protect the tanker from collision with UAS; (2) affordability and; (3) minimize the need of refueling a mixed fleet of manned and unmanned aircraft.

“The Air Refueling Receiver That Does Not Complain:” This 1999 monograph from USAF Major Jeffrey Stephenson, is premised on answering the question, “How should the Air Force approach unmanned aerial vehicle air-to-air refueling today?” Major Stephenson discusses the reasons for aerial refueling of UA, transit time of UAS to refueling track, and control of the UAS during aerial refueling. He analyzes the current unmanned systems, and provides recommendations.

Major Stephenson’s monograph gives a convincing argument for the aerial refueling of unmanned platforms; most notably, in the trade off between loiter time and payload. The only questionable issue in Major Stephenson’s paper is the fictitious scenario he uses to compare current UA transit distance between the UAS orbits and air refueling orbit. The 500 nautical miles round trip distance is about 200 nautical miles further than historic transit distances have been. This translates in nearly two hours of time “wasted” in transit for the Predator UAS. In general, Major Stephenson’s paper was well researched, clear, and recommended achievable capabilities.

¹White House, Executive Order Establishing Office of Homeland Security; available from <http://www.whitehouse.gov/news/releases/2001/10/20011008-2.html>; Internet; accessed on 16 December 2006.

²Paul C. Leibe, Proven on Battlefield, UAVs May Have Homeland Defense Role; available from <http://uav.navair.navy.mil/airdemo03/articles03/enterprise.htm>; Internet; accessed on 16 December 2006.

³Department of Homeland Security, UAS Overview; available from http://www.cbp.gov/xp/cgov/border_security/air_marine/uas_program/uasoverview.xml; Internet; accessed on 16 December 2006.

⁴White House, Protecting the Homeland; available from <http://www.whitehouse.gov/infocus/homeland/index.html>; Internet; accessed on 16 December 2006.

⁵White House, President Requests Funds to Strengthen Border Security; available from http://www.whitehouse.gov/omb/pubpress/2006/fact_sheet_border_supp.pdf; Internet; accessed on 16 December 2006.

⁶Jason Blazakis, Analyst in Social Legislation, Domestic Social Policy Division, CRS Report for Congress, Border Security and Unmanned Aerial Vehicles; available from <http://fpc.state.gov/documents/organization/30047.pdf>; Internet; accessed on 14 January 2007.

⁷Wilson, 31.

⁸Association for Unmanned Vehicle Systems International, Homepage; available from <http://www.auvsi.org/>; Internet; accessed on 29 November 2006.

⁹Aircraft Owners and Pilots Association, AOPA's Mission; available from <http://www.aopa.org/info/mission.html>; Internet; accessed on 29 November 2006.

¹⁰US Congress, Committee on Transportation and Infrastructure, Subcommittee on Aviation on Unmanned Aircraft Activities, Statement of Nicholas A. Sabatini, Associate Administrator for Aviation Safety; available from http://www.faa.gov/news/testimony/news_story.cfm?contentKey=4029; Internet; accessed on 14 January 2007.

¹¹Defense Advanced Research Projects Agency, DARPA's Mission; available from <http://www.darpa.mil/body/mission.html>; Internet; accessed on 14 January 2007.

¹²Department of the Air Force, *Unmanned Aerial Vehicle Strategic Vision 2005*, 10.

¹³Department of the Army, *Army Vision 2010* (Washington, DC: Government Printing Office, 1996), 15.

¹⁴Sandra I. Erwin, "Army to Field Four Classes of UAVs," *National Defense* (April 2003): 35.

¹⁵US Navy, VTUAS Narrated Video as Aired on Discovery Channel; available from <http://uav.navair.navy.mil/>; Internet; accessed on 17 December 2006.

¹⁶Department of Defense, *Quadrennial Defense Review* (Washington, DC: Government Printing Office, 2006), 31.

¹⁷*Ibid.*, 49.

¹⁸Micheal Sirak, Defense Daily; US Air Force Aim Points accessed 29 November 2006.

¹⁹Department of Defense, *Quadrennial Defense Review*, 46.

²⁰Ibid., 54.

²¹Joint Chiefs of Staff, J7 Joint Experimentation, Transformation, and Concepts Division (JETCD); available from <http://www.dtic.mil/futurejointwarfare/index.html>; Internet; accessed on 11 December 2006.

²²Timothy B. Clark, "Flight Check," *Government Executive*, 38, no. 15 (1 September 2006): 46.

²³William B. Scott, "UAVs/UCAVs Finally Join Air Combat Teams," *Aviation Week and Space Technology* (8 July 2002): 1-3.

²⁴Staff Sergeant C. Todd Lopez, "Tanker Hits Top of the Charts for Recapitalization Priority," *Air Force Print News*; available from http://www.af.mil/news/story_print.asp?storyID=123029037; Internet; accessed on 4 December 2006.

²⁵Michael Sirak, "Air Force Issuing Revised Version of KC-X Draft Request Proposals Today," *Defense Daily*; available from <http://aimpoints.hq.af.mil/display.cfm?id=15374>; Internet; accessed on 4 December 2006.

²⁶KC-X Executive Summary for the Draft RFP FA8625-07-R-6470, Announcement in Federal Business Opportunities, 25 September 2006; available from [http://fs1.fbo.gov/EPSTData/USAF/Synopses/905/FA8625-07-R-6470/KC-XExecutiveSummaryforDraftRFP\(25Sep2006\).doc](http://fs1.fbo.gov/EPSTData/USAF/Synopses/905/FA8625-07-R-6470/KC-XExecutiveSummaryforDraftRFP(25Sep2006).doc); Internet; accessed on 11 December 2006.

²⁷Office of the Secretary of Defense, *UAS Roadmap 2005-2030*, 43.

CHAPTER 3

RESEARCH METHODOLOGY

In order to answer the proposed research question--During future operations, what will the role of air refueling and unmanned aircraft systems be?--this thesis examines the composition of the future force, both manned tanker aircraft and unmanned systems. Chapter 4 examines the advantages and disadvantages of air refuelable and non-air refuelable unmanned aircraft systems. The purpose of the next chapter is to analyze the data in order to compare and contrast air refuelable unmanned systems of US military forces in the year 2025. All the information required to examine the research question is presented in the first four chapters. Chapter 5 will offer recommendations for the integration of future air refueling tankers and future unmanned aircraft in contemporary operating environments, followed by explanations, implications, and closing comments.

The analysis in chapter 4 is done by examining a wide spectrum of information. Thoroughly discussing the advantages and disadvantages of each system enables a logical solution to answer the main question.

Screening criteria ensures the decision can solve the problem or question. A well used tool for testing solutions is the Feasibility, Acceptability, Suitability, and Completeness criteria. These four criteria are defined in Army Field Manual 5-0:

1. Feasibility--Fits available resources.
2. Acceptability--Is solution worth the cost or risk?
3. Suitability--Solves the problem and is legal and ethical.
4. Completeness--Contains the critical aspects of solving the problem from start to finish.¹

The second step of this research concerns the limitations of UA. Are there limitations to air refueling due its remote control operation? For instance, if the UAS radio frequency is jammed or the satellite signal lost during in-flight refueling, is there a way to mitigate the risk to the tanker crew? Most of the answers to this question will come from interviews of UAS operators and scientists at Edwards Air Force Base, California, and Creech Air Force Base, Nevada. Furthermore, what are the limitations of UAS in combat, after they have deployed their weapons? Can they be refueled as an ISR asset or do they require a post-flight inspection? To answer this question, UAS operators and sensor technicians were interviewed and relevant articles and journals were reviewed.

