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Unmanned Airlift

A Viable Option for Meeting the Strategic Airlift Shortfall

Lt Col Chad T. Manske, USAF

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Manske

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A Viable Option for Meeting the Strategic Airlift Shortfall

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Foreword

This study on airlift, written before Operation Iraqi Freedom began, has greater relevance now that we have some clear lessons about the vital importance of airlift for operations in Iraq and Afghanistan. In *Unmanned Airlift: A Viable Option for Meeting the Strategic Airlift Shortfall,* Lt Col Chad T. Manske points to the growing dependency on strategic airlift as well as the abiding corollary that there will continue to be a shortfall in strategic airlift. Quite naturally, he asked whether there might be a suitable role for unmanned airlift in the Air Force.

To get to the analysis, Colonel Manske raised three crucial questions: (1) are operational requirements able to justify unmanned airlifters, (2) are current and emerging technologies likely to meet these potential operational requirements, and (3) are the operational concepts cost-effective? Unsurprisingly, the author found a paucity of operational requirements. The first step in applying new technology is to convince unified combatant commanders and defense planners of a viable potential. Generally, operational and combat planners think primarily about capabilities available in the present. In addition, a long history of unproven aircraft concepts translates to high reluctance by the DOD and senior military leaders to commit funds to programs that show little near-term prospects of success. Clear assurances are needed to invest in procurement and acquisition of these new systems and attendant capabilities. The author suggests that the current shortfall of aircrew, the evident progress in emerging unmanned aircraft technology, and the currently increasing funding of unmanned aerial vehicle (UAV) research and development are all providing impetus to investigate the unmanned airlift concept.

Colonel Manske thoughtfully provides an interesting scheme for employing these large vehicles using a monitoring mother ship to mitigate the very real problem of globally navigating in controlled airspace occupied by manned aircraft. He is also hopeful that air traffic management procedures will be upgraded to support autonomous UAV operations.

Finally, the author has three suggestions for a DOD investigation:

1. Agents must perform a detailed cost-benefit analysis, learning best practices from Joint Unmanned Combat Air Systems and UAV programs.
2. Charge Defense Advanced Research Projects Agency with the responsibility of determining the feasibility of concepts for unmanned airlift.
3. Use war games to determine and establish a feasible concept of operations and employment.

Originally written as a master's thesis for Air University's School of Advanced Air and Space Studies, the College of Aerospace Doctrine, Research and Education (CADRE) is pleased to publish this excellent study as a CADRE Paper. Clearly, the careful examination of this unmanned airlift idea with offerings of workable solutions validates the usefulness of Colonel Manske's research, facilitating this publication's attraction to a large airpower audience.

Dan R. Mortensen

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About the Author

Lt Col Chad T. Manske received a commission through the Air Force Reserve Officer Training Corps from Michigan State University in June 1989 and has extensive operational experience flying the KC-135, KC-10, and C-17, accumulating over 3,100 flying hours. Colonel Manske has a bachelor's degree in political science from Michigan State University, a master's degree in aerospace science and management from Embry-Riddle Aeronautical University, a master's degree in operational art and science from the Air Command and Staff College, and a master's degree in airpower art and science from the United States Air Force's School of Advanced Air and Space Studies at Maxwell Air Force Base, Alabama. He is also a graduate of the Air War College. Colonel Manske recently completed a tour as the Air Force special assistant to the commander of United States Joint Forces Command and Supreme Allied Commander Transformation in Norfolk, Virginia, and is currently the commander of the 7th Airlift Squadron (C-17s) at McChord Air Force Base, Washington.

Colonel Manske has published articles including "Looking Ahead: Future Airlift," in the *Air Force Journal of Logistics*, a required reading for Air War College students, as well as a short article on unmanned airlift in *Unmanned Systems Magazine*. He is married to the former Stacey LoPrete, and they have three girls—Taylor, Madison, and Reilly.

Acknowledgments

I would like to thank my research advisor, Maj John Terino, and my reader, Dr. Hal Winton, for their encouragement and guidance in helping me to clarify the issues in this study. I am grateful to the faculty of the School of Advanced Air and Space Studies who helped transform our class into budding airpower strategists. Lastly, I want to thank my wife, Stacey, whose help in editing drafts was invaluable, and my children who wondered why their dad had to spend so much time at the computer and in the books all year. I certainly appreciated their love, patience, and understanding throughout the year.

Chapter 1

Introduction

The only thing harder than getting a new idea into a military mind is getting an old one out.

—B. H. Liddell Hart

During the past decade, the US Air Force became increasingly aware of the utility of unmanned aerial vehicles (UAV). Positive experiences with UAVs in the Gulf War and subsequent conflicts highlighted the ability of these platforms to perform difficult missions with reduced human risk and generated increased demand among Air Force leaders. These experiences provided a foundation for logical steps forward into an uncertain future. Air Force UAVs, Predator and Global Hawk, demonstrated capabilities that provided decision makers with accurate and timely intelligence, surveillance, and reconnaissance data and firmly established their role in the USAF force structure. The success of these programs led to the development and testing of unmanned combat aerial vehicles (UCAV) designed to suppress enemy air defenses on the battlefield. The current successes enjoyed by the UCAV development program, now known as the Joint Unmanned Combat Air Systems (J-UCAS) program, generated questions about the utility of UAVs in other roles. One role that merited additional investigation was airlift. This became the primary research question for this paper: Is there a suitable role for unmanned airlifters in the Air Force? To discover whether such a need exists, the author examines the current body of literature on the history, development, and future of UAVs. The analysis of this data used the major elements of military historian Michael Howard's essay "Military Science in an Age of Peace" to determine the feasibility of the unmanned airlift concept. Howard noted that

> Military science is like any other kind of science. . . . It progresses . . . by a sort of triangular dialogue between three elements in the military bureaucracy: operational requirement, technological feasibility and financial capability. These last two elements proceed according to laws of their own. Their flexibility cannot be controlled by the military. Financial limitations are a matter of politics. Technological limitations are questions of scientific expertise. It is in the third element of this

> triangle—the operational requirement—that the military scientist, as opposed to the scientist with the military, really has to do his hard thinking. In discerning operational requirements the real conceptual difficulties of military science occur.[1]

This paper addresses the US strategic airlift shortfall and examines the research question by dividing it into the three elements in Howard's criteria. The first element analyzes operational airlift requirements to discern the airlift status for the Department of Defense (DOD) and US security and interests. It uses National Security Strategy (NSS) and National Military Strategy (NMS) documents and other strategic-level defense guidance to link the requirement for airlift to national security. USAF Scientific Advisory Board (SAB) studies on future force structure requirements contributed insights on this topic and aided in establishing potential requirements for unmanned airlift vehicles (UALV) for the US Air Force. This analysis provided UAV requirements and a foundation for using UALVs as a means to satisfy airlift requirements. The second element investigates the issue of UALV technological feasibility. It assesses current and emerging technologies to determine if, when, and under what conditions it will be possible to develop a prototype UAV. Finally, the author addresses the question of financial capability by reviewing the various costs and UAV acquisition processes to determine the fiscal advantages and disadvantages of UALV development.

In using these guidelines, the following three questions need to be answered:

1. What operational requirements justify unmanned airlifters?
2. Are current and emerging technologies likely to meet these potential operational requirements?
3. Are the concepts cost-effective?

Definitions

Some terms require definition. A UAV is "a powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload."[2] The terms *unmanned transport* (UT) and *unmanned airlift* (UA) are used interchangeably to denote the aerial movement of cargo, supplies, and equipment without a human operator aboard. Finally, several times throughout this paper the following designate specific periods of the future: short-term, 2002–2012; midterm, 2012–2022; and long-term, 2022–2032.

Background and Significance of the Problem

UAVs provide significant advantages over manned aircraft platforms in some mission areas. Given the long-term strategic airlift shortfall experienced by the DOD, the development of an unmanned airlift vehicle may provide a viable solution within existing funding levels. According to the Secretary of Defense's *Unmanned Aerial Vehicles: Roadmap 2000–2025* (hereafter called *UAV Roadmap*), the document used to assist the DOD in developing a long-term strategy for UAV development between 2000 and 2025, UAVs are force multipliers that can increase unit effectiveness in an era of decreasing force size.[3] The author seeks to determine if this statement is valid for the airlift mission.

The impetus for the UALV concept originates in USAF scientific studies advocating innovative possibilities for future missions and roles for UAVs in general—of unmanned transport, in particular.[4] When the SAB published these studies six-to-seven years ago, its evaluation of UT placed that capability in the realm of distant possibility. The studies did not elaborate on requirements for the vehicles nor did they discuss financial considerations. The SAB's primary focus was on the technological aspects of future transport concepts, but even that information was incomplete.

A paper titled *New World Vistas* contained several volumes specifically investigating widespread UAV applicability to meet future Air Force roles and missions. The panel that wrote the volume on mobility used five criteria to evaluate emerging technologies applicable to improving the air mobility mission. The criteria required the panel to (1) select areas of rapidly changing technology applicable to the mobility mission, (2) identify the most revolutionary technologies, (3) predict the impact on affordability of the mobility mission, (4) identify which technologies can be obtained by capitalizing on commercial development, and (5) identify uniquely military technologies.[5] Their report identified 19 mission areas in which future technologies could influence mobility applications.

The panel prioritized the list of missions using another set of evaluative criteria and concluded that UT ranked 12th of 18 on the list.[6] They maintained that because "flight personnel are expensive and vulnerable" aboard large, less maneuverable, airlift aircraft the risk to these personnel could be reduced through use of UA.[7] The panel also maintained that "major technology advances in reliability are required in all aircraft systems, particularly controls" before further studies are conducted.[8] The relatively low ranking UT received from the panel indicated that contemporary technology seven years ago was not sufficiently mature to place it higher on the list. But, UAVs are now being developed, produced, and funded with unprecedented growth.

Why Do We Have Unmanned Aerial Vehicles?

The United States considered UAVs a practical alternative to manned reconnaissance flight after Francis Gary Powers' U-2 was shot down over the Soviet Union in 1960.[9] The downing of another U-2 during the Cuban missile crisis in 1962 deepened American resolve to develop unmanned surveillance and reconnaissance capabilities. Therein lies the difficulty in determining operational requirements for unmanned airlift roles and missions. The need to mitigate risk to accomplish an important national mission drove the requirement to develop unmanned intelligence, surveillance, and reconnaissance (ISR) platforms. Risk, however, is not as significant a criterion in air transport missions as it is in other airpower roles. As with all Air Force missions, risk management procedures will dictate acceptable levels of risk. If one is to make a case for unmanned flight operations, the reasons must be sound before the DOD will provide funding.

UAVs have been popular instruments of war for the last 15 years. Their popularity results primarily in the avoidance of risk their use provides while doing so at a fraction of the cost of manned aircraft. Advances in unmanned technology systems and capabilities have aided this process. UAV capabilities have grown so much in the last few years that new requirements for UAVs have led to the development of advanced capabilities that were previously thought unattainable.[10] In many ways, rapid advancements in UAV technologies created by this circular process make for "technologically ambitious" UAV programs that also turn out to be very affordable.[11]

Assumptions

The author makes two assumptions in this paper.

1. No passengers will be carried on unmanned airlifters. If UALVs become a reality, they will likely only carry cargo until they are proven safe. The idea of carrying passengers in an aircraft with no pilots aboard is fraught with moral and ethical issues not addressed in this paper. In the future, when technology matures to a sufficiently safe level, UALV passenger aircraft may become a reality.
2. The unmanned airlift concepts advocated in this paper will complement current and future manned systems. For example, unmanned airlifters could be employed in conjunction with manned airlifters in a formation. Manned airlifters will also perform complex and specialized missions, which machine logic will not be mature enough to accomplish. Though man may leave the confines of some aircraft, he is required to operate the complex machinery necessary for the successful mission accomplishment of existing UAVs.[12]

Preview of the Argument

Chapter 2 covers the long-term strategic airlift shortfall that unmanned airlift can potentially solve. This highlights the importance of strategic airlift in the execution of national security and military strategy. Arguably, US strategy cannot be promulgated without adequate strategic airlift in sufficient quantities. UALVs overcome this airlift shortfall.

Chapter 3 includes the history and development of UAVs, as well as UAV and UALV operational requirements, with an eye towards developing requirements for unmanned airlift that currently do not exist. It includes an assessment of current UAV programs as well as the administration of UAV programs over the last 15 years.

Chapter 4 deals with the technological feasibility of unmanned airlift. An evaluation of current, emerging, and conceptual technologies is placed into a context that clarifies the possibility of turning vision into reality while determining if the technology necessary for unmanned airlift can meet proposed operational requirements.

Chapter 5 illustrates the cost-effectiveness of UAVs as a viable alternative for the nation's strategic airlift shortfall. This includes an analysis of costs associated with UAV development and includes manned and unmanned aircraft costs. Secondary costs factored into the analysis include degraded readiness and low retention rates of quality people. These secondary costs increase the risk to securing our national interests while simultaneously placing a burden on our men and women who remain.

Chapter 6 covers the findings of the previous chapters and their implications for the future of UALVs.

Notes

Most of the notes for this chapter and the following chapters appear in shortened form. For full details, see the appropriate entries in the bibliography.

1. Howard, "Military Science in an Age of Peace," 5.

2. Joint Publication (JP 1-02), *Department of Defense Dictionary of Military and Associated Terms*, 450.

3. Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000–2025*, 13.

4. See the following studies for more in-depth information: USAF SAB, *UAV Technologies and Combat Operations*, vol. 1; USAF SAB, *UAV Technologies and Combat Operations*, vol. 2; Fellows et al., "Airlift 2025"; and USAF SAB, *New World Vistas: Mobility Volume.*

5. USAF SAB, *New World Vistas*, A-1.

6. Ibid., 31.

7. Ibid., 19.

8. Ibid.

9. Ricks and Squeo, "Why the Pentagon Is often Slow to Pursue Promising New Weapons," 1.

10. Walden, "The Use of Modeling and Simulation in the Systems Engineering of Unmanned Aerial Vehicles," par. 1.0.

11. Ibid.

12. Longino, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios*, xi; and Chun, *Aerospace Power in the Twenty-First Century*, 295.

Chapter 2

The Strategic Airlift Shortfall

> *We have learned and must not forget that, from now on, air transport is an essential of airpower, in fact, of all national power.*
>
> —Gen Henry H. Arnold, US Army Air Forces, 1945

With the onset of the 1948 Berlin Airlift, US airlift forces gained new prominence in the eyes of national policy makers as they sustained a besieged city for nearly a year. Because of its decisiveness in affecting political opinion, policymakers unreservedly embraced airlift during the Korean War. This war exposed the inadequacy of the force structure, the logistical posture of airlift in-theater, and the obstacles that the distance from Korea to the continental United States presented for airlift. To facilitate an adequate force structure for the war, Air Force Gen William H. Tunner, in 1950, consolidated control of Air Force airlift, including operations, support, and maintenance functions. General Tunner's reorganization optimized airlift's ability to support rapid troop movements and resupply soldiers actively engaged in combat. However, after the war, aircraft, missions, and consolidation issues stirred a contentious debate about the best organization for airlift in the postwar equation.[1] Although a major part of the debate revolved around the allocations of the declining military budget, none of the participants wanted to part with their share of airlift resources. General Tunner and other airlift advocates persuasively argued that airlift had a significant role in the postwar atomic world. Consequently, the airlift fleet underwent an unprecedented peacetime expansion.[2] The Vietnam War further highlighted the increasing utility of strategic airlift through the transport of record-breaking tonnages.[3] The trend toward greater requirements continued through the Persian Gulf War to the present.

Even as political decision makers, military strategists, and theater commanders relied on strategic airlift to deliver large tonnages in short time spans, the requirements for this capability always exceeded supply. Despite airlift's higher profile, lawmakers never allocated enough funding to meet stated national security strategies and objectives. Recent commanders of America's airlift forces called for increased acquisitions to meet those objectives, but requests for more assets received mixed responses in spite of congressionally mandated studies calling for more aircraft.

Statements by former and current United States Transportation Command (USTRANSCOM) commanders highlighted the importance of and shortfall in strategic airlift. Gen Charles T. Robertson Jr., former combatant commander, USTRANSCOM, and commander, USAF Air Mobility Command (AMC), stated in 2000 that "there is no subject talked about more when the warfighting CINCs [combatant commanders] get together . . . than the shortfall in mobility. No. 1 on their priority list—or in the top five—is the shortfall in strategic airlift. And we know (there's a shortfall) because we're shortfalling customers every day in peacetime. . . . Every day in peacetime we're saying 'no' to somebody."[4] Similarly, Gen John W. Handy, the current combatant commander USTRANSCOM, stated in 2002 that "no one challenges the fact that as a nation, we need as much airlift as we can get. It's a self-evident truth."[5] These statements, backed by comprehensive studies on the issue, characterized the problem.

When terrorists struck the US homeland on 9/11, the United States launched a global war against terrorism that started in Afghanistan. Large numbers of troops and equipment were deployed to the Middle East to conduct military operations. The secretary of defense immediately tasked military airlift units to deploy the combat resources necessary to begin those operations. After a few months of extremely high-tempo operations by airlift units, it became apparent to Air Force leadership that continuous use of airlift aircraft induced accelerated aging of the fleet. Brig Gen Ted Bowlds, USAF program executive officer for airlift aircraft, maintained that the operations necessitated the need for more airlift.[6] C-5 and C-17 airlifters transported most of the equipment that went by air. With regard to the high use rate of C-17s in the war, Bowlds stated, "Like any weapon system, in times when you're using them at higher rates than anticipated, they tend to wear out faster."[7]

Because the war against terrorism is expected to "last as long as it takes"[8] and the administrations' homeland security measures are emphasized, the president budgeted an unprecedented $379 billion for defense programs in fiscal year (FY) 2003.[9] Thus, it is important for the DOD and the Air Force to consider long-term alternatives for increasing airlift capacity when Congress and the American people seem willing to open the nation's pocketbook for national defense.

After 9/11, the Pentagon initiated a comprehensive review of its mobility requirements that reflected the demands on the defense transportation system. The DOD review used data based on an updated operational scenario described in the September 2001 release of the Pentagon's *Quadrennial Defense Review* (*QDR*). The previous scenario assumed concurrent conflicts in Southwest Asia and on the Korean peninsula, otherwise known as a two major theater war (MTW) scenario. This scenario taxed airlift forces to the extent that deploying forces were put at risk.[10]

The 2001 *QDR* and the FY04–09 *Defense Planning Guidance* (*DPG*) established a new defense planning construct that steered us away from the older MTW strategy and resulted in new airlift requirements to meet the threat. The *DPG* calls for the support of what has come to be known as the 1-4-2-1 strategy for future support operations around the world:

- The first "1" mandates a priority focus on homeland security (HLS) that includes the use of outsize capable assets (C-5s and C-17s) to be withheld for HLS mission requirements. This is an additive capability since *Mobility Requirements Study 2005* (*MRS-05*) and the events of 9/11.