¹Department of the Army, Field Manual 5-0, *Army Planning and Orders Production* (Washington, DC: Government Printing Office, 2005), 2-9, 2-10.

CHAPTER 4

ANALYSIS

Victory smiles upon those who anticipate the changes in the character of war, not on those who wait to adapt themselves after the changes occur.¹

Giulio Douhet

This chapter deals with the examination of the literature from chapter 2 and the interviews with operators and scientist, ultimately to answer the main question, During future operations, what will the role of air refueling and unmanned aerial vehicles be?

Air Refueling: From Its Origin to the “Jet-Age”

In January 1929, the US Army Air Corps experimented with the new concept of aerial refueling (see figure 9). With chief mission pilot Captain (later General) Ira Eaker at the controls, the *Question Mark*, a modified Fokker Trimotor, completed the first aerial refueling and stayed aloft for over 150 hours! Major (later the first USAF Chief of Staff) Carl Spaatz wrote in his after actions report to Major General Fechet, the Chief of the Air Corps, “The flight of the Question Mark demonstrates conclusively that one transport plane can safely refuel another transport in the air.” However, this successful test mission was viewed simply as a fantastic aerial stunt. In its infancy the far-reaching effects of air refueling were not realized. Many were skeptical because of the technological hurdles of air refueling and later were reluctant to employ it. Furthermore, during World War II, most airfields were close enough to German bombing targets so it was not necessary to refuel bombers in the air. On the

other hand, imagine how many bomber crews would have been saved if their fighter-escort's range had been increased through aerial refueling. In the Pacific theater, Allied troops paid a heavy price in blood to seize Japanese-controlled islands for use as airfields. Many of these could have been bypassed if the strategic capability of aerial refueling were in place.

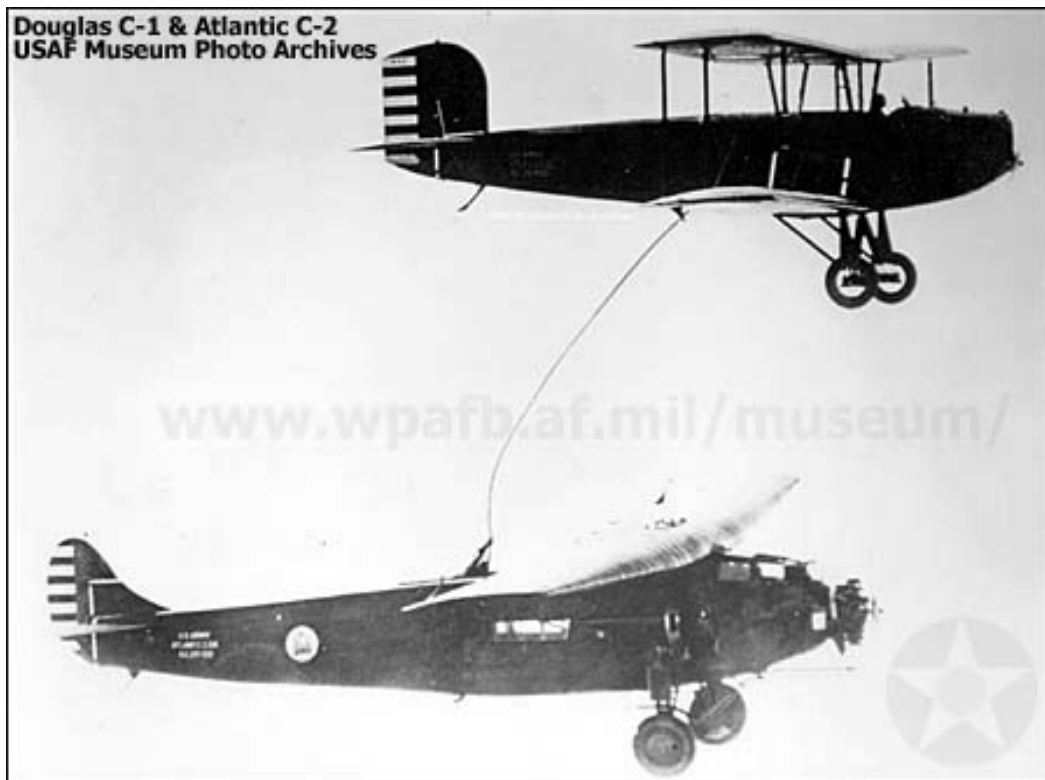


Figure 9. Fokker C-2A, 1929 *Question Mark* Receiving Fuel

Source: National Museum of the USAF, Webpage; available from http://www.nationalmuseum.af.mil/factsheets/factsheet_media.asp?fsID=3241 internet accessed 12 May 2007.

In the 1940s, the invention of the jet engine allowed airplanes to go much faster and streamlined the aircraft's profile, improving the aerodynamics, but this

advantage was reduced by a shortened combat radius. The desire to employ the speed of jet engines, while increasing their combat radius rekindled the interest of aerial refueling. General Spaatz, now the Air Force Chief of Staff, made aerial refueling the utmost priority because having a long range, jet-propelled bomber capable of striking the Soviet Union offered the US a tremendous strategic and psychological advantage. The first aerial refueling of a jet-propelled aircraft, a KB-47 tanker and a B-47 bomber, occurred on 1 September 1953.² Using history as an analogy to the present situation, tankers today must evolve to meet the future UAS requirements.

According to current Air Force doctrine, aerial refueling “increases the range, payload, loiter time, and ultimately the flexibility and versatility of combat, combat support, and mobility aircraft.”³ Currently, scientists are exploring the range, payload, loiter time, and flexibility characteristics of UA platforms and pondering if aerial refueling will have the impact on unmanned flight that it did on manned flight. Presently, the Air Force tanker platforms are employed to accomplish six missions: nuclear operations support, global strike, airbridge support, aircraft deployment, theater support, and special operations support. The new tanker will have to accomplish these six missions and be adaptable to the operational environment of the future.

Tanker Refueling Points: Drogues or Booms?

The DoD’s transition to capabilities based operations has shown the need for the procurement of a tanker platform capable of refueling boom and drogue-type receivers. According to an April 2004, *Sea Power* article, US Marine and Naval leaders decided to defer procurement of the future military tanker to the Air Force

rather than buy their own dedicated tanker. Today, however, the limited availability of “drogue-ready” tanker platforms restricts operational planners from maximizing the employment of their drogue-type strike and suppression of enemy air defense aircraft.

Additionally, the problem of receiver “boom/drogue cycle time” is a hurdle drastically impacting missions. The “cycle time” is the amount of time required for an aircraft to attach the tanker’s boom or drogue, receive fuel, disconnect the equipment and then wait while other mission aircraft cycle through. Multiple air refueling points on a tanker reduce the cycle time, while increasing reliability and efficiency. Rear Admiral Mark P. Fitzgerald, director of air warfare requirements on the Navy staff, illustrated this limitation of the KC-135s in Desert Storm, “The tanker had a single “hard hose” (equipment malfunction reducing the fuel transfer rate), and the Navy had to quickly cycle six to eight tactical aircraft thru the hose, and by the time the last aircraft tanked, the first needed gas.” The process required three to four refueling contacts for each aircraft before reaching Iraq. With up to twenty-four aircraft in a strike force and four supporting KC-135s, “on several occasions this required in-flight reshuffle and occasional aircraft gas aborts when one of the tanker hoses would fail.”⁴ Strike packages are tailored to maximize success of the tasked mission, with each aircraft supporting the others. When aircraft are forced to abort, the entire package is affected. Having more refueling drogues on the tanker seems like an obvious choice. However, each refueling point on a tanker increases the risk of a midair collision due to the close proximity and number of aircraft.