- The "4" in the *DPG* construct mandates concurrent support to deter forward (DF) in four separate geographic regions around the globe. Those four regions may be in support of humanitarian relief, disaster support, noncombat evacuation operations, or armed conflict. This multitheater, concurrent demand in addition to HLS is significant.

- The "2" is likened to the 2-MTW sequential environment outlined in *MRS-05* with a subtle distinction. The United States is now called on to "swiftly defeat the effort" of an adversary in two major regional theaters. Times of overlap and concurrency have yet to be defined as are the types of "effort" that must be defeated.
- The last "1" in the *DPG* mandates "winning decisively" one of the two efforts above while maintaining support to other theaters and homeland defense.[11]

In assessing the magnitude of the problem, General Robertson told Congress in 2001 that the shortage of sufficient airlift assets constituted a high risk in terms of accomplishing vital national and military strategy objectives. This risk was assessed in the *MRS-05* by evaluating "the ability of US/coalition forces to achieve measurable war-fighting objectives."[12] The *MRS-05* examined airlift requirements from top to bottom, planned for intertheater and intratheater strategic airlift capability, and investigated continental United States airlift requirements.[13] Chapter 3 examines these assessments.

One proposal to the airlift shortfall increased the number of Civil Reserve Air Fleet (CRAF) participants. However, another report concluded that "there are legal and practical limitations on the military's use of the voluntary CRAF and its civilian crews in hazardous conditions and on the kinds of military material it can carry."[14] These restrictions fueled debate over a satisfactory solution to the nation's airlift shortfall. It appeared that by contracting more CRAF carriers, the problem diminished. However, the CRAF does not possess the required specialized airlifters for transport into potentially hostile areas. Yet, "without CRAF, it would cost the American taxpayer over $50B [billion] to procure, and $1-3B annually to operate, an equivalent-sized force in the organic fleet."[15] While CRAF comprises an important component of US airlift capability, without a sufficient organic airlift fleet to move oversized and outsized cargo, as well as the capability to transport it far closer to hostilities than CRAF aircraft are able, the shortfall compromises military posture. Despite the Air Force's purchase of 60 more C-17s, bringing the total acquisition closer to *MRS-05* required levels, the United States still experienced a strategic airlift shortfall. The secretary of defense instituted a new national strategy dispensing with the former two MTW scenarios, substituting a much broader capabilities-based approach, and requiring "planning for a wider range of contingencies."[16] This policy suggested that the number of airlifters on order failed to meet operational requirements and the DOD lacked the funding or the willingness to procure significant airlift capability to meet requirements. A capabilities-based airlift force built for broad, unknown, and potentially hostile situations makes implementing the strategy a difficult, costly, and risky proposition. The concept of cost effectively increasing airlift capability, with significantly reduced risks and incorporating advances in unmanned aircraft technology, offers a new vision for unmanned air transport.

Notes

1. Owen, "The Rise of Global Airlift In the United States Air Force 1919–1977," 97. Robert C. Owen, PhD, is chair of the Department of Aeronautical Science, Embry-Riddle Aeronautical University, Daytona Beach, Florida.

2. Ibid., 101.

3. Hutcheson, *Air Mobility*, 14.

4. Lowe, "Military Not Able to Meet Airlift Requirement for War," 12.

5. Levins, "Transportation Command's Chief Emphasizes the Need for More C-17 Cargo Planes," 9.

6. "With C-17 Negotiations Final, Air Force Mulls Expanding New Contract," 1.

7. Ibid.

8. George W. Bush, "Statement of the president, 15 September 2001," *Weekly Compilation of Presidential Documents* 37, no. 38 (24 September 2001): 1320.

9. DOD, "President Announces Details of Wartime Defense Budget."

10. DOD, *QDR Report, September 30, 2001.*

11. Defense LINK News, *Defense Planning Guidance: Planning Construct*, 3.

12. Tirpak, "The Airlift Shortfall Deepens," 58.

13. Office of the Joint Staff, *MRS-05* (U), 6. (Secret) Information extracted is unclassified.

14. Owen and Fogle, "Air Mobility Command and the Objective Force," 15.

15. Senate, Statement of Gen Charles T. Robertson, Jr. USAF on *Strategic and Tactical Lift in the 21st Century*: *Hearings before the Subcommittee on*

Seapower of the Committee On Armed Services, 13. Hearing examined strategic and tactical lift requirements versus capabilities.

16. Office of the Secretary of Defense, *QDR*, 61.

Chapter 3

Operational Requirements

> *In view of the information [General Accounting Office] GAO developed and DOD's position, the Congress should scrutinize proposed manned aircraft developments to assure that the DOD gives adequate consideration to the use of the remotely piloted vehicle technology for some missions. While DOD is making some use of the technology, there is a need to assure that its use is maximized where suited to save lives and money.*
>
> —General Accounting Office, 1981

The DOD designated the AMC as lead command in the airlift program with responsibility for ensuring that airlift forces are trained and equipped to support national goals, objectives, and interests. AMC outlines its approach to meeting this responsibility in the *2002 Air Mobility Strategic Plan.* The executive summary of the strategic plan describes the fundamental role that airlift forces play in US national security through their conduct of operations other than war, power projection, and force protection.[1] In the plan, AMC cautioned that more effort must be expended to increase airlift capacity "to meet future capability requirements."[2] The fundamental questions are how did airlift become such an important component of US security and where does the strategic guidance originate for outlining airlift requirements?

A top-down survey provides some answers to why air mobility's critical role in achieving national objectives within a fast-moving global environment drives a new generation of airlift requirements. The survey examined UAV capabilities to demonstrate the increasing reliance on UAVs to fulfill a growing list of unified combatant commander missions. A notional UALV emerged from the amalgamation of airlift requirements and needs with the growing list of UAV capabilities. Possible scenarios emerge for the use of unmanned airlift vehicles in support of national strategy.

Strategic Document Review

US national strategic-level guidance originates with the president's NSS. This provides the basis for the chairman of the Joint Chiefs of Staff's (CJCS) NMS. Strategic airlift forces provide an important role in this policy. As a force operating around the world and around the clock, strategic airlift demonstrates US resolve and presence through the rapid aerial delivery of combat troops and equipment.

This paper uses examples from the 2000 NSS to examine the viability of UALVs to bolster air mobility capabilities. The elements of this strategy include shaping the international environment, responding to threats and crises, and preparing for an uncertain future. Responding to threats and crises with airlift requires an air transport force capable of global mobility and freedom of action. To prepare for an uncertain future, the United States must transform capabilities, technologies, and organizations to meet tomorrow's challenges.

National Security Strategy

The NSS provides high-level guidance leading to the accomplishment of national objectives. It requires an investment in focused science and technology efforts, concept development, and experimentation.[3]

The significance of strategic airlift becomes apparent: "Strategic mobility is critical to our ability to augment forces already present in the [*sic*] region with the projection of additional forces for domestic and international crisis response. This agility in response is key to successful American leadership and engagement."[4] Without a robust strategic airlift fleet, the United States lacks the credibility to fulfill commitments in support of its interests.

National Military Strategy

Similar in organization to the NSS, the NMS provides guidance from the CJCS in conjunction with the Joint Chiefs of Staff (JCS) and unified combatant commanders for the strategic direction of the services.[5] The NMS outlines the US national military objectives, the international strategic environment, and how

US military capabilities fulfill the strategy to achieve those objectives.[6] The NMS objectives parallel those in the NSS but are narrower in scope and focus specifically on military matters. The NMS defines airlift's critical role as an integral part of the CJCS strategy to support the NSS.

The NMS articulates three distinct objectives: to shape, respond, and prepare now for an uncertain future. For strategic airlift, the "respond" objective means responding "to crises across the full range of military operations, from humanitarian assistance to fighting and winning MTWs and conducting two nearly simultaneous smaller-scale contingencies."[7] Dire implications occur for the security of the nation by failing to meet that requirement. Although mandated to prepare for two nearly simultaneous MTWs by the NMS, the DOD never possessed the strategic airlift required to meet this goal. Col Michael Fricano, chief, AMC Studies and Analysis Division, who provided the Joint Staff data for consideration in the *MRS-05*, stated that "US organic airlift forces are sized to accommodate only one MTW at this time."[8] As an international power with global interests, US military forces must deter and defeat cross-border aggression around the globe. A failure to pursue this policy "would signal to key allies our inability to help defend mutual interests, thus weakening our alliances and coalitions."[9] Strategic airlift forces provide such capabilities while strengthening the coalition ties deemed valuable to protecting US national interests.

United States Transportation Command Strategic Guidance

USTRANSCOM, the functional unified command and the parent command to AMC, manages the Defense Transportation System. It generates operational requirements pertaining to its mission as the single-source defense transportation provider.

Accordingly, the USTRANSCOM strategic guidance document plays a vital role in military strategy execution.[10] Like the NSS and NMS, the USTRANSCOM strategic guidance identifies a strategy similar to the "shape, respond and prepare now for an uncertain future" paradigm mentioned previously. To shape the environment, it provides properly trained mobility forces, then responds with these forces to transport mission-essential personnel and equipment where needed. It prepares for an uncertain future of securing US technological superiority in selected war-fighting capabilities through an enterprising modernization program. The attainment of these goals supports Secretary of Defense Donald Rumsfeld's vision of achieving defense transformation for twenty-first century military forces.[11]

USTRANSCOM visualizes a future environment with the capabilities necessary to fulfill guidance contained in the NSS, the NMS, and its own strategic directive. It promotes an explicit requirement for "robust, effective, and survivable strategic lift" as part of its military strategy for the twenty-first century.[12] But it acknowledged difficulties in fulfilling national goals and objectives of future military forces when it stated, "The challenge is to exploit future technological advances, foresee the obsolescence of current systems, and plan for their replacement."[13] This challenge forms the basis for this paper.

A Core Competency: Rapid Global Mobility

The Air Force professes expertise in six core competencies: air and space superiority, precision engagement, rapid global mobility, information superiority, global attack, and agile combat support. Of the six, rapid global mobility involves the movement of troops and equipment required to accomplish the objectives of the national strategy. To accomplish these airlift requirements, the United States must possess sufficient capability to overcome the declining access to overseas bases that has occurred over the last decade.

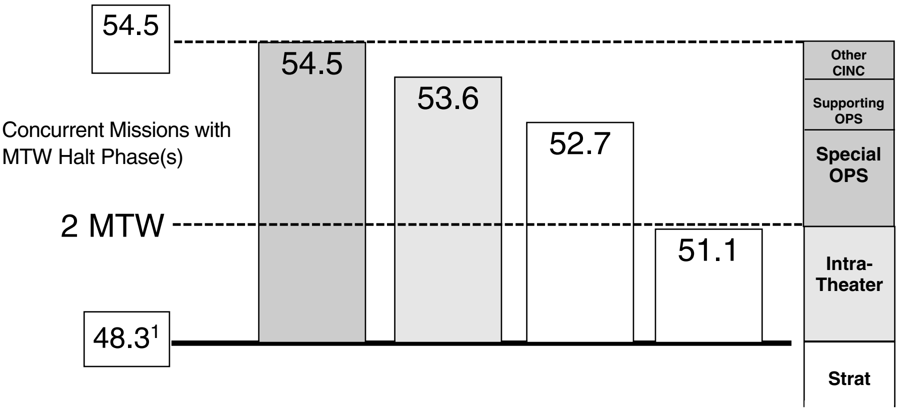
The United States must possess the economic strength to finance that capability. Because core competencies define the USAF's greatest attributes, sufficient airlift forces become imperative for the application of airpower. Defining what constitutes sufficient continues to be difficult.

Airlift Requirements

For more than 20 years, the United States attempted to quantify its airlift needs. The secretary of defense published the *Congressionally Mandated Mobility Study* in 1981, the first of several assessments. It set a strategic airlift objective for the transport of 66 "million ton miles per day" (MTM/D) of cargo to meet the requirements of the unified commanders in addition to published national security and military strategies. The DOD published the *Mobility Requirements Study* (*MRS*) in 1992 after the collapse of the Soviet Union. It set an objective of 57 MTM/D resulting from the NSS mandate to fight two MTWs. In 1995, the DOD published the *Mobility Requirements Study Bottom Up Review Update* (*MRS BURU*) reducing the airlift requirement to 49.7 MTM/D. This study accounted for the contributions of organic airlift, previously unconsidered in the *MRS*, and contracted commercial aircraft known as the CRAF fulfillment. The *MRS BURU* designated a small portion of the airlift requirement (approximately 20.7 MTM/D) for CRAF while the balance was made the responsibility of the USAF.[14]

The most recent *MRS*, known as *MRS-05*, forecast airlift requirements for the year 2005. As a baseline for the study, the DOD established a scenario in which airlifters would transport combat forces to fight and win two MTWs occurring nearly simultaneously.[15] The *MRS-05* attempted to account for some of the factors unconsidered in previous mobility studies by including them in its assumptions. These factors included requirements such as intratheater airlift and special airlift missions flown in excess of those supporting the two MTW scenarios. These refinements approximated actual airlift operations more precisely than previous studies.[16]

The *MRS-05* examined other significant factors previously unconsidered that affected airlift operations. Figure 1 depicts the airlift requirements derived from the *MRS-05* and warrants some explanation. As a minimum, the *MRS-05* required 51.1 MTM/D to prosecute the intratheater movement of equipment from one MTW to another. It required 1.6 MTM/D to support special operations, 0.9 MTM/D to support theater combatant commander requirements and the transport of missile defenses to a combat theater, and 0.9 MTM/D to support theaters not engaged in combat but nonetheless requiring airlift support. This increased the total requirement to 54.5 MTM/D, the established minimum necessary to transport wartime equipment and troops between two theaters of war.



[1]The 48.3 MTM/D figure represents a fleet of 120 C-17s and assumes a 65 percent mission capability rate for the C-5 and a CRAF contribution of 20.5 MTM/D. *MRS-05* did not account for C-141 aircraft capability due to the airlifters' programmed retirement in 2006.

Figure 1. *MRS-05* airlift requirements (Adapted from: Office of the Joint Staff, Mobility Requirements Study 2005 Executive Summary [Washington, D.C.: Deputy Director for Power, Projection, and Sustainment, December 2000], 5.)

Additionally, under other scenarios, *MRS-05* predicted airlift requirements as high as 67.0 MTM/D.[17] The CRAF can feasibly handle 20.5 MTM/D of the requirement, while AMC organic airlift can transport approximately 19.4 MTM/D.[18] Estimates in 2002 set the organic capability at 24.7 MTM/D, thus increasing the combined USAF and CRAF capability to 45.2 MTM/D.[19] Based on a requirement of 54.5 MTM/D, this resulted in a 9.3 MTM/D capability gap, which is 17.1 percent short of required capability. Altogether, these requirements exceeded the capability of US airlift.[20]

Capability Shortfall

This continuing capability gap suggests two things. First, feasible solutions are required to close the gap. If defense planners established realistic assumptions regarding future defense scenarios, capabilities would match requirements. Second, the strategy should reflect the reality that this requirement may be unattainable. Stretching US airlift forces beyond their limits will result in eventual failure to support requirements in accommodation of the strategy. The General Accounting Office (GAO), the independent auditing arm of Congress, addressed the implications of ignoring the shortfall. Realistically, though, the DOD will reduce the gap by increasing capability.

In a 2000 study on air transport capability, the GAO validated what Air Force officials were saying for some time about the state of the airlift fleet.[21] The study maintained the shortfall was not due solely to a lack of capability but to additional factors as well. For instance, from FY97–99, only 55 percent of the C-5 fleet, on average, maintained mission readiness.[22] This implied that merely possessing airlift capacity alone did not guarantee its availability for a crisis or contingency. Other variables affect the mission capability rate: the lack of available aircraft spare parts for the airlift fleet, the amount of time spent undergoing depot maintenance, and the reduction of aircraft resulting from initially procuring only half as many C-17s as retiring C-141s.[23] Cumulatively, the significance of these variables suggests the existing airlift force structure cannot support the NSS and NMS. As the airlift fleet ages, its capability continues to decrease, further fueling the heightened demand for airlift. Table 1 depicts the AMC airlift aircraft mission capability rates as of 2000.

Table 1. AMC airlift aircraft mission capability rates

Mission Capable Rates (percent)			
Aircraft Type	*AMC Standard Wartime Rates*	*FY97–99 Average* Peacetime Rates*	*FY00 Average Peacetime Rates*
C-5	75	55	53
C-17	87.5	66	63
C-141	80	61	68

*Average mission capable rates for the C-5 were based on rates for FY97–99. Average mission capable rates for the C-141 and C-17 were based on fourth quarter FY99 data because these aircraft are in transition to retirement, in the case of the C-141, and increased procurement in the case of the C-17. These rates were computed by dividing the number of aircraft mission capable by the total number of primary mission aircraft.

Adapted from: GAO, Defense Capabilities and Management Division, *Updated Readiness Status of U.S. Air Transport Capability*, GAO Report GAO-01-495R (Washington, D.C.: GAO, 16 March 2001), 10, http://www.aviationtoday.com/reports/air0327.pdf.

The below-standard peacetime rates depicted above, combined with a general shortage of capability, makes it difficult for AMC to fulfill its requirements. Buying more aircraft, in this case C-17s, alleviates the shortfall in the short-term.

Capability Solutions

The extent of the shortfall capability gap depends on the release of a new mobility requirements study. Emerging homeland security requirements further exacerbated the airlift shortage, while the global war on terrorism also had an adverse effect on the shortage.[24] The Joint Staff did not account for either of these factors in the *MRS-05* because they had not occurred. But they remain open-ended commitments that airlift forces must support. Air mobility must develop long-term solutions.[25]

While the DOD looked at some long-term options to resolve the airlift shortfall, the GAO advanced four of its own in a 2000 audit. They were as follows:

1. Do not change current plans and accept associated risks.
2. Decrease requirements by adjusting war plans to allow more time for deploying forces into theater or planning for less than two nearly simultaneous major theater wars.
3. Reduce peacetime operational commitments, thereby limiting the number of airlift . . . flights to the level commensurate with sustaining . . . mission capable standards.
4. Prioritize funding for airlift . . . operations and modernization to . . . levels commensurate with achieving and sustaining the desired capability levels.[26]

The dynamic nature of the strategic environment and US unwillingness to accept unnecessary risk makes option one unrealistic in comparison to options two and four. Option three, like option one, proved to be unrealistic, especially in light of the events that have occurred since 9/11. The *QDR* implemented option two. The DOD and the Air Force, through additional C-17 acquisition and C-5 modernization, pursued option four at great expense.