There are some advantages to boom refueling compared to drogue, the greatest being an increased fuel transfer rate. The KC-10 boom is able to transfer

6,700 pounds of fuel a minute, which translates to a quicker cycle time when compared to a single drogue hose. Boom refueling would enable a single Predator MQ-1B to receive its maximum fuel load in a mere six seconds! Another advantage of boom air refueling is most of the new DoD aircraft, such as the F-22 and C-17, are equipped for boom aerial refueling. So, in 2025, boom equipped tankers will be flying and offloading fuel to F-22 and C-17 receivers, unless receiver aircraft are modified with probes. A probe modification to the F-22 would cost millions and require a major reconfiguring of the fuel line plumbing, so it is highly unlikely that this will happen.

A disadvantage of boom refueling compared to drogue is it requires a human to operate and “fly” the boom into the receiver’s receptacle. Flying the boom into an eight-inch receptacle, while hurdling through the air at 400 nautical-miles-per-hour, takes skill and a lot of training. Ensuring boom operators remain proficient by performing a contact at least once a month (varies with experience level) becomes an exercise in scheduling management. Furthermore, having a boom operator in the tanker places another airman closer to danger--while air refueling or from enemy fire. Conversely, drogue refueling is much more reliant on the receiver to get in position to receive fuel and does not require a specialized operator to manipulate the equipment.

To accommodate Air Force boom-type and US Navy, US Marine Corps, or North Atlantic Treaty Organization drogue-type receivers, the new tanker platform (KC-X) will have a boom and multiple drogue refueling points.

Strategic Airpower Through Air Refueling

The US strategic policy builds on the fact that the US military is able to rapidly project air power anywhere on the globe. Adversaries are well aware of this ability and the civilian leadership uses this capability as leverage to protect US interests. This capability was demonstrated during Operation El Dorado Canyon, where eighteen F-111 strike and four EF-111 (Suppression of Enemy Air Defense) aircraft launched from bases in England and struck targets in Libya, in response to Qaddafi's support for terrorist groups.⁵ Initially the mission was not very complicated, but it soon became an operational headache when France, Germany, Spain, and Italy denied overflight clearance to US forces. The Air Force strike package was forced to fly around Europe (adding 1,300 miles and 29 air refuelings), rendezvous with US Naval aircraft, and complete the mission. El Dorado Canyon was a success and sent a loud and clear message to US adversaries--that US tactical strikes were possible anywhere, anytime. Air Force doctrine states: "By increasing range or endurance of receivers, it is a force enabler; by allowing aircraft to take off with higher payloads and not sacrifice payload for fuel, it is a force multiplier."⁶ Without air refueling the F-111s would not have been able to complete the mission and who knows what the Libyan leader might have done.

The Air Force projects that a strategic unmanned stealth bomber will become operational in 2018. This global strike capability is currently performed by B-2, B-52, and missiles. The aforementioned manned aircraft require multiple air refuelings to reach their targets, but they offer military and civilian leadership the flexibility of

recalling or canceling the sortie once launched, unlike missiles, which cannot be recalled once launched.

As Rebecca Grant of the Air Force Association wrote, “Range is the supreme requirement. . . . Boeing’s system concept for the JUCAS air vehicle proposed a combat radius of just under 1,400 statute miles. A bomber with a combat radius of 3,500 statute miles would be much better.” The concept of air refueling bombers becomes a very important issue especially if political concerns restrict overseas basing. Political restrictions may be overcome by air refueling over international waters to enable the bomber’s mission accomplishment. Rebecca Grant went on to write, “Even a bomber with a 3,000-mile combat radius still will need tankers to boost its range. Pre-strike and post-strike tanking over open ocean will be essential parts of the (JUCAS) mission profile.”⁷

Tanker Employment: Dedicated Orbits or Buddy Cruise?

For the employment of air-refueling platforms, generally two types of airspace areas used: anchor or track refueling. At times, both types may be used to facilitate the same operation. For example, prestrike refueling may be accomplished in an anchor to facilitate package formation, and poststrike refueling may be accomplished along a track to facilitate recovery of receiver and tanker aircraft.

According to Air Force Doctrine, due to the compressed airspace designated for air refueling operations, “Standardization is most important when refueling multiple receivers or multiple formations.”⁸ Ensuring receiver aircraft (including UA) follow the prescribed standards will ensure safety is maximized.

During a contingency, air-refueling airspace close to the enemy changes frequently to avoid predictability as well to respond to the changing tactical situation; additionally, routing to and from the air-refueling airspace may change in response to air operations and enemy threats. For instance, during Operations Southern Watch and Iraqi Freedom, air refueling anchor orbits were initially placed thirty to fifty miles behind the forward line own troops. During Operation Iraqi Freedom, as Coalition ground forces moved forward, the air refueling airspace was adjusted and moved to maximize operational support, while minimizing tanker exposure to enemy fire. However, despite the anchor relocation, coalition aircraft still had to leave their patrol orbits (Combat Air Patrol, ISR orbit, or “kill box”) and transit a corridor to receive fuel. This transitory time generally results in thirty minutes of lost time over the patrol orbit, which leaves a gap that can be exploited by a capable enemy. A critical gap during aerial operations occurs when the E-3 Airborne Warning and Control System must leave its command and control battle management orbit and must turn off its surveillance radar to receive fuel. The Command and Control Battle Management and aircraft deconfliction functions are parceled out to another Airborne Warning and Control System, if available, but more often than not, the responsibility of deconfliction and threat identification is tasked to each aircraft in the operational area. Other factors can also contribute to a loss of Command and Control Battle Management operations, such as weather, aircraft malfunctions, or in-flight mission changes. The loss of this aerial “big picture” is an operational seam that requires a lot of coordination during the planning phase of operations in order to minimize its effects.

The US Navy decided to use the probe and drogue-type system because one aircraft could become a “modified tanker” by attaching a centerline tank with a drogue basket. The Navy does not have the enormous gas-guzzling aircraft, like the Air Force’s B-52s; the naval airfleet is comprised of tactical fighter aircraft that require significantly less fuel. The drogue offload rate is between 200 to 300 gallons a minute which translates into a few minutes connected to receive the required amount of fuel; at that rate the B-52 would have had to remain attached for over an hour.⁹

Currently, the US Navy air refueling role is performed by modified S-3 aircraft, carrying 3,000 pound external pods. The Navy has begun retiring the S-3 air fleet, and the air refueling burden has been placed on the shoulders, or more appropriately the fuselage, of the F-18F “Super Hornet.” The F-18F is configured with a center-line fuel pod combined with a drum and wheel type drogue, dubbed the air refueling store, see figure 10. The center-line tank is capable of delivering fuel from its external wing tanks via internal fuel transfer lines and off-loading 3,000 to 3,200 pounds of fuel. In general, this “tanker” is used primarily for pre-strike and weather-hold and recovery of other aircraft to the aircraft carrier. Flying operations generally consist of a C2-type aircraft launching, followed by a Super Hornet with the tanker configuration, then the other strike aircraft. The tanker ascends 10,000 feet and sets up an orbit over the aircraft carrier and cycles the mission aircraft through the refueling drogue. The tanker will remain over the aircraft carrier until the other aircraft return and will dispense fuel to any aircraft that need it.



Figure 10. F-18s Drogue Refueling

Source: Navy.mil, Eye on the Fleet Photo Gallery; available from http://www.navy.mil/view_single.asp?id=22096; Internet; accessed on 8 May 2007.

Another employment method of delivering fuel to co-located aircraft is the “buddy cruise” method, where the tanker will lead a mission package to a designated waypoint, off-loading as much fuel as possible, saving only enough for a return to the aircraft carrier. This method was used extensively for Operation Enduring Freedom, when aircraft launched from the deck of the USS *George Washington* for a 1,000-nautical-mile roundtrip mission into Afghanistan.

Advantages and Disadvantages of Dedicated Tankers

An enormous advantage of modifying existing airframes is the cost savings, reaped from previous civilian research and development efforts. Another advantage is

time compression from design, flight testing, and operational delivery; the basic airframe has already received its airworthiness certificate, so it requires only minor testing of the air refueling pods or systems.

Current versions of non-dedicated tanker aircraft have a small fuel offload capability. As an example, the F-18 configured with the air refueling store can offload about 3,000 pounds of fuel total which is insignificant for a package of aircraft that use 4,500 pounds of fuel an hour each, or 9,000 pounds an hour in afterburner. However, for aircraft made strictly for endurance, such as the UAS, an offload rate of 3,000 pounds is plenty. For instance, the Predator MQ-1B and Global Hawk RQ-4B platforms, which carry 665 and 16,320 pounds respectively, have an average burn rate of 45 and 700 pounds an hour.

Propulsion

Recognized as one of the two key developmental UA technologies (the other is microprocessor),¹⁰ propulsion systems determine maximum speed, gross weight, fuel consumption and therefore loiter time. The joint future of large UAS platforms is jet propulsion, which consumes significantly more fuel per hour compared to propeller-driven aircraft. Jet aircraft are advantageous for combat missions because of their speed, reducing time in dangerous territory and therefore reducing susceptibility to enemy air defense. In today's battlefield, there are generally two classes of turbine engines: (1) man-rated and (2) expendables. The man-rated turbine engines are multiple-use, extended-life engines used for example in F-16s. Expendable turbine engines are used in cruise missiles. However, the onset of UAS technology has produced a hybrid class: the in-between, limited-life class developed for the Global

Hawk and JUCAS platforms. Unfortunately, these “off the shelf” versions are proving unreliable in battlefield operations because of constant demand of ISR and suppression of enemy air defense missions.¹¹ The engines are constantly in use and are not on the ground long enough to receive preventative maintenance to extend their operational life. Another hybrid motor being researched combines the best of solid and liquid propulsion systems, typically using an inert fuel and liquid oxygen to generate thrust, much like the Space Shuttle. Future UA systems will require better fuel consumption, thrust, reduced detection signatures and still be considered cost effective to be viable alternatives. According to the Department of Defense UAS Roadmap, many future propulsion and power systems are being examined for use in future unmanned aircraft. Scientists are testing traditional gas turbines, reciprocating engines, batteries and solar power, and are exploring scramjets, such as the X-43 and fuel cells.¹²

Propulsion is measured by efficiency and performance. Efficiency is described as specific fuel consumption and specific power for performance. Fuel cells convert hydrogen and oxygen into water, which produces electricity, just like a battery. However, unlike a battery which eventually “dies,” as long as there is a flow of chemicals into the cell, it will produce electricity. As depicted in figure 11, fuel cell technology is expected to be the best compromise between efficiency and performance. Currently, many automotive companies are experimenting with fuel cell technology.

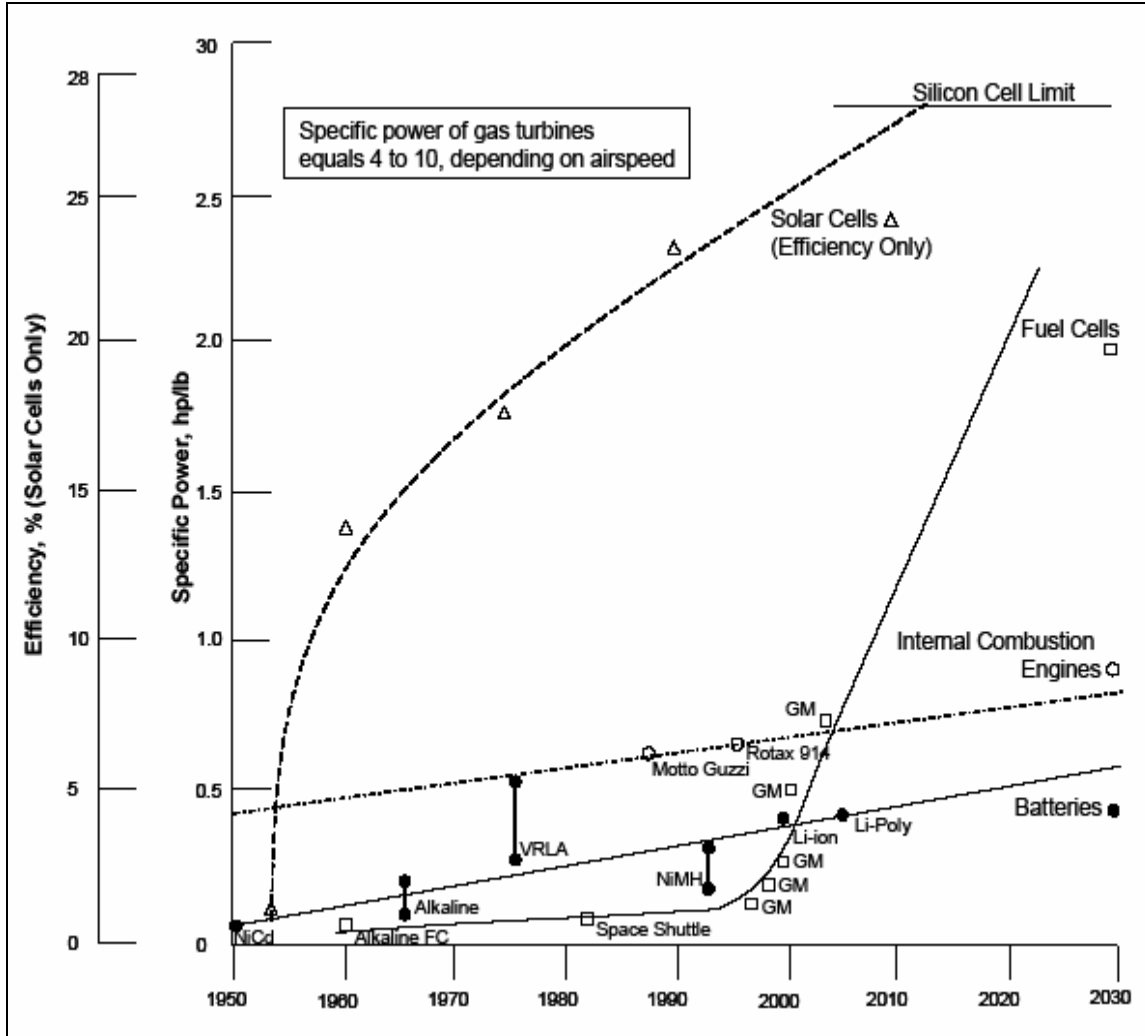


Figure 11. Estimated Timeline and Specific Power of Propulsion Technologies
 Source: Office of the Secretary of Defense, *Unmanned Aircraft System Roadmap 2005-2030* (Washington, DC: Government Printing Office, 2005), 54.