The quantification of necessary requirements to satisfy the seemingly endless number of operations tasked for airlift forces over the last decade became difficult.[27] The United States expects to become involved in a rising number of military operations other than war, including small-scale contingencies that would call for increased midterm airlift capability.

Existing capabilities fall short of meeting requirements for wartime air transportation. If airlift provides the "foundation of US national security at the strategic level," the DOD must adequately fund it.[28] In lieu of adequate funding, the DOD must adopt cost-effective measures to increase capability and meet the demands and requirements of the unified combatant commanders and the national security and military strategies. By combining the need for increased airlift capacity with the expansion of unmanned aircraft research in new roles and missions for UAVs, unmanned airlift may yield a solution for closing the airlift capability gap. Examining the UAV requirements process illuminates this investigation.

Unmanned Aerial Vehicle Requirements

Until recently, UAV requirements grew out of a demand for persistent, systematic ISR at lower risk to aircraft operators. The demand for UAV systems came primarily from defense users. This demand, in turn, drove requirements and the acquisition of UAV systems. Yet, how does demand for UAVs become a requirement? A researcher who authored a study on the DOD UAV requirements described the process as follows:

> Requirements for UAV system development come directly in the form of an operational requirements document . . . generated by a council [Joint Requirements Oversight Council] that represents all four branches of the armed services: Army, Air Force, Navy, [and] Marine Corps. This document states the overall capabilities required of the system, system performance, mission requirements, logistics for the system, human-system interaction requirements, and inventory objectives. . . . Once the requirements have been established and design standards are provided, the UAV system design [is] initiated. . . . The system requirements are used to drive the systems' design early in the design process to maintain traceability back to the original customers' needs.[29]

This process relies on input from potential users and developed mission needs statement.[30] The acquisition authority processes and approves a reconciled and consolidated input to avoid duplication and then funds UAV production. Figure 2 provides an illustration of the requirements-generation process.[31]

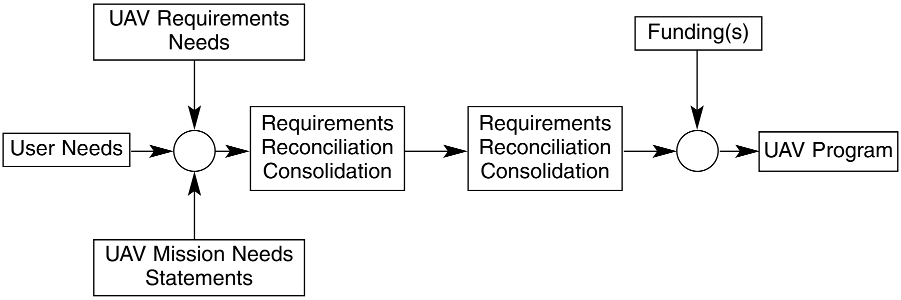


Figure 2. Requirements generation and UAV program development process (Reprinted from: R. Barry Walden, "The Use of Modeling and Simulation in the Systems Engineering of Unmanned Aerial Vehicles," Systems Engineering Project, University of Maryland, A. James Clark, School of Engineering, Fall 1998, http://www.glue.umd.edu/~bwalden/project.html.)

Identifying Unmanned Aerial Vehicle Requirements

Integrated priority lists (IPL) identify UAV requirements within the DOD. Every year, each unified combatant commander prioritizes the war-fighting capability shortfalls of their respective theater. According to the 2001 *UAV Roadmap*, "of the 146 requirements submitted in the combined 1999 IPL for funding in the FY02–07 Future Years Defense Plan, 57 [39 percent] needed capabilities that have previously been associated in some form [a flight demonstration, a technical study, etc.] with UAVs, i.e., requirements that could potentially be filled by using UAVs."[32] Technology provides the primary impetus behind UAV requirements generation.[33] UAV users want them to go "farther, faster, and do more things for low-cost and simplicity."[34] Using available and relevant technologies simplifies the UAV system yet requires a major investment.[35] Technology requires a push to meet users' requirements; however, underestimation of the technological challenges in developing UAV systems becomes a major problem. Technology limitations withstanding, the USAF embarked on a path toward developing and building UCAVs. This developmental methodology makes the most of the risk-eliminating characteristics inherent with UAVs.

As recently as five years ago, many in the defense industry and Congress could not envision unmanned combat systems development and testing continuing for at least a decade into the twenty-first century. Several factors changed that mentality. First, Operation Allied Force confirmed the assumption that unmanned combat aircraft could be practical alternatives to manned fighters after Serbian air defenses shot down an F-117 stealth fighter. In addition, the loss of two Predator unmanned reconnaissance aircraft during the campaign punctuated the need for unmanned systems that could actively defend themselves. Second, advances in robotics, electronics, and miniaturization fueled renewed interest in the possibility of sending armed unmanned combat aircraft into hostilities where risk is unknown or potentially high. Third, Congress felt compelled to respond to increased awareness by their constituents for reduced combat casualties as a result of advances in precision weaponry over the last 15 years. The response from Congress came in the form of initiatives in the FY01 Defense Authorization Bill that steeply increased previously inadequate funding for research and development of unmanned combat systems.

The JCS reviewed requirements for UAV programs in 1984. They determined at that time that sensors, electronics, and vehicle design had sufficiently matured to solve the technical problems plaguing previous efforts.[36] The JCS supported a vision for the advancement of UAV concepts that fueled renewed interest in previously neglected programs. Investments made throughout the 1980s paid dividends during Operation Desert Storm in which UAVs proved they could fill substantial gaps in intelligence. For instance, in its final report on Operation Desert Storm, the DOD noted that "during one mission, a Pioneer [UAV] located three Iraqi artillery battalions, three free-rocket-over-ground launch sites and an antitank battalion . . . [Pioneers] proved excellent at providing an immediately responsive intelligence capability."[37] Today, Air Force operations routinely use UAVs.

Many considerations contributed to the decision to fulfill operational requirements with a UAV. Therefore, deciding whether to fulfill a requirement with UAVs, manned aircraft, or both requires careful consideration of several factors. These include "the scenarios to be encountered, the missions and tasks to accomplish, the alternatives, the relative risks, the relative costs of the tasks and the maturity of the technologies."[38] Each factor weighed against the operational requirement ensures UAVs are the right tool. According to the opinion of the USAF SAB, the right combination of manned and unmanned aircraft platforms emerges after operational validation and use of the aircraft and the associated concepts of operation.[39] It took time to alter an institutional outlook once opposed to replacing pilots with UAVs. A similar acculturation process must take place for unmanned airlift to be accepted and proven feasible.

Determining Requirements for Unmanned Airlift Vehicles

Requirements for unmanned airlift currently do not exist. However, given analysis of the evidence presented herein, it is possible to develop them. Previous examples of reconnaissance UAV and UCAV development are indicative of the evolutionary paths that must be forged to encourage requirements development. For their development to take root, UALVs must prove feasible. Feasibility requires an objective determination of what is technologically possible, which is the topic of the next chapter. Therefore, a legitimate need and justification for UALVs must exist before proceeding.

A 1981 GAO report reflected on the lack of adequate UAV requirements despite the ongoing development of a UAV program when it stated, "The Air Force had an advanced Remotely Piloted Vehicle (RPV) program, but its continuation was not approved by the Congress for fiscal year 1980. We [the GAO] were informed by DOD that the reason the program was canceled was because the Air Force could not come up with the necessary *requirements documentation* [emphasis added] to support further development of the program. The program was at the point in its development cycle where a need or a user had to be identified. None were forthcoming, so the program was terminated."[40] Therefore, a potential user must submit a declared and supported operational requirement for unmanned airlift, to proceed past conceptualization.

Furthermore, for UALVs to be viable candidates for the airlift mission, they must have roughly equivalent capabilities to manned airlifters. Accordingly, UALVs must demonstrate the ability to compete with other systems attempting to meet the same requirement.[41] However, UALVs "will be unable to compete successfully as a system because no RPV [UALV] exists that can be used for comparative purposes."[42] Thus, an interesting paradox develops for UALVs and other emerging unmanned aircraft roles. How does one support an emerging UALV requirement if a prototype does not exist or cannot be built and tested?[43] If UALVs existed and proved themselves feasible, airlift customers might find them particularly useful.

In this vein, Dr. Robert Owen, a retired Air Force officer with wide knowledge of airlift history, hints at the possibility of future aircraft concepts through support to the Army's mission. In one article he wrote, "To support the Army's future Objective Force, AMC and the Air Force are looking at other systems to improve their ability to deliver and support land forces. At the high end of the spectrum, AMC considered an advanced theater transport," an airlifter concept currently being studied by Boeing Phantom Works.[44] Dr. Owen maintains that the Boeing advanced theater transport (ATT) concept is ideal because it would permit the delivery and offload of cargo and equipment to more locations than is now possible.[45] Converting the vehicle to an unmanned platform during development may be advantageous to the Air Force.

Thus far, unmanned airlift has been characterized as a means to close the airlift capability gap, but it also helps in the Air Force shortfall of pilots.

Insufficient Aircrews

The DOD's *UAV Roadmap* IPL analysis concluded that future UAVs should address the shortfall of sufficient aircrews.[46]

While the Air Force invests millions of dollars to train pilots because of a pilot shortage, this analysis served to highlight the point that this money could be invested in unmanned aircraft research and eventually the unmanned aircraft. In time, this would reduce Air Force pilot requirements. Insufficient aircrew, as described here, refers to one of two things: (1) the limitations of human physiology that hamper complete use of the air and space environment and (2) not retaining adequate numbers of pilots to operate manned airlift platforms. This section focuses on the latter.

Mobility pilot retention difficulties over the last few years demonstrate the severity of the aircrew shortfall problem. According to a point paper on mobility pilot retention, AMC leads all USAF major commands in severance rates of eligible pilots, posting an 81 percent severance rate through spring 2001.[47] Unmanned airlift can potentially alleviate this problem without interruption of the conduct of airlift missions through two possible solutions: (1) increase the number of personnel required for the kind of strategy being pursued, which may reduce the length of time personnel are deployed, and (2) increase airlift capacity without significantly increasing the number of personnel required to operate the additional lift. Considering that the economy rises and falls in cycles but the commitment of personnel to the NSS remains static, an unmanned airlift platform which increases capacity yet does not significantly increase personnel requirements may be a sound solution.

Summary

National strategic documents such as the NSS and NMS reflect the important role airlift plays in supporting national strategies. However, a lack of capability to match requirements calls into question their importance. Despite studies setting wartime airlift requirements at unattainable levels, USAF airlift forces always attempted to fulfill them. Fortunately, since World War II, the United States never responded to two MTWs or other operations matching that scale. If so, mobility requirements studies predict moderate levels of risk to forces responding to the crises.

Because AMC airlifters aged faster than programmed after the war on terrorism began in Afghanistan in 2001, the DOD called for additional airlift capacity. Lawmakers responded by funding additional C-17s while considering upgrades to portions of the C-5 fleet. These expensive initiatives could put a severe drain on the defense budget. Cost-efficient alternatives to expensive manned airlift that match capability requirements should be closely studied and proposals forwarded.

Operational requirements do not exist for unmanned airlift. Unmanned airlift must demonstrate the potential to perform the airlift mission as well as, or better than, manned airlifters before it is given serious consideration for augmentation of the manned fleet. The DOD has identified several types of missions as ideal candidates for fulfillment by UAVs, and the list grows. The possibility exists, based on wartime airlift shortages and advances in UAV technology, that unmanned airlifters could some day fulfill these requirements. However, the advantages must outweigh the disadvantages, and the technology must exist or emerge sufficiently to invest the necessary research funding for them.

Notes

1. AMC, *Air Mobility Strategic Plan 2002 Executive Summary.*
2. Ibid.
3. White House Office, *A National Security Strategy for a Global Age*, 1.
4. Ibid., 20.
5. JCS, *National Military Strategy of the United States of America: Shape, Respond, Prepare Now*, 1.
6. Ibid., 5.
7. Ibid., 15.
8. Col Michael Fricano (chief, AMC Studies and Analysis Division), interview by the author, 1 March 2002.
9. Ibid.
10. USTRANSCOM, “Strategic Guidance FY 2002,” 3.
11. Ibid., 4.
12. Ibid., 5.
13. Ibid.
14. GAO, *Military Readiness: Air Transport Capability Falls Short of Requirements*, 27. “Million ton miles per day” (MTM/D) is a measure of airlift capacity that AMC computes using a formula that is the product of the mission aircraft’s available hours per day, the nautical miles per hour, the expected average load, and a factor that accounts for returning empty, and divides this number by a million miles. It represents the fully mobilized

wartime capability of all cargo airlift, including active duty, Air National Guard, Air Force Reserve, and civilian aircraft (Ibid., 9).

15. Office of the Joint Staff, *MRS-05 Executive Summary*, 6.

16. Ibid., 4.

17. Ibid.

18. GAO, *Military Readiness: Updated Readiness Status of U.S. Air Transport Capability*, 11–12. The 19.4 MTM/D figure is based upon the projected military wartime surge capability of the C-5, C-17, and KC-10 only. The figure does not take into account the additive projected wartime surge capability of the C-141, 4.0 MTM/D, due to the fact *MRS-05* did not; however, it does account for the KC-10 additive capability of 3.0 MTM/D since *MRS-05* did account for its limited cargo contributions.

19. Ibid., 12; and AMC Studies and Analysis Division, in discussion with the author, June 2002. As of June 2002, combined CRAF and AMC organic airlift capability was 45.2 MTM/D. The increased capability resulted from the addition of C-17s coming off the assembly line. AMC's purchase of 60 additional C-17s beyond the 120 previously contracted added another 6.7 MTM/D for a forecasted total of 51.9 MTM/D. This number still falls short of the 54.5 called for in *MRS-05*.

20. AMC Studies and Analysis Division, in discussion with the author, March 2002.

21. GAO, *Air Transport Capability Falls Short of Requirements*, 50.

22. Ibid., 5.

23. Ibid., 9.

24. Wolfe, "Air Force Seeks to Allay Concerns of DOD, Hill on Multiyear Financing for C-17s," 4, and Wall, "Pentagon Scrubs Airlift Needs for Homeland Defense, War Effort," 62.

25. Ibid.

26. GAO, *Air Transport Capability Falls Short of Requirements*, 18–19.

27. Ibid.

28. Air Force Doctrine Document (AFDD) 2-1, *Air Warfare*, 17.

29. Walden, "The Use of Modeling and Simulation," par. 1.0.

30. GAO, *Report to Congress: DOD's Use of Remotely Piloted Vehicle Technology Offers Opportunities For Saving Lives And Dollars*, 15. The mission needs statement is a document used within the DOD to justify new major weapon system acquisition. It identifies the mission and states an operational requirement in terms of the mission or task to be performed rather than in terms of the capabilities or characteristics of the weapon system.

31. Walden, "The Use of Modeling and Simulation," par. 1.0.

32. Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000–2025*, 13. Hereafter cited as *UAV Roadmap* in this set of notes.

33. Walden, "The Use of Modeling and Simulation," par. 1.0.

34. Ibid.

35. Ibid.

36. Kosiak and Heeter, "Unmanned Aerial Vehicles: Current Plans and Prospects for the Future," 3.

37. Ibid.

38. USAF SAB, *UAV Technologies and Combat Operations*, vol. 1, *Summary*, par. 2-2.

39. Ibid.

40. GAO, *DOD's Use of Remotely Piloted Vehicle Technology Offers Opportunities For Saving Lives and Dollars*, 12.

41. Ibid., 15.

42. Ibid.

43. This topic is addressed in chapter 5 when UAV acquisition programs are examined in detail.

44. Owen and Fogle, "Air Mobility Command and the Objective Force: A Case for Cooperative Revolution," 16.

45. Ibid.

46. *UAV Roadmap*, 41.

47. Capt Angela Slagel, "Point Paper on Mobility Pilot Retention."

Chapter 4

Technological Feasibility

> *In the development of air power, one has to look ahead and not backward and figure out what is going to happen, not too much what has happened.*
>
> —William Mitchell

During the late 1980s and the 1990s, the United States made enormous advances in unmanned aircraft technology. These advancements proceeded considerably faster than expected, partly because of the demand for UAVs from commanders. Nevertheless, one must ask if future UAV capabilities will be sufficiently well-developed to support the airlift mission? This chapter investigates that question.

A brief history of UAV developments provides the context for the development and administration of past and current UAV programs while also serving as a baseline for future unmanned aircraft development and administration. This chapter examines several unmanned aircraft measures of merit deemed essential to the success of unmanned airlift to determine technological feasibility. This examination applies standard DOD UAV feasibility criteria to each measure of merit to establish a technological foundation for unmanned airlift. Furthermore, it makes a reasonable prognosis of development for the next 20 years for each measure of merit to determine unmanned airlift feasibility. The analysis covers additional UALV considerations pertinent to the successful development of UALVs. This includes J-UCAS development practices construed as potential developmental templates for future UALV development. The chapter concludes with a breakdown of technological feasibility challenges and a table that summarizes the evaluation of each measure of merit.

Brief History of Unmanned Aerial Vehicle Development

Unmanned flight existed in some form or another for centuries. For example, 2,000 years ago in China, kites soared into the sky controlled by a string and essentially functioned as remotely controlled vehicles.[1] More recently US armed forces achieved unmanned flight with varying degrees of success in World War I, World War II, the Vietnam War, and Operation Desert Storm. Different types of UAVs exist, and their diversity becomes important in terms of the discussion on UALVs.

Classes of vehicles that operate without a human aboard include cruise missiles, guided missiles, drones, RPVs, and UAVs. RPV (an older, rarely used term) and UAV are interchangeable. The mission of these vehicles determines if they are expendable or recoverable. Expendable vehicles used for the purpose of destruction include cruise and guided missiles, though many Airmen consider drones recoverable vehicles. Michael Armitage, author of *Unmanned Aircraft*, makes the following succinct distinction between drones and RPVs/ UAVs: "A drone can best be described as an autonomous and automatic pilotless aircraft. It will carry at least a mechanism to sustain stable flight, and it will . . . fly an uncorrected steady heading, in which case its only utility is likely to be as a target. . . . An RPV, a pilotless aircraft, transmits mission related data to a remote controller and reacts to their commands as well as to other control inputs."[2] There are four categories of recoverable UAVs: tactical reconnaissance vehicles, strategic reconnaissance vehicles, target drones, and UCAVs.[3]

Wars of the last century witnessed the use of UAVs in varying degrees over the battlefield. During World War I, the US Army Air Service experimented with an unmanned drone called the Kettering Bug. It could carry 182 pounds of explosives 40 miles at a speed of 55 miles per hour.[4] The army cancelled the program, after completing eight of 36 scheduled flights, due to a series of failed tests.[5] During World War II, the US Army Air Forces attempted a small number of glide bomb missions by converting worn-out B-17s and B-24s into primitive cruise missiles.[6] During the Vietnam War, the Pentagon deployed UAVs called Lightning Bugs over North Vietnam and Southeast China to reduce pilot losses.[7] In 1964 the United States deployed UAVs called Firebees for surveillance and reconnaissance gathering in Vietnam. Although the Firebees enjoyed moderate success and a loss rate of only 4 percent, the DOD terminated the program a few years after the war ended.[8]

They decided that the Firebee's mission to perform tactical unmanned reconnaissance no longer existed.