Signals

With remotely operated vehicles, the possibility exists that the enemy may jam or override the controls of the UAS. If a UAS came under enemy control either during refueling or in close proximity to the tanker, there is potential for a midair collision,

effectively destroying two multimillion dollar assets and taking the tanker's crew lives with one "click of the button." This threat is a very real problem that has caused great concern in the past because precedents exist. Steven Shaker mentions that an explosive ordinance disposal, remote control robot was disabling a bomb until its radio control transmission was overridden by terrorists.¹³ The operator barely escaped being blown up after the robot went after him. Shortly thereafter, scientists eliminated this threat by switching to a more secure tether-controlled robot. However, the UA platforms do not have the tether-control option and are reliant on secure satellite relays. The satellite line of communication will always be a vulnerability that must be protected to assure safe operation of the UA, especially during aerial refueling.

The dynamics of flight require huge amounts of communication bandwidth and a powerful processor to manage all the flight control inputs, which become very critical with increased aircraft airspeed. For instance, if an aircraft flying at 400 nautical-miles per-hour vertical axis is off one degree and has a three second time delay, it will be 1,700 feet off altitude! The position tolerances during air refueling are a 20 foot by 20 foot envelope.

Mr. Steven Shaker writes teleoperators (current UA platforms) are the most sophisticated type of remote-controlled vehicles that rely on sophisticated sensor systems. Teleoperators enable the military chain of command to have continuous control over the vehicle's movements. Some disadvantages to teleoperator technology are:

1. If the communications relay between the operator and vehicle are jammed or disrupted, the vehicle loses its functional utility.

2. Operator-controlled machines may perform certain activities much more slowly than a robot relying on machine intelligence.

3. The operators or UA control “system” may become highly prized targets to render the aircraft ineffective.¹⁴

Currently, the MQ-1 Predator Satellite Communications have a 1.5 to 3 second time delay from operator to aerial vehicle.¹⁵ During air refueling, a three second delay could have devastating effects on both receiver and tanker aircraft. This is an obstacle that Air Force Research Laboratory, Air Vehicles Directorate Program Manager, Jake Hinchman, must overcome. He stated, “The goal is to establish a level of integrity at which there is only a one-in-a-million chance that the refueling aircraft will bump into the tanker.”¹⁶

Fuels

Currently, the US government is investigating the viability of using synthetic fuels on military aircraft; largely, to reduce the dependence on foreign oil suppliers and secondly, to provide a more environment-friendly fuel. The US military accounts for 85 percent of the total government’s fuel consumption, and of that, aircraft use a whopping 73 percent.¹⁷ Testing of the synthetic fuel began on the B-52 in December 2006, at Minot Air Force Base, North Dakota. The synthetic fuel passed the numerous test criteria, and the Air Force hopes to certify its entire fleet by 2010.

The fuel issue becomes important because of the aggressive manner governmental agencies are pursuing alternative fuels as a viable source of energy. If an alternative fuel is found that enables aircraft to stay aloft much longer while using half as much fuel, the aircraft would not need to be refueled as often, if at all. The

UA's extended loiter time offered by synthetic or alternate fuels may be limited only by maintenance requirements at that point.

Unmanned Aircraft System Employment

According to figure 12, the DoD envisions unmanned systems to perform a wide variety of missions.

Many agencies are looking at current ISR assets and how they can be altered to perform more missions. For example, the Department of Homeland Security is examining expanding the roles of their Predator assets, "In response to emergencies such as the aftermath of Hurricane Katrina in 2005, a UA could provide an "aerial cell tower" to help re-establish local communications systems."¹⁸ The UA's ability to fly long durations for "dull" communications-relay missions or disaster surveillance is perfect for the unmanned platform. However, with the expansion of missions and proliferation of unmanned systems throughout the government, UA are quickly encroaching on domestic airspace. Since the Hurricane Katrina disaster, the USAF has been aggressively pursuing a letter of agreement with the FAA to allow larger UA platforms to operate in the NAS. To date the Predator is the only large platform that has been authorized to operate in the NAS. This process is slow and has encountered setbacks, even with the most advanced large UAS. For example, a USAF Global Hawk attempted flying in the NAS 21 November 2006, but was subsequently grounded after it lost its flight communications link.¹⁹ The erratic behavior surprised air traffic controllers and bolstered apprehensions of UA flying on the same airways that commercial airlines traverse.

MISSION		CURRENT AIRCRAFT		INTRODUCTION OF UA INTO OPERATIONS					
Payload with Persistence		2005	2010	2015	2020	2025	2030		
Communication Relay	ABCCC, TACAMO, ARIA Commando Solo		(e.g., AJCN)						
SIGINT Collection	Rivet Joint, ARIES II Senior Scout, Guardrail		(e.g., Global Hawk)						
Maritime Patrol	P-3		(e.g., BAMS)						
Aerial Refueling	KC-135, KC-10, KC-130								
Surveillance/ Battle Management	AWACS, JSTARS								
Airlift	C-5, C-17, C-130								
Weapon Delivery									
SEAD	EA-6B		(e.g., J-UCAS)						
Penetrating Strike	F-117		(e.g., J-UCAS)						
Integrated Strike/SEAD	EA-6B, F-16, F-117				(e.g., J-UCAS)				
Counter Air	F-14, F-15, F-16								
Integrated Strike/SEAD/ Counter Air	F/A-18, F/A-22								

Figure 12. Estimated UAS Mission Timeline

Source: Office of the Secretary of Defense, *Unmanned Aircraft Systems Roadmap 2005-2030* (Washington, DC: Government Printing Office, 2005), 74.

The integration of UA into domestic airspace is a complex problem and one that has not caught up with the proliferation of UA. This integration problem is not limited to the US. In 2004, a German-controlled UA operating in Afghanistan came within fifty feet of an Afghan Airbus carrying more than 100 passengers. Had it not been for the quick reactions of the Airbus pilot, there would have been a certain

collision with the UA, and the result would have been disastrous.²⁰ This incident brings to attention the lack of regulation of unmanned systems, which is challenging for the US, not to mention other countries.

The enormous US budgetary deficit is driving a thorough examination of redundant UA systems throughout the government, to identify them and eliminate them. Senior leaders are looking at procuring assets that are not only interoperable among the military services, but interoperable among governmental agencies. In the future, a USAF tanker may launch and refuel a UA belonging to the Federal Emergency Management Agency performing as a communications platform; or that same tanker may air refuel an unmanned system performing a surveillance mission along the national border for the US Customs and Border Control Agency.

Persistent ISR tracking will remain the bedrock of military UA missions, due to the high demand for information. For instance, Donald Kerr, Director of the National Reconnaissance Office, stated, “The United States nearly got to Abu Musab al-Zarqawi, the leader of al Qaeda in Iraq, in 2003. Zarqawi, who was being tracked as a moving target at the time, got away because of a 20-second gap in coverage. In those 20 seconds, the trail went cold.”²¹ Frustrating events, such as this, just add “fuel to the fire” in the UAS proliferation argument.

Command and Control During Aerial Refueling

The C2 function of a UAS is very complex, based on its different phases of flight--takeoff, mission portion, and landing. The debate of whether to give UAS C2 to the tanker or retain C2 functionality at the ground control station is hotly debated. It becomes increasingly more complex when multiple UAS platforms are in close

proximity to one another and a tanker aircraft. Who should have command and control? See figure 13. Air Force Research Laboratories conducted research on this question and found navigation-based controls were the most effective means of conducting automated aerial refueling. The concept is based on both tanker and receiver aircraft having global positioning system antennas, “zeroing in” on one another until boom contact was made. The biggest problem with this concept is the reliance on global positioning system signals. As discussed before, the global positioning system signal or satellite could become the opponent’s high-value target, to disrupt US operations.