Beginning with the Persian Gulf War in 1991, the US military used UAVs primarily for reconnaissance, surveillance, and attacks against fixed ground targets. Operation Desert Storm offered the first successful large-scale use of reconnaissance UAVs. The Marine Corps operated Pioneer, the principal UAV employed in Desert Storm. Six Pioneer units deployed with approximately 30 aircraft: three with Marine ground units, one with the Army, and two on Navy warships. Antiaircraft artillery fire destroyed two Pioneers and five perished due to noncombat causes.[9]

Current Unmanned Aerial Vehicle Programs

The DOD currently operates three operational and three developmental UAV programs. Operational UAVs include Pioneer, Predator, and Hunter. Developmental UAVs consist of Global Hawk, Fire Scout, and Shadow 200. Table 2 provides a summarized history of recent UAV programs.

Table 2. Summary history of recent unmanned aerial vehicle programs

System	Manufacturer	Lead Service	First Flight	IOC	No. Built	No. in Inventory	Status
RQ-1/ Predator	General Atomics	Air Force	1994	2001	54	15	87 ordered
RQ-2/ Pioneer	Pioneer UAVs Inc.	Navy	1985	1996	175	25	Sunset system
BQM-145	Teledyne Ryan	Navy	1992	n/a	6	0	Cancelled 1993
RQ-3/ Dark Star	Lockheed Martin	Air Force	1996	n/a	3	0	Cancelled 1999
RQ-4/ Global Hawk	Northrop Grumman	Air Force	1998	2005	5	0	In E & MD*
RQ-5/ Hunter	IAI/TRW	Army	1991	n/a	72	42	Sunset system
Outrider	Alliant Tech systems	Army	1997	n/a	19	0	Cancelled 1999
RQ-7/ Shadow	AAI	Army	1991	2003	8	0	176 planned
Fire Scout	Northrop Grumman	Navy	1999	2003	1	0	75 planned

*Engineering and Manufacturing Development

Reprinted from: Office of the Secretary of Defense, Unmanned Aerial Vehicles Roadmap 2000–2025 (Washington, D.C.: Office of the Secretary of Defense, April 2001), 6, http://www.acq.osd.mil/usd/uav_roadmap.pdf.

Pioneer

For over 17 years, the Army, Navy, and Marine Corps deployed the Pioneer system aboard ships and ashore to provide valuable reconnaissance and surveillance for up to four hours with a 75-pound payload of sensors. After the success of Pioneer in Operation Desert Storm, the RQ-1 Predator joined the fleet and provided real-time imagery of Bosnia for the North Atlantic Treaty Organization (NATO) peacekeeping forces.[10]

Predator

Predator performs a variety of functions for reconnaissance and surveillance missions. Equipped with an electro-optical/infrared (EO/IR) sensor and a synthetic aperture radar (SAR), it gives forces a day/night all-weather reconnaissance capability. The Air Force anticipates using Predators for an extended period of time.[11] In addition to the much-employed Pioneer and Predator platforms acquired by the Navy and Air Force, respectively, the Army developed the Hunter UAV.[12]

Hunter

The Hunter UAV system is particularly noteworthy among existing unmanned ISR platforms. It has a day/night mission of ISR and target acquisition for corps commanders.[13] Although Hunter performed to standards, it encountered technical problems. Its software data-link capabilities and engines suffered from technical defects too expensive to fix.[14] Despite production cancellation in 1996, the Army acquired seven low-rate initial production systems of eight aircraft each; presently, four of the systems remain in service.[15]

Global Hawk

Global Hawk is a high-altitude, long-endurance surveillance and reconnaissance UAV, with a wingspan of over 116 feet and endurance exceeding 36 hours. Like Predator, it carries an EO/IR sensor and SAR, but it also contains a moving-target indicator. Until it achieves Initial Operational Capability (IOC), Global Hawk remains a developmental program. The Air Force expects IOC by FY05.[16]

In addition to the current and developmental UAV programs under the administration of the DOD, the Defense Advanced Research Projects Agency (DARPA), the primary research organization for advanced DOD projects, sponsors five innovative programs for introduction before 2010. Among them was the Air Force's UCAV, dubbed the X-45, designed for the suppression of enemy air defenses (SEAD) role. In October 2003, the Air Force's program merged with the Navy's UCAV-N program and became the J-UCAS under DARPA leadership.

Promoting Unmanned Aerial Vehicle Development

When this paper was written, the following three organizations managed the DOD's UAV programs including their cross-service oversight responsibilities:

1. Undersecretary of Defense for Acquisition, Technology and Logistics: acquisition and technology oversight;
2. Assistant Secretary of Defense for Command, Control, Communications, and Intelligence: policy, interoperability standards, and ISR systems oversight; and
3. JCS/Joint Requirements Oversight Council: Unified Combatant Commander priorities evaluation and requirements formulation.[17]

From 1993 to 1998, the Defense Airborne Reconnaissance Office served as the single focal point for UAV administration.[18]

Although Congress generally provides support for the DOD's UAV programs, it exercises extensive oversight, reflecting concerns and differences within the DOD over the cost, speed, and direction of UAV programs.[19] During testing of the Army's Aquila UAV program in 1987, the vehicle "was only able to successfully meet mission requirements on 7 of 105 flights."[20] Testing failures were not conducive to fostering the support needed to investigate new and viable roles and missions for UAVs. Due to escalating requirements, high costs, and technical difficulties, Congress cancelled the Army's Aquila UAV program in 1987, then directed the DOD to establish a centralized

UAV program. The DOD created the Joint Program Office for Unmanned Aerial Vehicles (JPO-UAV).

In 1988 Congress acted to prevent further UAV program failures. Specifically, the FY88 Continuing Appropriations Act required the DOD to submit a UAV master plan for execution under centralized direction. The act stipulated that "the conferees agreed to eliminate funding within the services' separate RDT&E [research, development, training and evaluation] accounts for individual RPV[s], and to consolidate these efforts in a Joint RPV program."[21]In other words, the act legislated inter-service coordination in the UAV developmental process.

In implementing the act, the DOD organized the JPO-UAV under the auspices of the Naval Air Systems Command (NAVAIR SYSCOM) to simplify all services' UAV developmental efforts.[22] The goal of the JPO-UAV was to incorporate as much commercial technology as practicable to foster development of UAVs while shortening the fielding time for UAV operational employment.[23] By this method, DOD leaders hoped to avoid "duplication of effort, provide joint development to ensure interoperability and interchangeability to the maximum extent possible, and . . . expedite the fielding of operational systems to the services."[24] However, the enormous expansion of UAVs eventually became too much for the JPO-UAV to manage. Therefore, strong, independent organizations within the DOD and JCS came to administer the current UAV oversight structure, which seemed adequate for fostering UAV development programs.

In summary, UAVs existed in some form or another for thousands of years. The United States employed UAVs with varying degrees of success in a variety of roles since World War I. Current and past UAV programs provided mixed results in efforts to perfect the technology that inevitably drives their design. Developmental programs show promise as efforts to improve Predator and Global Hawk and accelerate testing of the J-UCAS continue.

Evaluating Unmanned Aerial Vehicle Technological Feasibility

According to the DOD *UAV Roadmap*, "before acceptance and use of UAVs can be expected to expand, advances must occur in three general areas: reliability, survivability, and autonomy. All of these attributes hinge on technology."[25] These criteria determine the success of any future UAV program and will act as a starting point for analysis; however, they require other input for the successful employment of UALVs. Table 3 summarizes the evaluation of each measure of merit and technological consideration. The rest of this chapter analyzes each measure of merit and determines if it offers sufficient reliability, survivability, and autonomy with respect to UALVs. Table 3 also provides a determination of the technological feasibility of UALVs for the Air Force based on this analysis.

Table 3. Evaluation of essential unmanned airlift vehicle measures of merit and concepts

Measure of Merit or Concept	**Projected Availability***			**R, S, A ****	**Remarks**
	Short-term FY02–12	*Midterm FY12–22*	*Long-term FY22–32*		
Airspace Management	X			A, R	Assumes UALVs in formation with a manned airlifter. Otherwise, capability not available until midterm to long-term
Payload Capacity	X				100,000 to 160,000 pounds recommended
Automated Cargo Handling Systems		X		A, R	For use in the cargo aerial delivery/airdrop mission
Range		X		R, A	Dependent to some degree on automated aerial refueling capabilities and procedures
C3I Systems	X				Quickly emerging
Command Directed Control	X			A, R	Difficult to do remotely—depends on degree of autonomy required
Man-in-the-Loop Control	X			A, R	Depends on proximity/span of control desired
Bandwidth and Data Link	X			R, A	UALVs require less if deployed as a constellation
Artificial Intelligence		X		A, R	Depends on level of autonomy desired for neural networks
Navigation Systems		X		R, A	Require improvements to enhance command directed control

Table 3. continued

Measure of Merit or Concept	Projected Availability*			R, S, A **	Remarks
	Short-term FY02–12	*Midterm FY12–22*	*Long-term FY22–32*		
Counter-GPS Jammers		X		R, A	Must detect and defeat adversary capabilities
Point-of-Use Airdrop		X		R	Requires better precision navigation than currently available for airdrop guidance
Automated Approach and Landing	X			A, R, S	Joint Precision Approach and Landing System (JPALS)—currently in active test
Defensive Systems	X				Quickly emerging
Infrared Countermeasures (LAIRCM)	X			S, R, A	Currently inadequate, but quickly emerging, for defense of UALVs
Countermeasures dispense sets (CMDS)	X			S, R, A	Currently inadequate, but quickly emerging, for defense of UALVs
System Redundancy	X			R, S, A	Double redundancy is required
Simulation	X			R	Primary training tool
Mishap Rates		X		R, S	Should sufficiently decrease as UAV technology advances and experience increases

*Represents a prognosis of each measure of merit or concept in which a minimum acceptable capability is required to begin development of an unmanned airlift vehicle program.

**R, S, and A represent the technological feasibility criteria of reliability, survivability, and autonomy each measure of merit or concept satisfies.

Reliability, Survivability, and Autonomy

A number of factors determine the reliability of a system. According to the *UAV Roadmap*, reliability is "a product of technology and training" and a vital part of increased UAV mission availability.[26] Primarily, the designing of reliability enhancements into UAVs involves trade-offs between a minimum level of redundancy and costs. Components installed on UAVs may not necessarily be appropriate for use in manned aircraft because of less-than-thorough testing with humans but must be sufficiently reliable for mission accomplishment. Determining the proper level of reliability for UAVs challenges their designers.

Survivability generally refers to an unmanned vehicle's ability to depart on a mission, complete it, and land safely.[27] Survivability is a product of tactics and technology in which aircraft defensive systems play an important role.[28] The *Basic Aerospace Doctrine of the US Air Force*, published in 1992, states that "logistics capabilities must be designed to survive and operate under attack; that is, they must be designed for combat effectiveness, not peacetime efficiency."[29] This remains true today as existing USAF airlifters incorporate state-of-the-art defensive systems for self-protection. For UALVs in the absence of a human operator, defensive actions, such as rapid maneuvering to avoid enemy fire, should be automated to aid in vehicle survivability.

Autonomy refers to an unmanned system's ability to function independently. UALVs should have enough self-sufficiency to permit mission accomplishment. Autonomy depends on jam-proof navigation and communication systems to facilitate mission completion and automated decision logic capable of performing routine operator functions requiring minimum operator input.

The degree of control humans will have in future UAV operations must be determined. Their primary limitation is the number of parameters they can attend to, as well as the speed they control them; nevertheless, they have unique cognitive skills that cannot be duplicated by machines.[30]Man will likely want to exercise tight control over UAVs, but to what degree is the question? How much autonomy should UALVs give up for the accomplishment of their mission? The answer depends almost entirely on the available technology, its feasibility for use, and the defined relationship between the vehicle and man in the conduct of unmanned airlift missions.

A USAF SAB study determined that the level of human involvement in the design of UAVs tends to be forgotten by UAV developers and users. The study concluded that in many cases they minimized the importance of the human operators, assuming that most of the UAV functions would be automated. However, the study's authors suggested that rather than being minimized, man's role in unmanned aircraft operations would increase and perhaps be more important because of automation. The authors summarized their position regarding man's role when they stated, "The human is not replaced by automation but is freed from simple and boring tasks to accomplish those functions most suited to human intellect"; however, the simple and boring tasks accomplished by humans may be beyond the capacity of UAVs to perform.[31]It is easy to overlook the human-machine interface given UAV technology's progression because complex machines such as unmanned aircraft rely on advanced engineering concepts still in early stages of development.

In short, when designing the technology for the man-machine interface of UALVs, users must determine how much autonomy the vehicle will require. The strategic airlift environment relies on pilots to perform complex tasks not yet possible with automated systems, like monitoring navigational aid outages and responding to airfield restrictions and Notices to Airmen.[32] If requirements existed for machines to perform these functions, algorithms could be designed to assimilate and apply this information as required. If UALVs fly in formation, as this thesis advocates, the aircrew of the manned airlifter would handle these functions.

"Airlift 2025"

Before examining the various technologies and measures of merit, it is worthwhile to mention the work of a 1996 USAF-sponsored study to chart a path for airlift's future. The study's authors examined desired airlift attributes for the year 2025 and sought to stimulate thinking on the structure of airlift forces in response to forecast airlift missions in 2025. The study, dubbed "Airlift 2025," investigated future airlift technologies based on the predicted national security environment in 2025, available technologies at the time the study was written, and emerging technologies likely available by 2025.[33]

It is important to note that when Air Force Chief of Staff Gen Ronald Fogleman commissioned the "Airlift 2025" study, power projection was an important facet of US national security. Recognizing airlift's role in national security, he realized that future airlift capabilities should be developed through concepts and ideas of employment that ensured greater viability. Several interesting ideas and capabilities from the study are worth noting: cargo payload size, point-of-use delivery and extraction, long unrefueled vehicle range, total resource visibility, intermodality, modularity, interoperability, responsiveness, and cost. The study concluded that meeting national objectives forecast for 2025 required all of these capabilities.[34] However, while unmanned airlift developers should regard these capability characteristics in future designs, they should not consider them necessary for UALVs.

Unmanned Airlift Measures Of Merit

There are several measures of merit vital to the technological feasibility of unmanned airlifters. The following sections evaluate the most important of these measures including payload capacity; range; command, control, communication, and information systems; navigation systems; and defensive systems. At the end of each section, an evaluation of development for unmanned airlift of each measure of merit determines its technological feasibility. Table 3 sums up these results, providing a total technological feasibility estimate.

First, this evaluation requires an examination of UAV airspace management. UAV airspace issues affect all UAVs; therefore, the progress made in managing airspace will have significant impact on the design of future UAVs. The following section provides the conceptual employment foundation for UALVs to evaluate their successive measures of merit.

Unmanned Aerial Vehicle Airspace Management Considerations

The integration of manned and unmanned aircraft into the same airspace is one of the most difficult technological hurdles for UAV operations. Currently, the Federal Aviation Administration (FAA) in the United States and its international counterpart, the International Civil Aviation Organization (ICAO), make plans to integrate the increasing number of UAVs into the airspace. A School of Advanced Airpower Studies thesis on the subject made the following observation with regard to UAV airspace management difficulties: "The issue of airspace management and deconfliction is key to successful operation in civil and military environments, so appropriate approaches to airspace deconfliction are essential. . . . At this time, little thinking, planning, or action to develop agreements, rules, and procedures have been accomplished."[35]

The United States is starting to consider solutions regarding the difficulties associated with airspace management. The *UAV Roadmap* prescribes actions US airspace managers must consider to facilitate integration; therefore, "standards must be established to allow UAVs to operate flexibly within the National Airspace System (NAS), even for high altitude missions involving flight above all civil traffic, because UAVs reach such altitudes only after climbing through potentially crowded airspace. These transits through the NAS while en route from Continental United States (CONUS) bases to overseas operating areas, like that performed by Global Hawk (Florida to Portugal for NATO's Linked Seas exercise in May 2000), will become increasingly common. Emergency/weather diversion through the NAS into [*sic*] alternate en route airfields will eventually occur."[36] Authorities must develop and implement potential solutions in a way that does not disrupt civil aviation safety and operations.[37]

As UAV use expands, inevitably these vehicles will operate in the same airspace as manned aircraft, and the safety of the people aboard manned aircraft remains the greatest concern. Currently, UAVs operate in restricted airspace independent of civil traffic "with significant advanced written notification that can be widely disseminated."[38] They are accorded time and space via specifically designated airspace such as special corridors and restricted operational zones.[39] Yet, with UAVs like the J-UCAS joining the fight, cooperation and integration with manned aircraft and new methods of integration must evolve. The DOD recognized the complexity of this issue well before the widespread use of ISR UAVs in Operation Allied Force. The Joint Doctrine Division, J-7 Operational Plans and Interoperability

Directorate of the CJCS expressed the military's policy in a joint publication that states "UAV operations must be coordinated with the airspace control authority to provide safe separation of UAVs and manned aircraft and to prevent engagement by friendly air defense systems."[40] If UAVs self-deploy overseas to participate in exercises or to go to war, coordination with the FAA and ICAO, as applicable, must overcome significant technological challenges.[41] Overcoming these challenges will be the key to the widespread use of UAVs in other roles and missions. Although the United States fields an armada of UAVs that can perform nearly every role and mission of the Air Force, it means little if the support infrastructure is incapable of integrating UAVs with manned aircraft.

Therefore, UALVs must operate in a manner that optimizes their performance. The *UAV Roadmap* states that "this positioning will range from station keeping in wide spread constellations to close formation with other UAVs and/or manned aircraft."[42] Optimally, the best positioning must balance bandwidth and data-link requirements with safety and survivability of the formation. Formations of UALVs linked with a single manned "mother ship" airlifter would greatly mitigate airspace management issues while reducing the vulnerability of communication and command and control links. The Air Force UAV Battlelab at Eglin Air Force Base, Florida, conducted experiments testing the feasibility of UAV formation flight and successfully applied the use of a traffic collision and avoidance system (TCAS) "to better integrate manned and unmanned flight operations."[43] However, this is but the first step of a program that must go beyond using TCAS as a synchronization measure.

So far, this examination of airspace management has focused primarily on US efforts. However, these UALVs will actively operate in territories throughout the world. Therefore, actions initiated by ICAO nation airspace managers are of consequence to the United States. For instance, European airspace managers made a serious effort to ensure safe UAV operations on the continent, including airspace integration policies mirroring the FAA's. J-UCAS integration test trials in European airspace continue and "will evaluate whether UCAVs [now J-UCAS] and

UAVs can be certified to operate safely alongside manned aircraft in Europe's crowded skies."[44]

A potential solution to unmanned airspace management difficulties may be near. The National Aeronautics and Space Administration and the FAA developed a program called the Small Aircraft Transportation System (SATS) that "will help provide a path toward seamless UAV operation" with manned aircraft.[45] SATS will function to provide integration of the currently disparate communication, navigation, and surveillance measures employed by manned aircraft, thereby moving closer to autonomous aircraft operations in restricted airspace.

In summation, current airspace management efforts prove less than optimal for autonomous UAV users. Although countries allocate airspace for UAV operations, this comes at the expense of employment flexibility and limits the potential for new UAV roles and missions. Safety becomes the most important factor when determining how to integrate unmanned aircraft into manned airspace, and integration is the primary objective when J-UCAS operates among manned aircraft. Airspace synchronization methods must be reliable and permit safe and survivable operations for all airspace users. Therefore, without accurate projections available for the implementation of the foregoing airspace initiatives, the author advocates employing UALVs in formations with a manned "mother ship" airlifter that can monitor in-flight progress while also assuming responsibility for flight following and in-flight separation with other aircraft.

Payload Capacity

The number one factor affecting UALV design and development will be the capability to transport sufficient quantities of cargo to offset wartime airlift requirements. To maximize flexibility, UALVs require the capability to transport palletized cargo, oversized and outsized cargo loads, and rolling stock exceeding the size of standard aircraft pallets. At the present time, only the C-5 and C-17 possess the capability to transport bulky outsize cargo—a critical US requirement for airlift. To be an effective complement to manned strategic airlifters, UALVs should be able to transport cargo a sufficient distance that minimizes their dependence on ground and in-flight aerial refueling. An effective payload of between 100,000 and 160,000 pounds strikes a balance between adequate capacity and vehicle size necessary to operate at a wide range of airfields while sufficiently meeting requirements to transport oversize and outsize cargo.[46] With a smaller payload capacity, the vehicle risks the inability to transport bulky oversized cargo, a requirement of any future airlifter, and a larger payload capacity risks denied access to a greater number of airfields due to landing weight restrictions.[47] No known technological barriers exist that prohibit the designing of an unmanned airlifter fuselage to accommodate the stated capacity requirements. However, autonomous cargo handling capability required for aerial delivery of cargo depends on the evolution of this emerging technology.

The degree of autonomy in cargo handling systems for UALVs also depends on their intended function. For example, if employed in formation with manned aircraft, the cargo handling system does not have to be completely autonomous. Conversely, those employed independently of manned aircraft require a higher degree of autonomy. In addition, if UALVs employed exclusively in major hub regions where logistics support is extensive, cargo-handling systems do not need to be automated; however, those employed to low-support regions require highly automated cargo handling systems (ACHS).[48] The technological feasibility of ACHSs capable of in-flight internal movement of cargo containers and equipment requires a system to maintain vehicle center-of-gravity within structural airframe limits. This system may also assist in optimizing cargo on/off-loading at the destination, thereby reducing the number of loading and unloading personnel required.[49]

One currently available ACHS employs a roller system that hydraulically maneuvers palletized cargo within the fuselage. This system uses a conveyor belt to move cargo back and forth on the cargo floor and a hook device that assists in securing cargo to the floor. This system will work with rollers and a conveyor belt to control movement of cargo in and out of the aircraft.[50] Other ACHS designs, in various stages of development, may offer greater degrees of autonomy for the airdrop mission.[51] If UALVs require automated cargo handling systems in fulfillment of aerial delivery missions, the technology must continue to mature, which will result in greater vehicle viability. Reliable, semiautonomous cargo handling systems should be available for aerial delivery use in the short-term to midterm depending on the degree of autonomy required.

Range

Sufficient range becomes another developmental factor of great importance for strategic UALVs. The conflicts that involved US forces over the past decade stretched the US airlift system. Additionally, tanker aircraft required to support the movement of airlifters remain in short supply, signifying the need for additional tankers in the US fleet. To reduce the dependency on tankers, any future airlift aircraft should possess sufficient range to conduct global operations with minimal dependency on these scarce resources. However, to increase flexibility of use, UALVs should incorporate an automatic in-flight air refueling capability with feasible procedures of employment.[52] If wars of the future follow previous conflicts in the war on terrorism, as in Afghanistan, air-refueling tankers will remain an essential part of the equation. In Afghanistan, every mission in the early stages of the war required air refueling.[53]

The USAF SAB advocated greater airlifter range requirements in its 1996 study in response to capabilities not available without aerial refueling. The authors of the study observed that a radius of 6,000 nautical miles (nm) ensured that most populated regions of the world could be reached from CONUS basing without relying on tanker aircraft support.[54] However, a radius of this magnitude requires more fuel on board the vehicle, which in turn would decrease the available payload capacity. To put this 6,000 nm radius in perspective, existing strategic airlifters, like the C-5, the USAF's largest cargo aircraft, possess an unrefueled range of approximately 2,650 nm while transporting its maximum payload of 270,000 pounds.[55] By comparison, the smaller C-17 possesses an unrefueled range of approximately 2,400 nm while transporting a payload of 160,000 pounds.[56] The authors of the SAB study also observed that "a smaller 3,000 nm radius allows nearly worldwide coverage from four politically secure bases (Roosevelt Roads, Mildenhall, Diego Garcia, and Guam)," while a "1,000 nm radius is sufficient for most in-theater sanctuary operations."[57] Therefore, strategic UALVs should possess an unrefueled range of 3,000 nm or greater. This figure is sufficient and feasible given designs of existing long-range cargo aircraft and strategic airlifter intermediate stage basing. The closer the radius approaches 6,000 nm, the greater the dependence on in-flight aerial refueling or ground refueling at en route locations. According to one study on air mobility, "a reduced requirement for aerial refueling of airlifters will free up tanker assets for other missions already in demand," while "a reduced requirement for en route refueling will alleviate the bottlenecks prevalent in AMC's en route infrastructure."[58] If possible, UALVs should incorporate receiver aerial refueling capability for maximum flexibility and extended operational range.[59] In case automated air refueling technology does not sufficiently mature to incorporate into UALVs, consideration should be given to increasing their range.

Command, Control, Communication, and Information Systems

Command, control, communication, and information (C3I) systems permit human command and control of UAVs. Communication requirements for UAVs in use today include the need to exercise command and control and to exchange payload (e.g., synthetic aperture radar and EO data). Existing methods of UAV command and control consist of satellite-dependent radio frequency (RF) communication links using bandwidth as conduits. For example, in the near future UAV command and control capability will be embodied in the J-UCAS.

Effective command and control will be sine qua non for J-UCAS operations. Command-directed systems, also known as preprogrammed or autonomous systems, rely on instructions and decision tree logic to execute the mission. This makes command-directed systems ideal for boring and low-risk missions. Its shortcomings in emergencies or fast-changing combat environments in which the decision logic software is not resident within the vehicle's avionics suite make it unsuitable in these situations.[60] Because of the unique aspects of the

SEAD mission, J-UCAS decision-making logic will be the most complex system of its kind.

Although autonomous operations remain the command and control goal for J-UCAS, they require some degree of man-in-the-loop (MITL) capability due to the complex decisions to be made by the operator to avoid defenses, attack targets, and immediately make corrections to flight path.[61] Global Hawk employs a hybrid (operator controlled and autonomously controlled) UAV C2 system that allows for limited dynamic retasking in flight. The MITL system that controls Predator requires operator involvement in nearly all aspects of the operation from mission planning through engine start, taxi-out, takeoff, mission execution, landing, taxi-in, and shutdown. Although MITL control allows for more flexibility, especially if mission parameters change during flight, it is labor-intensive and invites mistakes.

For instance, during the conduct of a Predator mission, its operator must continuously make decisions regarding its operation. The operator acquires minimal situational awareness with respect to the vehicle's external environment, making the task difficult. Furthermore, the feedback mechanisms on the UAV do not provide the operator with situational cues normally perceived by an aircrew aboard an aircraft. The situation intensifies if the operator is unaware of potential threats such as terrain, weather, ground fire, or enemy aircraft.

UALVs, in contrast, would require less sophisticated decision logic than J-UCAS. Airlift missions do not face the array of threats associated with the SEAD mission; however, if UALVs unexpectedly encounter threats, their decision logic must be able to recognize them and take appropriate corrective action. Under these circumstances, manned airlifters normally retrograde, and/or maneuver rapidly in all flight axes to evade the threat. Additionally, UALVs will not be employed to receive and send bandwidth-consuming imagery like ISR UAVs; therefore, they should require less bandwidth than existing ISR UAVs.[62] Operating UALVs independently of manned airlifters requires the same connectivity to command and control agencies on a one-for-one basis as currently performed by existing UAVs. Employing UALVs in formations with manned aircraft decreases bandwidth requirements, as only the manned airlifter in the formation needs to have long-range connectivity with a controlling agency. The unmanned airlifters only need "local" connectivity with the manned airlifter that monitors and controls its actions.

When designing and developing C3I for UALVs, engineers must consider the degree of control operators will possess over the vehicles. The UAVs reliance on sensors and data-links for the transfer of information makes them susceptible to jamming. Operators may lack the bandwidth necessary to conduct safe operations if controlling numerous UAVs simultaneously.[63] According to one Air University research paper, "data-link or radio controlled transmissions create a vulnerability. An adversary could jam or engage these signals, take command of the aircraft, or at least intercept the downlink."[64] Therefore, counterjamming technology development becomes essential. The loss of the electronic link that controls their movements remains a serious vulnerability. Currently, the United States employs protective measures against the intrusion of data broadcast from its Global Hawk and Predator UAVs, but as adversary capabilities to intercept or jam these data links improve, they require new protective solutions.

One new, inexpensive, and innovative data-link technology offers increased bandwidth capability while also providing better communications security. According to the *UAV Roadmap,* the US Naval Research Laboratory "demonstrated an IR [infrared] laser data-link using a multiple quantum well (MQW). . . . In the MQW concept, the UAV carries no communications systems at all. . . . Rather, the ground station provides this via a laser beam focused on a spherical array of voltage modulated polymer panels" located on the UAV's exterior. Its range, limited to only a few kilometers, presents the major disadvantage to the MQW technology.[65] As a substitute for the ground station providing the laser beam, a manned airlifter in formation with UALVs could perform this function and provide the necessary communications.

The solution to the effects of RF congestion could reside in several new and potentially revolutionary technologies in various stages of development. According to the *UAV Roadmap,*

> the key trend in . . . future airborne communication systems is increasing data rates . . . primarily brought on by migration towards higher RFs and the emerging dominance of optical over RF systems. Optical systems are laser-based systems, which will offer data rates two to three orders of magnitude greater than those of the best future RF systems. The advantages of optical communication were demonstrated in 1996 when a ground-based laser communications (lasercom) system provided rates of 1.1 terabits/second (Tbps) at over 80 nm range. Airborne . . . Tbps lasercom systems will certainly be possible by 2025. . . . [Until then] both RF and optical technology development will continue to progress out to 2025.[66]

Basically, C3I systems relinquish more autonomy to command and control UALVs, which reduces the ability of current technologies to accommodate them. If a human controls every UALV action, MITL technologies will become adequately autonomous and reliable for use in the short-term to midterm timeframe. However, if UALVs operate autonomously, which is technologically feasible in the short-term, C3I architectures, including enhanced artificial intelligence (AI) technologies, must continue to emerge.

Enhanced AI technologies remain critical to the success of any unmanned aircraft required to execute tasks that result from complex human decision-making processes. An example might be the decision a fighter aircraft makes when determining whether or not to engage a target. Much research done in the AI arena focused on building intelligent adaptive neural networks that "learn" over time and remember what they have learned for future application. As one can imagine, this expensive technology must advance significantly before being incorporated into UAVs.[67] Perfecting adequate AI technology remains a future challenge, as UAVs are vested with greater autonomy over traditional human functions. As a key technology, process, and system attribute (TPSA) for the UCAV, AI progress should be monitored for potential application to other UAV programs. It should be sufficiently reliable and autonomous for use in unmanned airlifters by the midterm timeframe.

Navigation Systems

Reliable navigation systems are vital to the function of all aircraft. UALVs require a higher degree of reliability and autonomy.

Not only do the navigation systems need to be reliable, they must employ methods to detect and correct navigation errors.

A technology known as receiver autonomous integrity monitoring (RAIM) works with global positioning system (GPS) receivers to detect and correct such errors. "RAIM notifies pilots of several types of malfunctions including loss of satellite coverage and out-of-range navigation data [and] continuously evaluates the quality of the data it provides to the flight crew."[68] RAIM, or its updated successor, should be available for UALVs, providing them the required degree of reliability for autonomous operations. RAIM faces the challenge to develop an antijam GPS system.[69] GPS jammers are potentially destructive devices capable of interrupting the navigation signal many aircraft rely upon for primary navigation. Precise and reliable navigation systems required for precision airdrop missions may enhance point-of-use delivery capabilities of UALVs.[70] AMC expects that advances in point-of-use standoff delivery systems, like automatic steering parachutes, to be reliable at the beginning of the midterm timeframe.

Another navigation system important to the feasibility of UALVs is the automatic approach and landing system. Raytheon, an aerospace products company under Air Force contract, worked on a precise automated landing system for manned aircraft that shows potential in applications for unmanned aircraft. The Air Force uses an electronic navigation and landing system for Global Hawk, but Raytheon's system possesses even greater capability. According to Raytheon's Bruce Solomon, project director for the Joint Precision Approach and Landing System (JPALS) program, manned and unmanned aircraft can benefit from the extremely precise approach and landing technology JPALS offers. JPALS functions through an approach and landing system using differential GPS (DGPS). DGPS, in contrast to standard GPS, "knows" the amount of error by which standard GPS receivers "drift" from accurate readings. DGPS then takes this error and uses it to correct its own position. DGPS uplinks this data to very high frequency (VHF) receivers aboard aircraft flying in the terminal area, providing precise position information. This capability allows for the execution of precise approaches and safe landings on the surface.[71]

The company tested JPALS with a military test aircraft on 200 precision approaches. Some of the tests used a specially configured Boeing 727 aircraft, signifying its potential application to large unmanned aircraft. In addition, JPALS meets the DOD's need for an antijam and secure approach and is a landing system capable of operation in a hostile environment.[72] Because of JPALS and technologies like it, UAV mishaps in the landing phase should be drastically reduced. As an emerging technology, JPALS enhances the reliability, survivability, and autonomy of potential UALVs.

In summation, navigation systems for manned and unmanned aircraft are currently reliable, autonomous, and mature enough for incorporation into unmanned airlifters. Advanced GPS receivers with RAIM provide a capability for autonomous operations but only in permissive environments due to the possibility of jamming. GPS jammers pose antiaccess challenges to UALVs, leaving questions of their survivability in a wartime environment unanswered. In addition, technological feasibility for the precision airdrop mission remains a challenge even for manned airlifters today. To perform the airdrop mission effectively with UALVs, technology must sufficiently emerge to permit precise point-of-use aerial delivery operations.

Defensive Systems

Likely to be employed in hostile conditions, UALVs also need protection from potential threats, much like manned airlifters. Existing ISR UAVs do not have active defensive systems to protect them, as they generally cost less when compared to their manned counterparts with the exception of Global Hawk. The ISR UAV's primary purpose, collecting information in the face of potential threats, removes the hazards to humans. Active defensive systems unnecessarily add costs to these UAVs. They also carry smaller payloads (most are less than 3,000 pounds) in comparison to potential payloads for UALVs. ISR UAV payloads consist primarily of sensors needed to execute the vehicle's mission. In addition, enemies find it much harder to target a small UAV than a larger, less maneuverable one. The higher expense, larger payload, larger size, less maneuverability, and greater vulnerability of UALVs should meet the criteria for incorporating defensive capabilities.

During Operation Allied Force, Serbian air defenses forced the inefficient routing of many AMC sorties. In this context, the combatant commander, USTRANSCOM, noted before Congress that "the hostile skies over Kosovo presented a threat to air mobility aircraft and crews that we have only recently begun to recognize," and that this was the kind of "threat we see growing in significance in future contingencies." Furthermore, he declared, "As the man-portable air defense (MANPAD) threat continues to proliferate throughout the world, especially in the hands of terrorists and other rogues, the threat may become great enough to force us to curtail mobility operations in a particular area. To counter this threat, we must develop a comprehensive program to protect our air mobility assets."[73] An *Aviation Week and Space Technology* writer echoed this sentiment, proclaiming that the war in Kosovo brought to the surface the issue of outfitting active countermeasures on future UAVs. He argued that countermeasures were "not worthwhile for small tactical UAVs that are much smaller than contemporary fighter aircraft, but they might be considered on large, high-cost systems."[74] If the United States plans continued employment of airlifters in hostile theaters of operations, defensive systems will remain a top priority for AMC aircraft, manned or unmanned.

This philosophy goes counter to tactical UAV conventions in which the UAV operational commander assumes the risk. AMC's *Strategic Plan 2002 Executive Summary* examined the issue in some detail, highlighting the need for defensive systems on all airlift aircraft. It determined that due to the nature of airlift missions, (e.g., humanitarian, peacekeeping, peace enforcement, etc.) active defensive systems became necessary. Yet, the plan stated that existing defensive systems installed on manned airlifters lack the ability to deal with threats. "Proliferation of threat systems, coupled with multi-faceted mission requirements, define[s] the need for more discerning, precise threat warning systems."[75] To employ unmanned airlifters into known hostile areas with the intent of recovering them, robust, reliable, and survivable defensive systems become a necessary capability.

The key to obtaining survivable and reliable defensive systems resides in the relationship between USAF research labs and AMC leadership. Former combatant commander USTRANSCOM, General Robertson, felt that the relationship between the mobility air forces, research labs, and industry was vital to developing, testing, and evaluating proper defensive systems to counter the threat.[76]

What kind of defensive systems, then, should UALVs possess? It depends largely on the value of the UALV as a transporter of valuable cargo. As a minimum, this should include the large aircraft infrared countermeasures (LAIRCM) system. LAIRCM protects large, vulnerable aircraft from MANPADs and counters advanced IR missile systems; therefore, "the missile warning subsystem will use multiple sensors to provide full spatial coverage. The counter-measures subsystem will use lasers mounted in pointer-tracker turret assemblies."[77]Based on the experiences of airlifters in Operation Allied Force, AMC placed LAIRCM number one on its list of acquisition priorities.[78] In addition, potential threats necessitate the use of countermeasures dispense sets designed to eject flares and chaff, which are standard equipment on existing airlifters.