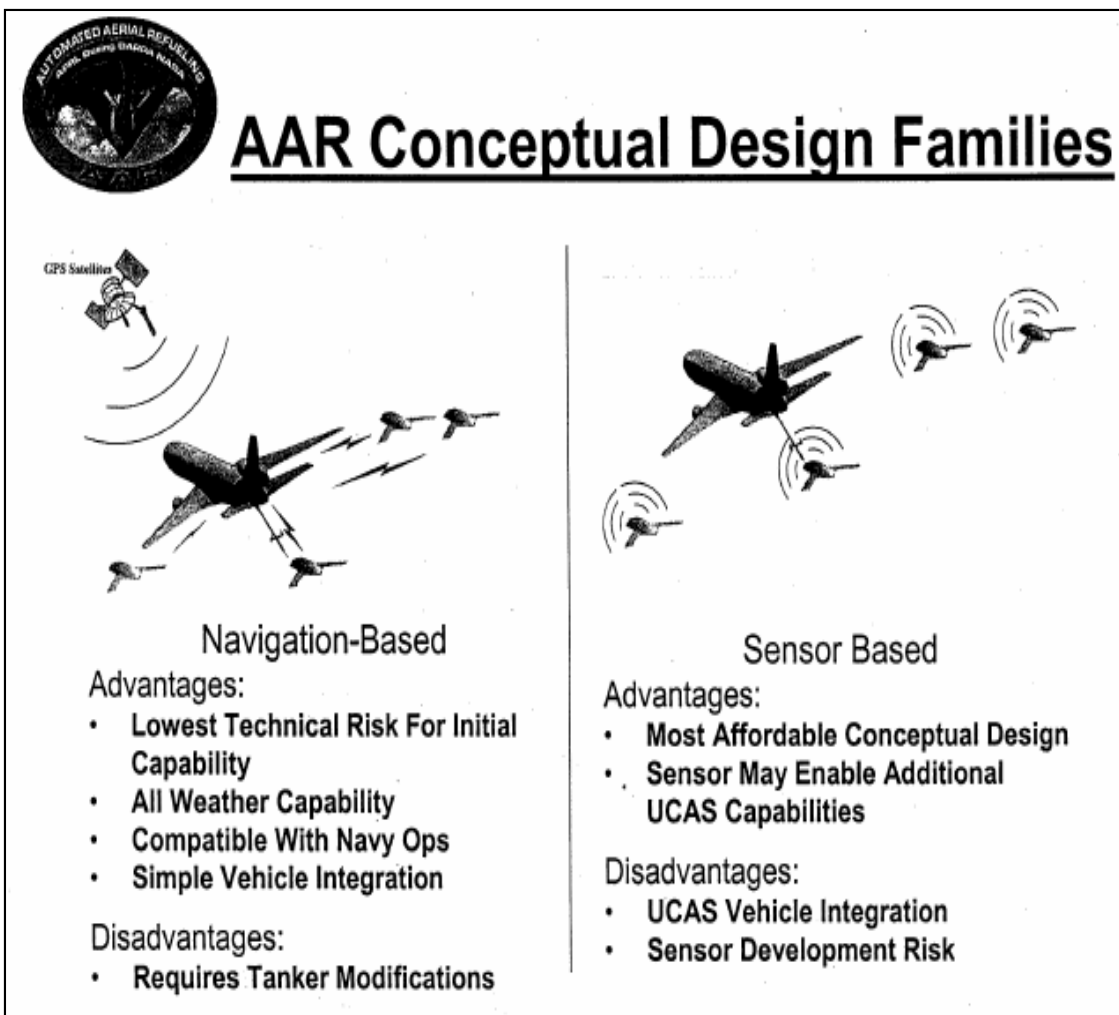


Figure 13. Control Systems During Air Refueling

Source: Air Force Research Laboratory, Automated Aerial Refuel (AAR) Technologies and Challenges; available from <http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA428617&Location=U2&doc=GetTRDoc.pdf>; Internet; accessed on 21 April, 2007.

KC-X, the Future USAF Tanker

Many have argued about what capabilities the future tanker should have and whether it should even be a dedicated tanker platform or like the multirole F-18 platform. A thesis from the Air Force School of Advanced Airpower Studies

recommended purchasing a communications platform that had a secondary mission as air refueling tanker.²² This recommendation was built upon the premise that the tanker has transitioned from a nuclear bomb enabling force to a communication and cargo mission force. General Duncan McNabb, Commander of Air Mobility Command (AMC--parent command of the AF tanker fleet), stated he expects the KC-X to be capable of carrying significant amounts of cargo, providing some relief to a taxed fleet of C-17s, C-5s and C-130s that are focused largely on supporting operations in Iraq.²³ However, the AMC Commander is quick to add, the KC-X would be first and foremost an air refueling platform.

In line with General McNabb's desires, the USAF recently released the future RFP, which is the first step of the procurement process. The overall goal of the procurement is to replace the aging KC-135 fleet with a modern, fuel-efficient, multicapable platform. The RFP stipulates the government will evaluate the vendor's ability to meet System Requirement Document criteria:

- a. Aerial Refueling: The Government will evaluate the offeror's approach to meeting requirements related to aerial refueling. This evaluation will include: tanker aerial refueling, receiver aerial refueling, fuel offload versus radius range, drogue refueling systems (including simultaneous multipoint refueling), the operationally effective size of the boom envelope, the aerial refueling operator station and aircraft fuel efficiency.
- b. Airlift: The Government will evaluate the offeror's approach to meeting requirements related to airlift capability. This evaluation will include: airlift efficiency, cargo, passengers, aero-medical evacuation, ground turn time, and cargo bay re-configuration. The offeror's airlift efficiency will be normalized against the KC-135R airlift efficiency calculated with the same ground rules. An offeror's airlift efficiency value greater than 1.0 will be viewed as advantageous to the Government.
- c. Operational Utility: This evaluation will consist of an assessment of the contractor's approach to meeting the requirements relating to operational utility, including the following: aircraft maneuverability, worldwide airspace

operations, communication/information systems (including Net-Ready capability), treaty compliance support, formation flight, intercontinental range, 7,000 foot runway operations, bare base airfield operations, and growth provisions for upgrades.

d. Survivability: This evaluation will consist of an assessment of the contractor's approach to meeting the requirements relating to survivability, including the following: situational awareness, defensive systems against threats, chemical/biological capability, electro-magnetic pulse (EMP) protection, fuel tank fire/explosion protection, and night vision capability.²⁴

The important aspects of this RFP, in the UAS context are the air refueling portion, operational utility, and survivability. The air refueling portion states the tanker must be able to refuel multiple receivers and of different types (boom or drogue). This requirement will allow refueling of multiple UA as well as conventional aircraft that are expected to be part of the operational inventory in 2025, such as the F-22, F-18, and F-35.

The operational utility is important in regards to UAS refueling operations because of the network-ready portion. This allows for upgrade options for the net-centric operations towards which senior military leaders are progressing towards. The networked backbone of the coalition would provide a real-time common operational picture visible to all coalition forces, enhancing situational awareness and reducing the risk of fratricide.