Should stealth technology be adapted to UALVs as a passive defense measure? Stealth serves an important function for the F-117 Nighthawk and B-2 Spirit. Stealth permits these assets to strike and destroy deep, high-value targets with a reduced risk of enemy detection. It will also serve a similar purpose for the high-risk SEAD mission of the J-UCAS. However, stealth is more expensive to incorporate and maintain, especially if large numbers of vehicles are purchased. Until stealth aircraft skins become easier to procure and maintain, incorporating stealth technology on unmanned airlifters significantly increases costs, making them financially infeasible.

Current defensive systems provide marginal reliability for today's manned airlifter fleet. The LAIRCM system and its successor technologies when developed and incorporated into the current manned airlift fleet should provide an adequate degree of reliability and survivability protection for the current and next generation of airlift vehicles, manned or unmanned. Because UALVs would likely operate in a strategic intertheater role versus a tactical intratheater role, it may not be necessary to equip unmanned airlifters with the same degree of defensive capability as manned airlifters. UALVs would probably not operate at small, unimproved airfields because the technology required to invest them with that capability would be cost-prohibitive. Therefore, the author contends that to retain maximum mission flexibility with UALVs, a minimum active defensive system should be installed on the vehicle. The cost-benefit tradeoff of equipping UALVs with defensive systems dictates their installation. UALVs equipped with a minimum defensive capability provides protection for the vehicle and its cargo from destruction of airborne and ground threats. Since technological feasibility and cost are inextricably linked to each other in all UAV programs, cost of defensive capabilities will ultimately determine their inclusion.

Additional Unmanned Airlift Vehicle Considerations

The balance of the chapter focuses on additional considerations contributing to the feasibility of unmanned airlift. In addition to the measures of merit examined above, two additional design considerations pertinent to UALV design are worth reviewing. First, system redundancy in the design of any unmanned aircraft including UALVs necessitates a tradeoff between reliability, survivability, and autonomy. Tradeoffs exist between cost and technological feasibility; therefore, incorporating the appropriate level of redundancy in UALVs will be key to their efficiency. Second, the role of simulation in unmanned aircraft design, development, training, and operations play a key role in UALV technological feasibility, amounting to more reliable, survivable, and autonomous weapon systems.

Following these examinations, a section on UCAV program processes presents an illustration of the latest in UAV developmental practices. Many of these practices set a new standard for UAV development and bear a direct relationship to the technological feasibility of UALVs. The chapter concludes with general comments on the technological feasibility obstacles

UALV developers may face and a reasonable prognosis for surmounting them.

System Redundancy

System redundancy, incorporated for safety and liability reasons, forms a key component of feasibility. Most manned aircraft built today incorporate triple redundancy into their major systems. The hydraulic, electrical, avionic, and environmental systems provide the most redundancy, which reduces the potential for loss of life that typically results from the failure of major systems. Unlike manned aircraft, UALVs do not require the same high degree of redundancy, as the loss of life is not an issue.

To preserve UALVs in the event of major system failure, double redundancy should suffice for two important reasons. First, double redundancy allows a backup system to take over in case a primary system fails. This minimum level of redundancy also helps compensate for the lack of a human pilot. Second, since the vehicle will be transporting supplies and equipment of great value to the user, double redundancy acts as insurance against vehicle and more importantly cargo loss. Although the decision of how much redundancy to build into a UALV must be weighed against cost factors, system redundancy allows a valuable asset with valuable cargo to arrive at its destination free from its own malfunction-related destruction.

The Role of Simulation in Unmanned Aircraft Operations

From design and development to training, simulation of operations provides an inexpensive means of utility analysis for emerging UAV designs, concepts, and ideas. Simulation must accurately duplicate the conditions that it emulates. According to the USAF SAB report on UAV technologies, "simulation can help address key front-end human systems issues, such as the role of the human, workload and staffing, display and control concepts, and general problems of crew station layout as well as concept of operations, command and control, etc."[79] In other words, simulation helps determine the feasibility of an unmanned aircraft operations concept.

Simulation provides a means to train UAV operators, who make UAVs inexpensive alternatives to manned aircraft.[80] According to the *UAV Roadmap*, "today's manned aircraft are flown over 95% (50 percent for ISR aircraft) of the time for peacetime training of aircrews . . . because aircrews must practice in their environment to maintain their flying proficiency."[81] A majority of the training for future UAVs could be conducted in simulators. "While some level of actual UAV flying will be required to train manned aircraft crews in executing cooperative missions with UAVs, a substantial reduction in peacetime UAV attrition losses can probably be achieved."[82] Assuming UALVs are employed in formations with a manned airlifter, the airlifter could have UALV control stations in the cargo area in which vehicle operators monitor their flight status. Global Hawk employs a similar method of vehicle control using operators to monitor flight progress and vehicle status. In the manned airlifter, each UALV operator would be responsible for monitoring two or more of the vehicles much the same way as the J-UCAS.[83]

Joint Unmanned Air Combat Systems Program Development Practices

If unmanned airlift development is to flourish, successful development practices from other successful UAV programs must be adopted. Conceived through a defined requirement to perform the SEAD mission, the J-UCAS program has been successful thus far. According to DARPA, the objective of the UCAV (now J-UCAS) program "is to design, develop, integrate, and demonstrate the critical and key technologies, processes, and systems attributes (TPSA) pertaining to an operational UCAV system."[84] TPSAs include the critical technology areas of adaptive autonomous control; advanced cognitive aids integration; secure robust command, control, and communications; and compatibility with integrated battlespace. In a general sense, they are necessary technological attributes for all UAVs. DARPA planned on developing and demonstrating 15 key and critical TPSAs during a series of 150 ground, flight, and simulation tests. "Collectively, these activities will demonstrate the technical feasibility, validate mission effectiveness projections, and provide an 80% cost confidence in the affordability projections" of the UCAV.[85] DARPA grouped the 15 TPSAs into the following four categories:

Air vehicle

1. Affordable air-vehicle unit/recurring flyaway cost
2. Weapons suspension and release
3. Survivable air-vehicle integration

Mission control system

4. Dynamic distributed mission/vehicle control
5. Advanced cognitive aids integration, mission planning

System integration

6. Advanced targeting and engagement process
7. Force integration, interoperability, and information assurance
8. Secure, robust communication capability
9. Adaptive, autonomous operations
10. Affordable large-scale software
11. Coordinated multivehicle-flight motion

Support system

12. Low observable maintainability
13. Affordable operating and support cost, and integrated vehicle health management
14. Mobility, rapid deployment and footprint
15. Sortie rate, turn time and ground ops[86]

Of these 15 TPSAs, 1, 4, 5, and 7–15 directly apply to UALV program development. Processes and lessons learned from the integration of these TPSAs should be used in all future UAV developmental efforts and evaluated with respect to reliability, survivability, and autonomy. Measures of progress should be established to ensure each conform to the objectives of any development program. Goals established for the program need to be realistic and tailored according to a specified timeline, as is the case with the J-UCAS program. The timeline for each of the TPSAs denotes a realistic expectation for availability and inclusion into the J-UCAS program. Although the J-UCAS program provides an excellent example to model UALV development, many of its objectives focus strictly on combat strike operations. A need exists to transfer the application of those ideas and technologies to UALVs. Despite the progress and technological advancements made to develop more reliable, survivable, and autonomous UAVs, formidable obstacles must be surmounted.

Thus far, this chapter demonstrates that essential UALV technologies exist or will reasonably emerge, yielding the potential for unmanned airlifters in the midterm. However, when UAV designers and developers attempt to integrate individual near-feasible technologies into a practicable and airworthy unmanned aircraft system, system synthesis challenges arise. The next section addresses these challenges and offers possible solutions.

Technological Feasibility Challenges

Advancements in sensors, propulsion, and navigation technologies, among others, led to capabilities never before imagined for UAVs. Yet, skepticism of the DOD's efforts toward UAV feasibility abound. The Congressional Budget Office (CBO) proved especially critical as evidenced by the following statement: "Although unmanned aerial vehicles appear to show great promise and many people have high expectations for them, the Congress is concerned that so many of the UAV systems that [the] DOD has developed or is developing have experienced problems. Historically, many of the services' UAV programs have run into technical difficulties."[87] These problems appear unlikely to go away in the near future and must be thoroughly examined before any new UAV roles and missions are considered. Because the DOD manages all US armed forces' UAV programs, it must take the lead in fostering improved unmanned aircraft systems. The *QDR* outlined the technological mandate for future UAV programs, contrasting the exploitation of a strong science and technology program with “evolving military needs” designed to defeat potential adversaries.[88]

UAVs experienced mishap rates 10 to 100 times greater than manned aircraft.[89] If manned aircraft programs sustained the same rates, they would be grounded until a solution was found. Such high mishap rates would be unacceptable for any UALV program given the preceding discussion. However, at what point in program development should this decision be made? The cost of frequently destroyed user cargo and the cost of destroyed vehicles may be reason enough to consider whether to continue supporting a UALV program. There must be reasonable assurances that mishap rates for UALVs compare to manned aircraft before significant investment will be made in their future.

Significantly, there have been more, failures with past UAVs than successes. Popular wisdom suggests that successive UAV programs grew stronger from past failures, but that may not satisfy congressional appropriations committees that influence budgetary decision makers. Crashes plagued nearly all programs and caused a few to cancel. What do UAV accident statistics say about the safety and viability of unmanned aircraft? Israel’s extensive UAV experience provides one perspective.

Israel accumulated more operational experience with UAVs than any other nation. A recent study of Israeli UAV mishaps after accumulating 80,000 hours of operations (the US fleet was at the 50,000 hour mark in 2002) showed three reliability related areas—flight control systems, propulsion, and operator training—accounting for 75 percent of the mishaps. “The potential savings from improvements in these three areas makes a strong case for identifying and incorporating such reliability enhancements in existing and all future UAV designs.”[90]According to the *UAV Roadmap*, by significantly reducing the occurrence of these reliability and survivability incidents, an appreciable savings in vehicle acquisition costs could result.[91]

Advancements in the three reliability related areas provide sufficient assurances that lend themselves to acceptable parameters for UALVs in the short-term to midterm timeframe. In other words, UAV mishap rates over the next 10 to 20 years will likely equal or better those of manned aircraft. Increased experience with UAVs resulted in many technological advances that over time will reduce mishap rates, suggesting a potential reversal in these rates. A closer look at each reliability related area reveals more. A Stanford University study that tested UAV flight control systems observed that technology exists to significantly reduce flight control–related mishaps, but may involve cost trade-offs when applied to larger aircraft.[92] Additionally, the propulsion related mishaps of Israel with Pioneer as well as the US experience with Pioneer and Predator, occurred mostly as a function of less reliable propeller-driven engine UAVs. UALVs should have either more reliable jet engines to transport their larger payloads or a successor propulsion technology, significantly reducing propulsion related mishaps. Operator training must focus more closely on mis-hap causes in the same way that aircrews study manned aircraft-accident reports. This provides the best way to lessen the occurrence of operator related mishaps and enhance the feasibility of UALVs.

Lastly, for future UAV programs to succeed, the most technologically advanced nation in the world must overcome the challenge of successfully integrating UAV technologies and employ them to their fullest potential. Individually feasible technologies prove worthless unless they can be successfully combined and incorporated into an airworthy unmanned aircraft system. The evidence presented in this chapter indicates that designing and building reliable, survivable, and sufficiently autonomous UALVs is certainly in the realm of possibility.

Summary

This chapter examined the technological feasibility of UA as a potential future function of the USAF. The chapter included a history of UAV developments and current DOD UAV programs.

The facts show that throughout the last century, UAV development progressed favorably in response to operational requirements and available technologies. Scientists evaluated technological feasibility against the standard DOD UAV criteria of reliability, survivability, and autonomy. Subsequently, additional considerations bearing on the design and development of UALVs including UCAV program development practices established a new and improved paradigm for UAV evolvement. Lastly, technological feasibility challenges provided cautions against what some experts perceive as obstacles to future UAV development and demonstrated that technological progress advanced, and these obstacles will be surmounted in the near future. The history of UAV development over the last decade and a review of essential measures of merit applied to the specific requirements of the airlift mission indicate that there exists reasonable assurance to design, develop, and field a functional UALV in the short-term to midterm timeframe.

Notes

1. Wagner and Sloan, *Fireflies and Other UAVs*, 15.
2. Armitage, *Unmanned Aircraft*, xi.
3. Herskovitz, "A Sampling of Unmanned Aerial Vehicles," 66.
4. Taylor and Munson, *Jane's Pocket Book of Remotely Piloted Vehicles: Robot Aircraft Today*, 18.
5. Clark, *Uninhabited Combat Aerial Vehicles: Airpower by the People, for the People, but not with the People*, 8.
6. Larm, "Expendable Remotely Piloted Vehicles for Strategic Offensive Airpower Roles," 14–15.
7. Ricks and Squeo, "Why the Pentagon is often Slow to Pursue Promising New Weapons," 8.
8. Biass and Braybrook, "The UAV as a Sensor Platform: From Pioneer to Global Hawk," 4.
9. Ibid., 2.
10. Reinhardt, James, and Flanagan, "Future Employment of UAVs: Issues of Jointness," 37.
11. Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000–2025*, 4.
12. Biass and Braybrook, "The UAV as a Sensor Platform," 2.
13. GAO, *Unmanned Aerial Vehicles*, 4.
14. Rivers, "UAVs: 100 Eyes in the Sky," 45.
15. Office of the Secretary of Defense, *UAV Roadmap*, 4.
16. Ibid.
17. Ibid., 27.
18. Ibid.
19. Kosiak and Heeter, "Unmanned Aerial Vehicles: Current Plans and Prospects for the Future," 3.
20. GAO, *Unmanned Aerial Vehicles*, 2. The Aquila was a small tactical information gathering UAV carried by four army soldiers that fed real-time information back to troops and commanders from beyond line-of-sight distances.
21. Kosiak and Heeter, "Unmanned Aerial Vehicles," 3.

22. Ibid.; and Longino, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios*, 15.

23. Kosiak and Heeter, "Unmanned Aerial Vehicles," 3.

24. Longino, "Role of Unmanned Aerial Vehicles," 15.

25. Office of the Secretary of Defense, *UAV Roadmap*, 17.

26. Ibid.

27. Fellows et al., "Airlift 2025," 11.

28. Office of the Secretary of Defense, *UAV Roadmap*, 17.

29. Air Force Manual 1-1, *Basic Aerospace Doctrine of the United States Air Force*, vol. 1, 15.

30. USAF SAB, *UAV Technologies and Combat Operations*, vol. 1, *Summary*, 4-3.

31. Ibid., 7-1, 7-2.

32. Tobin, "Piloting the USAF's UAV Fleet," 27.

33. Fellows, "Airlift 2025," vi.

34. Ibid., 16.

35. Tobin, "Piloting the USAF's UAV Fleet," 9.

36. Office of the Secretary of Defense, *UAV Roadmap*, 56.

37. Barry and Zimet, "UCAVs: Technological, Policy, and Operational Challenges," 1–8.

38. Ibid.

39. Noguier, "Next Mission Unmanned," 109.

40. JP 3-55.1, *Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles*, II-6.

41. Ibid.

42. Office of the Secretary of Defense, *UAV Roadmap*, 47.

43. Ibid., 43.

44. Cook, "Europe's Dilemma: Manned or Unmanned?" 43–44.

45. Budd, "Unmanned Airlift," 3. This paper goes into great depth on the SATS concept, revealing an implementation window in the United States between 2005 and 2010.

46. Battershell, *The DoD C-17 versus the Boeing 777*, 72–3. This range of payload capacities is selected based on C-17 data because the C-17 design incorporates the latest technological enhancements for optimizing payload capacity. Original effective payload requirements for the C-17 varied from 160,000 pounds, transporting the payload 2,400 nm unrefueled down to 110,000 pounds, nominally transporting the payload 3,200 nm unrefueled.

47. AMC, *Air Mobility Strategic Plan 2002 Executive Summary*. Approximately 70 percent of the cargo to fulfill the requirements of existing wartime scenarios in the first month is oversized and outsized. With unreliable C-5s (less than 60 percent operational by most estimates) and the slow accession of C-17s (one to two ratio of retiring C-141s), the next strategic airlifter must possess oversized and outsized capability to avoid a high level of war-fighting risk. Added to these payload capacities are fuel and vehicle fuselage weights, the sum of which can restrict operations.

48. USAF SAB, *UAV Technologies and Combat Operations*, vol. 2, *Panel Reports*, 2-34.

49. Fellows, "Airlift 2025," 41.

50. Mitchell Industries, "Final Proposal," 26.

51. Allvin, "Paradigm Lost," 56–59. This paper provides an illuminating description of several automated cargo-handling technologies developed by Wright Laboratory at Wright-Patterson Air Force Base, Ohio.

52. Air Force Research Laboratory, *Automated Aerial Refueling*, (PowerPoint presentation, 26 March 2002), slide 3.

53. Loeb, "Fill 'er Up," F01.

54. USAF SAB, *UAV Technologies and Combat Operations*, 4-2.

55. Air Force Link, "C-5 Galaxy."

56. Air Force Link, "C-17 Globemaster III." The C-17 has a maximum payload capacity of 170,900 pounds.

57. USAF SAB, *UAV Technologies and Combat Operations*, 4-2.

58. Hazdra, *Air Mobility*, 95.

59. DARPA-USAF, "UCAV Program Overview," slide 44. Any future UAV program requiring automated in-flight aerial refueling will depend on the tests conducted within the next few years with the J-UCAS.

60. Chun, *Aerospace Power in the Twenty-First Century*, 296.

61. Ibid.

62. Jumper, "Corona South 2002," 1. If UALVs are employed in formations with a manned airlifter, the manned airlifter is likely to have an ISR collection suite onboard. There is currently a push from current Air Force Chief of Staff General Jumper to foster development of multifunctional-aircraft platforms such as the "smart tanker" initiative that involves taking advantage of technological advances in ISR to outfit existing and new tankers with sensor equipment.