Lastly, the survivability portion of the RFP is important because of the future electromagnetic pulse threat from adversaries. The heavy reliance on software and communication suites renders air assets vulnerable to enemy magnetic attack. In an effort to reduce vulnerability to this threat, the government stipulated that survivability is required in the future tanker platform.

¹Department of the Air Force, Air Force Doctrine Document 1, *Air Force Basic Doctrine* (Maxwell Air Force Base, AL: Government Printing Office, 2003), 87.

²Walter J. Boyne, *Beyond the Wild Blue: A History of the U.S. Air Force 1947-1997* (New York, NY: St. Martin's Press, 1997), 380.

³Department of the Air Force, Air Force Doctrine Document 1, 51.

⁴Hunter C. Keeter, SEA POWER: Naval Air Refueling Needs Deferred in Air Force Tanker Plan; available from http://www.military.com/NewContent/0,13190,NL_AFTank_042804,00.html; Internet; accessed on 8 May 2007.

⁵Walter J. Boyne, "El Dorado Canyon," *Air Force Magazine* 82, no. 3 (March 1999); available from <http://www.afa.org/magazine/march1999/0399canyon.asp>; Internet; accessed on 14 February 2007.

⁶Department of the Air Force, AFDD 1, 51.

⁷Rebecca Grant, *Return of the Bomber: The Future of Long-Range Strike* (Arlington, VA: Air Force Association, 2007), 21; available from <http://www.afa.org/media/reports/Bomber0207c.pdf>; Internet; accessed on 1 March 2007.

⁸Department of the Air Force, Air Force Doctrine Document 2-6, *Air Mobility Operations* (Maxwell Air Force Base, AL: Government Printing Office, 1999), 52.

⁹Phillip S. Meilinger, "The 90-Year Tanker Saga," *Air Force Magazine* (February 2007); available from <http://aimpoints.hq.af.mil/display.cfm?id=16424>; Internet; accessed on 2 February 2007.

¹⁰Office of the Secretary of Defense, *UAS Roadmap 2005-2030*, 53.

¹¹*Ibid.*, D-1.

¹²*Ibid.*, 52.

¹³Steven M. Shaker, *War Without Men* (Washington, DC: Pergamon-Brassey's International Defense Publishers, Inc., 1988), 169.

¹⁴*Ibid.*, 50.

¹⁵Brian Lane, Predator Operator, Electronic Predator Capabilities Brief provided to author, 10 January 2007.

¹⁶Catherine Macrae Hockmuth, "UAVs--The Next Generation," *Air Force Magazine* (February 2007); available from <http://aimpoints.hq.af.mil/display.cfm?id=16423>; Internet; accessed on 2 February 2007.

¹⁷David Pugliese, "Oil Prices Driving U.S. Military to Invest in Green Energy," *Canwest News Service*; available from <http://aimpoints.hq.af.mil/display.cfm?id=16891>; Internet; accessed on 26 February 2007.

¹⁸Larry Dickerson, "UAVs on the Rise," *Aviation Week and Space Technology* (15 January 2007): 116.

¹⁹Jefferson Morris, "Global Hawk Flights on Hold at Beale AFB Due to Comm Glitch," *Aerospace Daily and Defense Report*; available from http://www.aviationweek.com/aw/generic/story_generic.jsp?channel=aerospacedaily&id=news/GLOB12136.xml; Internet; accessed on 14 December 2006.

²⁰Hockmuth.

²¹Marc V. Schanz, "NATO Moves to Buy C-17s," *Air Force Magazine* 89, no. 11 (November 2006); available from <http://www.afa.org/magazine/nov2006/1106world.asp>; Internet; accessed on 3 February 2007.

²²Thomas L. Gibson, "The Death of 'Superman:' The Case Against Specialized Tanker Aircraft in the USAF" (Thesis, School of Advanced Airpower Studies, Maxwell Air Force Base, AL, 2002), 73.

²³Amy Butler, *Aerospace Daily and Defense Report*, AMC Chief Wants KC-X to Augment C-5, C-17 Fleets; available from <http://aimpoints.hq.af.mil/display.cfm?id=14932>; Internet; accessed on 8 November 2006.

²⁴Aeronautical Systems Center, Solicitation, Offer and Award, Solicitation Number FA8625-07-R-6470, 29 January 2007, M-4; available from <http://fs1.fbo.gov/EPSTData/USAF/Synopses/905/FA8625-07-R-6470/FinalRFP29Jan07.pdf>; Internet; accessed on 3 February 2007.

CHAPTER 5

RECOMMENDATIONS and CONCLUSION

I'm committed to building a future force that is defined less by size and more by mobility and swiftness, one that is easier to deploy and sustain, one that relies more heavily on stealth, precision weaponry and information technologies.¹

George Bush, May 2001

The capabilities of the UAS make it a military system whose time has come. In the near future, technological factors will no longer restrain the development of UA.² The proliferation of UA is stunning and if the US government continues to procure UA systems at this rate, in 2025, the deconfliction of manned and unmanned aircraft will be a major challenge. To address this challenge, the US government has started the lengthy process of integration through legislation; the first step is defining UAS, and then categorizing them as high-, medium-, and low-altitude platforms, followed by required transponder equipment and the level of certification the aircraft operator requires. Categorization and certification is important because the Federal Aviation Administration will require unmanned platforms to be compliant within the NAS, and the military needs access in the NAS for training missions or operational missions (Homeland Defense, Disaster Relief, and others). However, air refueling capable UA should reduce the number airborne (in the mid- to high-level airspace structure) to achieve near constant ISR and a capable communications platform. Furthermore, the transponders on all future aircraft operating in the medium- and high-altitude structure will most likely communicate with one another to aid deconfliction.

Just as the Goldwater-Nichols Act of 1986 laid the foundations for all military services to integrate capabilities for operations, another mandate is needed that will integrate the various departments and agencies. The 11 September 2001 events highlighted the need for an integrated intelligence agency across all departments. This need resulted in the greater integration and a major restructuring of intelligence organizations. The restructuring has reduced redundant systems and streamlined intelligence operations. Similarly, the integration of manned and unmanned aerial assets between departments and agencies is needed.

In an effort to assume the lead for future DoD UAS procurement, the Air Force requested to be the Executive Agent for all medium and high altitude UA flying above 3,500 feet.³ This move was met with heavy opposition from the US Army, largely due to inter-service wars because ultimately it would detract from the losing service's budget. Furthermore, there is concern that the losing service will not receive the desired capability, forced to settle with a moderately capable UAS. However, choosing an executive agent designates project responsibility and oversight, reduces spending, standardizes operations, and reduces the ballooning bandwidth requirements of separate systems. The Air Force reports \$1.7 billion could be saved by consolidating Army, Navy, and Air Force UAS procurements. The USAF is the logical choice for the procurement of UAS operations above 3,500 feet and the ground commanders should be responsible for UAS operations in their area below 3,500 feet. Appointing an executive agent would reduce procurement of like platforms like the Army's Warrior and the Air Force's Reaper, both of which are armed derivatives of the Predator UAS.

The UA have matured to the point where they are no longer considered suitable only for “niche missions” but can be employed across the range of military activities. Many wonder if the F-22 will be the last manned strike aircraft produced largely because if the pilot becomes the limiting factor, why not remove him or her totally? It is a legitimate question. The answer to this question is that technology is not there yet, but it is making giant strides in that direction. The UAS is a great platform for the dull, dirty and dangerous missions. In future operations, the will of the American public will probably be more adverse to casualties in war, so reducing exposure of personnel to dangerous will become more important. An example of this trend is the hourly news updates that occurred in June 1995, after the Captain Scott O' Grady shootdown. Yet, two months later when two Predator unmanned aircraft were lost over Bosnia, nothing was mentioned on television.⁴ As military operations become less kinetic and more stability and security focused, the combat UAS offers a viable solution for both. The UAS will use its ISR capabilities for security enforcement, then quickly transition to kinetic operations when a threat is detected, thus combining surprise and lethality.

During future major combat operations, the UAS and manned aircraft will work in concert with one another to maximize efficiency and effectiveness. General Ronald Keys, Commander of the USAF Air Combat Command, stated, “We can put unmanned combat aircraft systems in there with Raptor. You’ve got three fairly low-observable UCAS in the battlespace. An air defense system pops up, and I click on a UCAS icon and drag it over [the emitter's location] and click. The UCAS throttles over and jams it, blows it up or whatever.”⁵ Integration of manned and unmanned systems for strike packages will become more and more prevalent in future operations because of low observable

stealth technology and the UAS ability to penetrate dangerous airspace. Air refueling will enable the strike package to penetrate further and return to base or be used as an ISR platform if needed.

The reliance on satellite communications is another issue that really needs to be examined. The military is driving towards net-centric operations. This provides advantages, such as maneuver enhancement, mass, economy of force, and surprise; however, relying on this networked backbone for operations presents the enemy with a high-payoff target. If the enemy is able to interrupt or disable US satellite communications, it would be disastrous at the very least for UA which relies on receiving flight inputs from the ground control station. On a grander scale, many military and civilian systems receive critical data from the satellites, such as Global Positioning System and “atomic clock” information. The reliance on satellite systems for net-centric operations is becoming a crutch upon which current and future systems are relying more and more. If an adversary manages to disable the US’ satellites, it would negatively affect numerous military weapons. Military and civilian leaders are therefore confronted with the task of ensuring the integrity and survivability of the satellites in order to prevent adversaries from exploiting this weakness.

Some argue that the Northrop/European Aeronautic Defence and Space Company KC-30, is superior to the Boeing-built KC-767, based solely on capabilities, performance, and overall economics. The KC-30 can carry more cargo, transport more troops and has a greater range. However, it is a larger airframe and requires more ramp space and costs more per aircraft than the Boeing tanker. Scott Hamilton wrote in *Armed Forces Journal*, “Even if the Air Force decides the KC-30 is the better airplane on its technical merits, the

final decision won't be made by the service branch--it will be made in Congress.”⁶ The politically charged, multi-billion dollar KC-X debate is important because the vintage KC-135 tanker fleet needs to be replaced.

The key requirements with the KC-X is its adaptability: multi point refueling, defensive systems, and network communications. The KC-X needs to be adaptable for future multipoint refueling because future UA will continue to get smaller and smaller, enabling a strike package to refuel simultaneously while retaining separation minimums between aircraft. The KC-X also needs to be adaptable to defensive equipment upgrades. Tankers are being pushed closer to the battle lines and will continue that progression to reduce transitory time between air refueling orbits and ISR, combat air patrol, and other orbits. As missile systems, electro-magnetic pulse, and laser weapons continue to advance having a tanker capable of mitigating those threats becomes increasingly important. As Larry Wortzel testified before Congress, “China is developing over-the-horizon technology for its cruise missiles that could strike US Naval forces and the air-to-air refueling capability needed to extend the range of its aircraft.”⁷ The future tanker must be able to defeat those threats to be effective in future operations. Lastly, the communications network needs to be adaptable for upgrades. As the US military moves towards a net-centric battlespace, it is important that all major weapon systems be viewing the same common operational picture. This enables the unmanned systems to quickly assess objects as friend or foe, or UA locate the nearest tanker to refuel from.

The procurement plan of buying 100 aircraft initially and then more as needed is a sound way of replacing the aging KC-135 fleet. The staggered purchase plan will allow testing and evaluation of future modifications of the KC-X aircraft, ensuring

compatibility and functionality with receiver UA systems. This allows options to buy more if it is functional or go with a totally different platform. General Moseley stated, “As we look at buying this thing, we will buy them in blocks of 180 to 200. So there will be a continual set of opportunities for both companies to compete.” This procurement process will be more expensive to the taxpayer, but will provide a more capable and “right-sized” force, rather than buying 500 KC-X all at once. The KC-X will undoubtedly enhance manned aircraft in 2025; however, if the KC-X does not augment the UAS force in 2025, the US will not be locked into spending billions on a tanker that cannot evolve with the UA platforms. There are added benefits to having a mixed tanker fleet--large and small tankers, capable of cargo loading, personnel ferrying, and refueling during operations. As General Moseley, the Air Force Chief of Staff, stated, “I think down the road you’ll see us go to a mixed fleet . . . [because] there was some “some utility” to having larger and smaller tankers.”⁸

The budgetary spending on the KC-X has been ratcheted down by Congress as more and more DoD funds go to fight the growing insurgency in Iraq. In an effort to protect the KC-X procurement, Air Force officials have whittled the tanker program down to ensure that only a platform meeting the minimum requirements is procured. This strategy is a good move presently to prevent the entire KC-X program from being cut; however, this will most likely leave the US with a less adaptable tanker platform. This move has the potential to be very expensive in the future as UA perform more and more missions and become smaller and smaller.

In conclusion, the benefits gained from air refuelable UA platforms are great and give leadership more options to complete dull, dirty, and dangerous missions. There will

come a time when technology will allow UA to stay airborne for long periods without air refueling or maintenance checks. However, until then, the marriage of UA and air refueling assets will only increase in frequency across the full spectrum of US governmental operations.

¹George W. Bush, News Release 25 May 2001; available from <http://www.whitehouse.gov/news/releases/2001/05/20010525-1.html>; Internet; accessed on 4 December 2006.

²Major James C. Hoffman, USAF, and Charles Tustin Kamps, "At the Crossroads: Future 'Manning' for Unmanned Aerial Vehicles," *Air and Space Power Journal* (spring 2005); available from <http://www.airpower.maxwell.af.mil/airchronicles/apj/apj05/spr05/hoffman.html>; Internet; accessed on 14 January 2007.

³Inside the Air Force, Moseley says USAF Should Be Executive Agent For Large Drones; available from <http://aimpoints.hq.af.mil/display.cfm?id=17215>; Internet; accessed on 13 March 2007.

⁴Bill Sweetman, "Pilotless Fighters: Has Their Time Come?," *Jane's International Defence Review* 30, no. 6 (June 1997): 59-68.

⁵David A. Fulghum, and Michael J. Fabey, "F-22: Unseen and Lethal," *Aviation Week* (8 January 2007): 46-48.

⁶Scott Hamilton, Why Boeing Will Win the Aerial Refueler Contest," *Armed Forces Journal* (February 2007); available from <http://www.armedforcesjournal.com/2007/02/2418963>; Internet; accessed on 14 March 2007.

⁷House of Representatives, Armed Services Committee, *China's Strategic Intentions and Goals*, Testimony of Larry M. Wortzel, Ph.D., Director, Asian Studies Center, The Heritage Foundation; available from <http://armedservices.house.gov/comdocs/testimony/106thcongress/00-06-21wortzel.html>; Internet; accessed on 16 March 2007.

⁸Jim Wolf, "U.S. Air Force Chief Foresees Mixed Tanker Fleet," *REUTERS* (22 February 2007); available from <http://aimpoints.hq.af.mil/display.cfm?id=16823>; Internet; accessed on 22 February 2007.

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