63. Chun, *Aerospace Power*, 296.

64. Nolan, "The Pilotless Air Force?" 28.

65. Office of the Secretary of Defense, *UAV Roadmap*, 34.

66. Ibid., 32.

67. Puttre and Sherman, "A Little Payload Goes a Long Way," 42; and Glade, "Unmanned Aerial Vehicles," 10.

68. Manske, "Looking Ahead at the Future of Airlift," 9.

69. Barry and Zimet, "UCAVs," 1–8.

70. USAF SAB, *New World Vistas: Air and Space Power for the 21st Century, Summary Volume*, 65.

71. Bruce Solomon, (program director for Raytheon Company's JPALS), interview by the author, 30 January 2002.

72. Ibid.

73. House, Statement of Gen Charles T. Robertson Jr., USAF, *Readiness Impact of Operations in Kosovo.*

74. Zaloga, "Conflicts Underscore UAV Value, Vulnerability," 103.

75. AMC, *Air Mobility Strategic Plan 2002 Executive Summary.*

76. Ibid.

77. Federation of American Scientists, “Large Aircraft Infrared Countermeasures (LAIRCM).”

78. Ibid.

79. USAF SAB, *UAV Technologies and Combat Operations*, 7-3, 7-4.

80. Kaufman, “Predator UAV Operators take Distance Learning to Challenging Heights,” 3. Predator UAV training consists of 50 classroom hours, 28.5 simulator hours, and 34.5 hours spent flying 15 missions. More time is spent flying Predator on training missions because of the vehicle’s inherent lack of autonomous systems. UALVs could be designed with greater autonomy, like Global Hawk and J-UCAS, requiring less operator intervention.

81. Office of the Secretary of Defense, *UAV Roadmap*, 45.

82. Ibid., 55.

83. DARPA-USAF, “UCAV Overview,” slides 6 and 40. Block five highlights of the UCAV concept of operations calls for single operators to control multiple vehicles by mid-FY 06. Accordingly, UALVs should be able to use this technology for their own concept of operations.

84. Ibid., slide 3.

85. Ibid.

86. Ibid.

87. CBO, *Options for Enhancing the Department of Defense’s Unmanned Aerial Vehicle Programs*, 18.

88. Office of the Secretary of Defense, *QDR*, 41.

89. Ibid.

90. Office of the Secretary of Defense, *UAV Roadmap*, 45.

91. Ibid.

92. Evans et al., “Flight Tests of an Unmanned Air Vehicle with Integrated Multi-Antenna GPS Receiver and IMU,” 9.

Chapter 5

Financial Capability

> *Estimating cost is often an art. This is particularly true for systems that are performing new tasks with technologies not heretofore used. Estimating costs for evolutionary systems and subsystems is not simple, but there is a process and there are analogs which help guide the cost estimator. Parametric approaches against existing manned aircraft costs must be applied with care, for an unmanned aircraft will entail a very different design approach.*
>
> —USAF Scientific Advisory Board

Besides the mitigation of risk, the next greatest benefit of UAVs is their lower expense when compared to manned aircraft.[1] US ISR-UAV programs administered over the last 10 years have striven to keep the development, procurement and acquisition, operations and support (O&S), and life-cycle costs below those of comparable manned programs. Other cost savings have also resulted from unmanned aircraft use, most notably, the absence of the cost infrastructure associated with supporting the human(s) operating manned aircraft. This cost infrastructure includes pay, allowances, initial training, and continuation training, among others. These high overhead costs when combined can vary from 30 to 40 percent of the total aircraft program cost. To determine if there can be a role for unmanned airlifters in the Air Force, the author examines in this chapter the financial capability of unmanned aircraft programs in relation to manned aircraft programs. The comparisons drawn by this data are then extrapolated and applied to UALVs and manned airlifters. If operational requirements and technological feasibility exist, as previously established and if unmanned aircraft programs can demonstrate financial cost-effectiveness over manned programs, a role exists for UALVs in the USAF.

The United States must capitalize on its technological superiority by attempting to field cost-effective systems allowing its armed forces to maintain an edge on the battlefield. USAF airlifters are aging faster than programmed due to continuous response to worldwide contingencies. This demands that defense transportation planners now examine midterm and long-term capabilities to meet those requirements.[2] Increased operating costs have been the result of an airlift fleet averaging nearly 25 years and suffering from poor reliability and extensive maintenance.[3] Lowered reliability and increased operating costs coupled with diminishing budgets for airlift ultimately result in a smaller and less effective airlift force that makes it difficult to meet global airlift requirements.[4]

This chapter begins with an analysis of the development, procurement, O&S, training, and life-cycle costs of current UAV programs. It also investigates DOD acquisition processes and general UAV savings. The analysis also examines and highlights cost comparisons between manned and unmanned aircraft programs throughout.

Costs and Comparisons

Cost is an important consideration in the development of future airlift platforms and their support systems.[5] Determining the cost-effectiveness of unmanned aircraft systems requires a balanced comparison between manned and unmanned systems. The *UAV Roadmap* defines what costs should be considered in this comparison: "Any full and fair comparison of manned and unmanned aircraft costs must consider the three phases of any weapon system's life-cycle cost: development, procurement, and operations & support (O&S). . . . It is not necessary that a single UAV replicate its manned counterpart's performance; what matters is whether the UAV can functionally achieve the same mission objectives more cost effectively."[6]

Providing a definitive cost-benefit analysis of manned versus unmanned aircraft vehicles is beyond the scope of this paper. However, the cost comparisons presented here should sufficiently answer the research question regarding the overall financial soundness of the UALV concept.

Unmanned Aerial Vehicle Funding and the Defense Budget

Over the last several years, the DOD steadily increased the budget for UAV programs. In FY99, the DOD invested approximately $115 million, which accounted for less than 1 percent of its acquisition budget.[7] For FY03, the DOD has budgeted $189 million for UAV programs, planning higher increases of funding beyond that.[8] In addition, it allocated $339 million for FY04, $366 million for FY05, and $392 million for FY06.[9] It seems there has never been a time when UAV funding has been more generous. If the trend continues, perhaps the DOD will consider UAVs for other roles and missions as theater commanders extol their war-fighting benefits. However, a major problem exists with respect to funding UAV programs, as operating costs are unknown.[10] Until recently, a fiscally constrained funding environment that focused funding on higher priority USAF aircraft programs exacerbated this uncertainty and left strategic airlift funding absent, especially for the procurement of the expensive but capable C-17 and upgrades for the unreliable C-5.

Before the events of 9/11, there was a struggle to procure airlift to meet the requirements and conditions established by *MRS-05*. As described in chapter 2, *MRS-05* recommended purchase of 170 to 180 C-17s to close the airlift gap and fulfill wartime airlift requirements.[11] USAF officials are lobbying for an additional 42 C-17s beyond that for a total inventory of 222. The fundamental consideration is if world events had not occurred as they did on 9/11, the US airlift fleet would still be in jeopardy of failing to meet established requirements. Can the United States get the same capability more cost-effectively in the future? Global Hawk provides one example.

Global Hawk has been developed with a cost-saving strategy from its inception. This strategy was implemented by using cost as the independent variable; "The only firm requirement is that the average cost of the 11th through 20th air vehicles . . . be no more than $10 million (in 1994 dollars). All other technical characteristics can be traded to fulfill that requirement."[12] The DOD planned to procure Global Hawk numbers five through seven at a cost of approximately $56.93 million each, a figure that will decrease as development costs are amortized.[13] By comparison, these development costs are roughly half that of the U-2 aircraft Global Hawk is designed to replace.[14] Though it is easy to keep costs down for ISR UAVs, because basic UAV technologies have existed for some time, it may be difficult to do the same for unproven unmanned aircraft technologies such as the UALV. As the epigraph at the beginning of this chapter declares, cost is an uncertainty, which is especially true for unproven technologies.

Cost Overview

Before examining costs, one must understand the basics of the defense acquisition process. First, broadly stated mission needs are translated into operational requirements through a process known as requirements evolution. From there, basic acquisition planning begins, including risk management analysis. Subsequent to this process, a systems engineering phase begins, which incorporates design and development processes and development cost allocation. These front-end costs, depending on the viability of the program, determine whether a program will continue through the acquisition cycle.

Once a program is selected for acquisition, procurement costs are budgeted to fund the system into the inventory. O&S costs assist in the subsequent operation and maintenance of the fielded system. Altogether, the development, procurement, and O&S costs constitute the life-cycle costs of a fielded system during its active service. This simplified explanation provides the conceptual foundation necessary for understanding the ensuing examination of the cost concepts used in this chapter.

Research And Development Costs

Research and development (R&D) costs can be very high for UAVs, especially unproven ones. Yet, they are not as high as development costs for manned aircraft. The reason they are high is that they are also categorized with research, test, and evaluation costs, which front a disproportionately high percentage of any weapon system's budget, manned or unmanned.[15] A difficulty with securing adequate funding for a new defense program is substantiating its anticipated capabilities. An expert on unmanned aircraft concepts commented astutely on the difficulties of developing unproven unmanned aircraft concepts: “In general it can be said that if a particular unmanned aircraft is designed to be simple, limited in role and recoverable . . . then its cost-effectiveness can scarcely be in doubt. But if the unmanned aircraft is more complex, larger and thus more vulnerable; if it requires skilled controllers and other expensive support . . . then its cost-effectiveness compared with manned aircraft that can carry out repeated, varied and complex missions, is by no means easy to judge.”[16] Though written 14 years ago, these words still hold true today. Otherwise, large, complex UAVs would have already been developed and fielded. How should the United States proceed in developing and procuring cost-effective unmanned aircraft to fulfill new roles and missions, particularly airlift missions?

One way is to follow the progress made in the development of the J-UCAS, which will arguably be the most complex UAV developed to date. Many developers believe that the J-UCAS will “cost less per unit to acquire, operate, and maintain than manned aircraft,” but will “require significant research and development (R&D) investment to bring them to the point of production. . . . However, once R&D costs are amortized across a larger fleet, the UCAV unit cost is anticipated to drop to around $30 million or less—about half that of a manned system.”[17] Just like the J-UCAS in which the mission and vehicle concept are unproven, the costs of developing UALVs are also likely to be high. R&D costs for UALVs will depend on the level of support the program garners, how effectively the program fulfills operational requirements, and how technologically feasible the vehicles prove to be. Over time, despite initially high R&D costs, UALVs should amortize their costs if procured in sufficient numbers. Global Hawk and U-2 reconnaissance platforms provide an example of R&D cost comparisons between unmanned and manned aircraft.

R&D costs to first flight for Global Hawk and U-2 were $205 million and $243 million, respectively.[18] Although not significantly less, Global Hawk costs are about 16 percent lower than U-2 R&D costs. These figures, however, are significant when one considers the time to first flight for Global Hawk took 41 months while the U-2 took only eight months. Generally, the longer an aircraft's program development takes, the higher the R&D costs incurred. Nevertheless, there are exceptions.

For example, comparisons between the X-45 UCAV and the attack/strike version of the F-16 reveal virtually little difference in developmental costs. The cost to first flight for the UCAV was $102 million and spanned a 35-month period, while the same cost for the F-16 was $103 million and spanned a shorter 23-month period—a difference of $1 million.[19]

In an attempt to draw similar comparisons between manned and unmanned airlift R&D costs, a useful place to start is with our previous example—the C-17. C-17 R&D costs spanned a 14-year period between 1981 and 1995 when the aircraft attained IOC. In that period, developing the C-17 cost US taxpayers $5.6 billion. McDonnell Douglas funded an additional $1.7 billion—bringing the total C-17 development cost to $7.3 billion.[20] Because there are no UALV R&D costs to compare with the C-17, the author makes a reasonable assumption, based on the examples provided, that if UAV R&D costs are equal to or less than their manned counterpart R&D costs, the program may receive funding.[21] In other words, cost-confidence estimates for UALVs must demonstrate "less-than-or-equal-to" R&D costs in comparison to equivalent manned airlift capability.

Procurement Costs

Procurement costs fund a weapon system and are separate from R&D costs. When combined with the R&D cost, they constitute the acquisition costs. Though current unmanned aircraft tend to have lower procurement costs compared to their manned counterparts, the comparison is not completely accurate. According to the *UAV Roadmap*, "any savings in procurement costs cited for UAVs by deleting the cockpit, its displays, and survival gear is typically offset by the cost of similar equipment in the UAV ground element."[22] In other words, consideration of support system costs must not be overlooked when comparing costs. In the case of UALVs, however, the last chapter posits that the best method for their employment is in formations with a manned airlifter, eliminating the need for costly ground stations.

Procurement costs, unlike R&D costs, remain relatively static over the life cycle of a weapon system and are normally based on a per platform price negotiated between the user and contractor. For example, the procurement cost of two Global Hawks from the FY02 budget was $116.6 million, while three were budgeted in FY03 for $170.8 million. This puts the per vehicle price in each year at roughly $57 million.[23] Unfortunately, similar procurement cost comparisons cannot be drawn between J-UCAS and Joint Strike Fighters (JSF) since both are still in the R&D phase.[24]

Another example is provided by the C-17. According to the *UAV Roadmap*, "the aviation industry has long recognized the informal rule, based on historical experience, that the production [read as procurement] cost of an aircraft is directly proportional to its empty weight (before mission equipment is added). That figure is some $1,500 per pound."[25] Additionally, from "10 to 15 percent of the manned aircraft's empty weight" is comprised of man-supportable mission equipment.[26] By applying the cost-to-weight methodology, a cost of $403,500 is derived from a 269,000-pound empty weight C-17. If the onboard equipment supporting the human operators on the C-17 is removed, a cost savings of approximately $40,000 to $61,000 results for the same capability.[27] When one considers that Congress appropriated over $16.6 billion for C-17 procurement between 1981 and 1995, the potential savings become readily apparent.[28] UALV procurement costs depend on the sophistication of the vehicle technology. The more sophisticated the technology, the higher the procurement cost. Before examining O&S costs, a brief explanation of the UAV acquisition process is necessary.

Unmanned Aerial Vehicle Acquisition

One of the keys to economical acquisition of UAVs is the streamlined process by which the DOD acquires them. This process, however, has not always been streamlined. Before the DOD started procuring UAV weapon systems using the current acquisition concept technology demonstration (ACTD) method, inefficiencies were rampant, causing costs to swell unnecessarily. The ACTD process, examined in the following section, avoided many of the anomalies that drove previous UAV acquisition program costs up.

Three major acquisition anomalies must be avoided for future UAV acquisition programs to succeed. The first is "requirements creep."[29] Also known as "gold-plating," requirements creep means "trying to make the UAV do too much too soon."[30] As mentioned in an earlier chapter, the Army's Aquila program suffered from requirements creep, eventually causing its cancellation. Requirements creep occurs because additional requirements are added to the program throughout its development phase until the costs become too great. Besides making UAVs costly, piling on additional requirements eventually makes meeting them technically impossible.[31]

Second, available UAV technologies should not be considered capable technologies.[32] Many times commercial off-the-shelf technology, dubbed nondevelopmental, is incorporated into UAVs without undergoing sufficient testing. Often, developers consider these technologies mature enough for the UAV system that uses them, but GAO studies have shown otherwise.[33] For example, the Army's Hunter UAV stand-alone software, data-link equipment, and engines met standards before installation. However, when installed in the UAV, the DOD failed to allow enough time for smooth integration of these components, which eventually led to program cancellation.[34] In past UAV programs, available technologies were assumed mature enough for program incorporation. Nevertheless, costs increased out of control, making the program cost prohibitive. Extensive technology testing is required with real prototypes before technologies are considered mature.

Third, when UAVs are acquired, not only are the vehicles themselves acquired but also an entire system of integrated components, including the maintenance, training, air vehicle operator stations, and ground operator manpower costs are also acquired. The GAO, in a 1997 report on the DOD's acquisition efforts, cautioned that potential UAV users and developers must remember that UAV systems are not cheap and that prudent cost-efficiency should drive the development strategy.[35]

Advanced Concept Technology Demonstration Acquisition

The Air Force acquires its UAVs through ACTD acquisition. Started in 1994, ACTDs "are intended to be quick-development programs designed to get mature technologies into the hands of users for early evaluation of operational utility."[36] ACTD acquisition facilitates the development, testing, and fielding of UAV concept programs within a two-to-four year period. ACTDs begin with the building of a technology demonstration prototype for the users to evaluate. The prototype assists users and decision makers in determining the best method for further vehicle development.[37]

Although ACTD programs are improvements over previously lengthy and costly acquisition strategies, they are fraught with difficulties of their own. They are the same difficulties that forced creation of ACTD acquisition in the first place. A CBO report made the following observations regarding ACTD difficulties: "Because of the complexities of UAVs, . . . ACTD programs for those vehicles have had mixed success. Their rocky progress suggests that some of the causes of inflated costs and delayed schedules are beyond the ability of the ACTD process to reform. Despite those problems, the ACTD approach appears to have had some success in areas where past UAV programs struggled, such as avoiding growth in operational requirements, improving cooperation among services and military commands, and providing commanders with the opportunity to try a new system in the field" before buying it.[38] If ACTD programs fail to meet their developmental requirements, one of four possible outcomes result:

1. termination of the system,
2. continued operation of only a few models,
3. return of the system to the laboratory for continued development, or
4. transition to procurement.[39]

Each outcome gives the user maximum flexibility for proceeding with operational requirements without investing enormous sums of money or allocating significant time to a program not delivering acceptable results.[40]

The primary advantages of ACTDs are a shortened development cycle and a thorough determination of system utility before the commitment of funds to full-rate procurement.[41] These advantages are the cornerstone of the efficient financial utility of UAVs, fostering improved cost-effectiveness over manned aircraft acquisition methods and strategies.

Joint Unmanned Combat Air Systems Acquisition

UALVs are likely to follow the same developmental path as J-UCAS, owing to the unproven technology development similarities of both. Therefore, successful J-UCAS acquisition processes should be replicated for other developing UAV programs. For example, DARPA responsible, for J-UCAS development, "firmly believes that the unit . . . cost of the UCAV [now J-UCAS] weapon system will be one-third that of the Joint Strike Fighter" according to the director of the Pentagon's Operational Test and Evaluation Office.[42] If comparable cost savings can be attained with UALVs, three unmanned vehicles could be procured for the price of one. The implications are clear. If an unmanned airlifter with the capacity of the C-17 costs one-third the price of a manned version, all other factors remaining equal, the DOD would acquire dozens of them. Unfortunately, the comparison is not that simple. Comparing the size and projected capabilities of J-UCAS with JSFs is much easier than comparing C-17s with unknown and unproven, unmanned airlift vehicles.

How is the J-UCAS assuring its development and acquisition costs stay one-third of the JSF? The approach, not unlike the ACTD process use for Predator and Global Hawk, seeks to shorten the normal acquisition cycle by merging the demonstration phase with a risk reduction phase to permit faster entry of the vehicle into an acquisition program.[43] The implementation of this strategy will provide decision makers with the technical and financial feasibility information required to make an informed procurement decision.[44] It is incumbent upon future UAV developers to extract the J-UCAS program lessons and apply them to potential unmanned roles and missions.

So far, UAV development, procurement, and acquisition costs have been examined. Existing UAV acquisition methods and processes demonstrate a fast, cost-effective approach to procurement of unmanned aircraft weapon systems. UAV O&S costs offer an even greater potential for savings over manned aircraft than development, procurement, and acquisition costs.

Operations and Support Costs

O&S costs are associated with owning, operating, maintaining, and supporting a fielded DOD system.[45] They include fuel, pay for unit personnel, and pay for indirect support personnel. Early studies of UCAV O&S costs suggest they will be 75 percent lower than F-16 and JSF O&S costs.[46] Others have estimated the cost savings potential close to 90 percent as calculated for peacetime operations.[47] The potential savings in O&S costs in unmanned aircraft result from two observations: (1) needed manned aircraft to fly costly training and pilot proficiency sorties and (2) some, if not the majority, of the training in a UAV can be conducted without the vehicle actually in flight.[48] In other words, simulators offer training to pilots at substantially lower costs than training in actual aircraft.[49]

Though training costs are lower for unmanned aircraft, requirements creep contributes to increases.[50] According to one source, “in the past, the services were unwilling to continue UAV programs when their costs grew beyond original estimates. . . . In addition, some analysts have noted the services were too ambitious in the capabilities that they demanded of past programs.”[51] Obviously, if they spend more time augmenting manned aircraft operations, UAV O&S costs increase appropriately. Before O&S costs are calculated with any accuracy, an investigation of UAV ground system support costs must be done.[52]

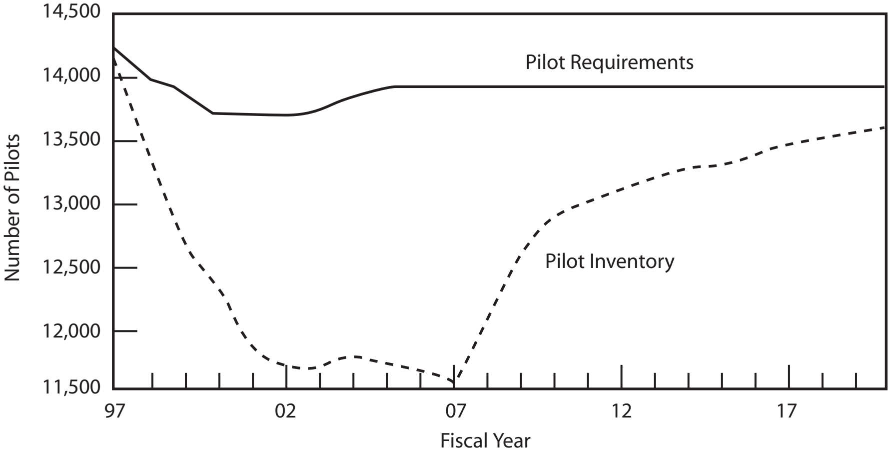
Training Costs and Pilot Retention

Unmanned training costs, like many of the other costs examined here, are also lower than comparable manned aircraft training costs. Currently, Predator UAV operators accomplish all initial and continuation training in simulators and do not use expensive aircraft for their training. However, the comparisons between unmanned and manned training costs are skewed because Predator UAV operators are selected from the ranks of rated pilots steeped in airmanship. The airmanship accumulated by current Predator operators developed from years of operational experience and at a price that has already been paid. Because the demand for Predator operators is great, alternative training methods to increase their numbers faster are being evaluated. One plan takes potential operators with no flying experience and infuses them with a training program that teaches them the minimum skills necessary to operate the vehicles. It includes sending the future Predator operators through an abbreviated version of undergraduate pilot training in which operator airmanship, gained previously through years of active flying experience, will be lacking.[53] In the future, technological advances in automation as well as improved flight controls and software upgrades will help offset this lack of operator airmanship, which is normally deemed essential for effective flight operations. A comparison of the training costs between manned and unmanned programs illustrates distinct advantages for unmanned aircraft.

One way to illustrate the distinct advantage of unmanned aircraft is to compare Predator UAV training costs directly with Specialized Undergraduate Pilot Training (SUPT) costs. SUPT is the method initially used to train USAF pilots. The FY00 cost of putting a newly trained pilot through a year of USAF SUPT was $472,920.[54] This figure included flying hours, manpower costs, student pay, nonpersonnel, and command-support costs.[55] However, more costs are incurred from training required in the follow-on weapon system. For example, it costs an additional $129,316 to train a C-17 copilot.[56] There are numerous other costs implied in making a pilot fully qualified and mission-ready, such as mobility, life support, aircrew chemical defense, aircrew tactics, and continuation training costs, to name a few.[57] UAV operators do not receive these kinds of training; therefore, these costs are not incurred. Another important cost consideration, particularly with airlifters, is that there are multiple crewmembers onboard essential to the mission. The cost to train and equip them adds expenses beyond single operator programs.[58] The complexities of the current Predator training contract makes it difficult to give an exact cost for each individual operator.[59] However, a proposal by Air Combat Command projects initial Predator operator training costs, under a nonpilot training program, to be $12,000 per operator.[60]

Simple training cost comparisons, however, do not paint a complete picture. Unmanned aircraft reduce the need to offer pilot bonuses while also reducing the need for pilots, of which the Air Force has a shortage. The manned aircraft community suffers from retention problems not resident in the UAV operator community. The addition of UALVs would alleviate USAF leadership struggles to retain aircraft pilots. Air Force data indicates that 78 percent of pilots who separated from the USAF in FY01 were not eligible for retirement. This is despite the Air Force's improved aviator continuation pay (ACP) incentives over the last several years amounting to the "most robust compensation program to date."[61] These incentives include up-front payment increases from between $100,000 to $150,000 and increases in annual bonuses from $12,000 to $25,000. Pilots could also choose from varying service commitment lengths. Yet, even ACP acceptance rates among eligible pilots plunged to an Air Force–wide low of only 18 percent.[62] This figure represented a mere 470 out of 2,629 total USAF pilots eligible to accept the bonus.[63] These are disheartening figures considering the Air Force has increased flight-training rates and raised the active duty service commitment length to 10 years from eight. Six years ago, the pilot retention situation became acute. In 1998, "efforts left the USAF 648 pilots short of its 13,986 [pilot] requirements."[64] By 2007, the USAF will be approximately 2,300 pilots short.[65] Figure 3 illustrates the nature of the shortage.

What does the preceding examination represent in terms of training cost savings and unmanned airlift? It means the USAF will spend a large amount of money to train pilots through costly increases in pilot production and attempt to retain them through expensive incentive programs that statistics indicate do little to keep them. Unmanned aircraft potentially reduce the USAF dependence on pilots while reducing funds required to train the operators. Additionally, overall



Reprinted from: William W. Taylor, Craig Moore, and C. Robert Roll Jr., *The Air Force Pilot Shortage: A Crisis for Operational Units*? (Santa Monica, Calif.: RAND, 2000), 5, http://www.rand.org/publications/MR/MRI204/.

Figure 3. Predicted USAF pilot requirements versus pilot inventory

pilot retention incentives are reduced drastically because the USAF will require greater than 50 percent fewer pilots, thus negating the need to appropriate costly financial incentives.

Life-Cycle Costs

Life-cycle costs consider a summation of all the cost concepts examined thus far and are concerned primarily with the long-term amortization of weapon system costs. As is the case with the other costs examined in this chapter, life-cycle costs are trimmed by removing the aircrew from the aircraft.[66] Analysts have attempted to quantify these cost savings, but as mentioned earlier, it is a difficult task. Prudent cost management practices, especially in the earlier stages of unmanned aircraft ACTD acquisition, will ensure life-cycle costs remain manageable.[67]

Thus far, this chapter covered unmanned aircraft and their cost advantages over manned aircraft systems. The following section examines additional generalized savings.

Other Unmanned Aerial Vehicle Savings

UAVs offer many other generalized cost savings over manned aircraft. One results from the absence of the physical cockpit and all that it houses. In place of the cockpit, UALV computer workstations could be equipped in the cargo compartment of the manned "mother ship" airlifter.[68] Depending on the level of sophistication and automation, there are tremendous costs associated with today's manned aircraft glass cockpits. One French air force officer wrote, "in the last generation of manned aircraft, the cockpit design and pilot interface requires a considerable amount of resources and expensive electronic and computer devices. This, combined with pilot life support equipment, can represent almost 30 percent of the development and operational cost of the aircraft."[69] Noguier noted that removing the pilot also removed the possibility of him being taken prisoner or becoming a casualty of war and resulted in a reduction in search and rescue forces.[70] Another advantage results from a decrease in base infrastructure needed to support manned aircraft operations (altitude chambers, life support organizations, etc.).

Yet, other factors associated with UAVs overshadow these generalized savings over manned aircraft. One is the high cost of UAVs that are typically produced in small numbers. Small production runs do not allow high development and life-cycle costs to be amortized favorably. Predator will likely be an exception, as 22 were budgeted for FY03, 16 in FY02, and seven in FY01.[71] These vehicles should pay for themselves quickly because the acquisition costs will be amortized over a larger fleet. Another factor to consider is that UAVs have extremely high accident rates over manned aircraft, which is accounted for by the very nature of the mission many perform. Yet, unmanned airlifters cannot afford to be destroyed because the cargo aboard the vehicle is essential to mission accomplishment.

General Unmanned Airlift Vehicle Savings

C-17 costs constitute a large portion of the defense budget. The DOD's 2003 budget request for C-17 procurement, including O&S costs for 12 aircraft, was $3.826 billion.[72] That calculation put the per price procurement for each aircraft at roughly $318 million. The RDT&E costs accompanying procurement topped out at $157.2 million.[73] UALV costs in these areas must beat that price while providing comparable cargo capabilities if the Air Force is to seriously consider UALVs.

Although the Air Force committed to procure 60 more C-17s in 2002, it is uncertain whether or not the Air Force would have made this commitment prior to the 9/11 terrorist attacks on America. The constrained fiscal environment before that time focused acquisition priority on other platforms such as the F-22, creating a budget battle to fund other important capabilities like airlift.[74]A situational example of UALV cost savings below illustrates this point.

Assuming UALVs have defined operational requirements that are technologically feasible and applying the same cost differential between J-UCAS and JSFs (three to one) as noted earlier, the USAF could potentially save trillions of dollars purchasing UALVs. For the sake of argument, let us assume all 60 C-17s contracted in 2002 were procured for $318 million each. Applying the three-for-one cost difference could either procure the same number of airplanes (60) for one-third of the price ($106 million) or for $318 million procure 180 UALVs. The C-17 can transport roughly 170,000 pounds.[75] To be conservative, one may assume that the UALV has the same capacity as the Boeing ATT concept aircraft previously mentioned—80,000 pounds.[76] The total capacity of the 60 C-17s equates to 10.2 million pounds. If the DOD acquired 180 UALVs, their combined capacity would be 14.4 million pounds. This results in roughly 43 percent more capacity for the same amount of funding. Total capacity increases significantly if the available UALV capacity is increased. There is one last potential cost advantage of UALVs to examine.

Unmanned Airlift Vehicle Storage and Leasing

Because the DOD would probably employ UALVs primarily during contingency operations when airlift demand peaks, they might otherwise remain idle, except for those designated or required to retain system proficiency.[77] Due to this decreased usage rate and the need to keep UALVs cost-effective, creative ways of maintaining low costs must be entertained. One possible solution is through long-term storage. Much like the J-UCAS, which will only be used when required to perform its mission, UALVs could be stored until ready for use. UALVs will potentially merit their greatest savings over manned airlift when not in use. This will keep maintenance and life-cycle costs low while insuring long-term viability.

As an alternative to long-term storage, the Air Force might consider leasing the vehicles to cargo companies needing low-cost unmanned airlift to augment their cargo transport operations. In times of high use, these vehicles would revert to Air Force ownership for immediate use. In much the same way as CRAF partners are called to serve the nation, a similar call-up for UALVs from commercial lessees would obligate their return. This cooperative arrangement would provide considerable savings for the Air Force and the commercial lessee.

Regarding the J-UCAS program, storage should result in a savings of 80 percent of life-cycle costs.[78] This is a key factor in reducing the overall life-cycle costs of UAVs. For example, in the war against terrorism in Afghanistan, the United States deployed hundreds of tons of supplies daily to the region. The limiting factor in achieving airlift capacity requirements in the region was the numbers of aircraft and crewmembers. Storing the UALVs when not in use would save on O&S costs. In the end, ULAVs would serve as a cost-effective solution to US airlift shortfall woes.

Fleet Size

The DOD should consider a limited but significant number of UALVs to complement the manned airlifter fleet. The number of UALVs will depend on a host of factors, including airlift requirements forecast for the time UALVs will be fielded. The following example illustrates a logical rationale for UALV fleet size.

Many C-5s are likely to begin retiring based on forecast airframe structural service life estimates, near the end of the midterm timeframe defined by this paper. It is unknown at this time exactly how many aircraft will retire and when. However, for the sake of argument, a reasonable assumption is that C-5s will retire at the same rate as the most recent retiring strategic airlifter, the C-141. In 2000 there were approximately 108 C-141s in the airlift force structure. By 2001 there were 93 and in the out years of 2002–2005 the numbers were forecast to be 73, 56, 31, and 22, respectively.[79] The average number of C-141s retiring over this five-year period was expected to be 17.2 per year. This aircraft retirement figure will now be applied to C-5 retirement.

If the C-5 retires at a rate of 17.2 per year, a significant loss in oversize and outsize airlift capability will result, requiring a replacement. The threshold airlift capability of the C-5, as stated earlier, is 180,000 pounds.[80] The threshold is the figure used to compute aircraft MTM/D. Therefore, the loss of 17.2 C-5s per year results in an annual loss of approximately 3.1 MTM/D and over a five-year period a loss of approximately 15.5 MTM/D. This means that replacement airlift capability must be fielded so that wartime airlift requirements can be sufficiently met. Therefore, based on the UALV effective payload capacity (threshold) range between 100,000 and 160,000 pounds (as calculated in chap. 4), a *MRS-05* airlift requirement of 54.5 MTM/D (as mentioned in chap. 3), and a fleet of 180 C-17s providing 20.1 MTM/D, a UALV fleet size of between 87 and 139, procured at a rate of 20 to 31 per year will provide sufficient airlift capability to meet wartime airlift requirements at their highest.[81]

Summary

Estimating UAV program costs is a difficult task that takes great care and judgment. This chapter illustrates that UA offers distinct cost advantages over manned aircraft. It began with an examination of UAV funding and the defense budget and progressed through a series of UAV program costs, including R&D, procurement, and acquisition costs. After that, the ACTD and UCAV/J-UCAS acquisition processes were examined, demonstrating the merits and cost advantages of quickly fielding UAVs in an effort to keep them affordable. Next, O&S and training costs were examined, illustrating the potential savings for UALVs. Finally, pilot retention issues, life-cycle costs, and other unmanned aircraft savings were reviewed with respect to UALVs. In every instance, unmanned aircraft, and possibly UALVs, demonstrated the potential ability to possess costs equal or better than their manned counterparts, answering the research subquestion, "are the concepts cost-effective?" in the affirmative.

Notes

1. Noguier, "Next Mission Unmanned," 105.

2. Office of the Secretary of Defense, *QDR*, 68.

3. Senate, Statement of Gen Charles T. Robertson, Jr. USAF on *Strategic and Tactical Lift in the 21st Century*: *Hearings before the Subcommittee on Seapower of the Committee On Armed Services*.

4. AMC, *Air Mobility Strategic Plan 2002 Executive Summary*.

5. Fellows et al., "Airlift 2025," 14.

6. Office of the Secretary of Defense, *QDR*, 51.

7. O'Reilly, "Uninhabited Air Vehicles," 19; and CBO, *Options for Enhancing the Department of Defense's Unmanned Aerial Vehicle Programs*, 56.

8. Svitak, "Pentagon Details Extra Money for War on Terror," 4.

9. Ibid.

10. Glade, "Unmanned Aerial Vehicles," 21.

11. Office of the Joint Staff, *MRS-05*, 5. These figures illustrate that no C-5 aircraft would go through the Reliability Enhancement and Re-Engineering Program modification.

12. CBO, *Options for Enhancing the DODs UAV Programs*, 14.

13. DOD, *Program Acquisition Costs by Weapon System*, 20. Hereafter cited as *Defense Budget for Fiscal Year 2003*.

14. Barry and Zimet, "UCAVs," 1–8.

15. AT&L Knowledge Sharing System, *Defense Acquisition Deskbook*, http://akss.dau.mil/jsp/default.jsp.

16. Armitage, *Unmanned Aircraft*, 100–101.

17. Barry and Zimet, "UCAVs," 1–8.

18. Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000–2025*, 53. Hereafter cited as *UAV Roadmap*. These figures are adjusted to FY00 dollars.

19. Ibid.

20. Battershell, *The DoD C-17 versus the Boeing 777*, 84.

21. This assumes the unmanned aircraft possesses equivalent capabilities to its manned counterpart.

22. Office of the Secretary of Defense, *UAV Roadmap*, ii.

23. *Defense Budget for Fiscal Year 2003*, 20.

24. Ibid., 19–20.

25. Office of the Secretary of Defense, *UAV Roadmap*, 53.

26. Ibid.

27. The staff of the Secretary of the Air Force for Acquisition and Brig Gen Ted F. Bowlds, Air Force Program Executive Officer for Airlift and Tanker aircraft, interview by the author via email, 12 April 2002. These systems and equipment include the flight compartment; buffet and galley; lavatories;

oxygen system; water and waste system including potable water stores; crew and passenger seats; passenger, crew, and emergency exit doors; and the crew escape and safety hatches (and associated equipment), among others. However, tradeoffs in weight may result if additional sensors, automated cargo handling systems, and so forth are added to the aircraft empty weight.

28. Battershell, *DoD C-17 versus the Boeing 777*, 85. By applying the "10 to 15 percent" rule, UALV procurement savings could potentially amount to $1.67–$2.5 billion.

29. Walden, "The Use of Modeling and Simulation in the Systems Engineering of Unmanned Aerial Vehicles," par. 1.0.

30. Morris, "Unmanned Aerial Vehicles," 5.

31. Walden, "Modeling and Simulation," par. 1.0.

32. GAO, National Security and International Affairs Division, *Unmanned Aerial Vehicles*, 6–7.

33. Ibid., 7.

34. Ibid., 9.

35. Ibid., 7.

36. Jones, "Unmanned Aerial Vehicles," 43.

37. CBO, *Options for Enhancing the Department of Defense's Unmanned Aerial Vehicle Programs*, 25.

38. Ibid., 21.

39. Ibid., 23.

40. Ibid.

41. Jones, "Unmanned Aerial Vehicles," 43.

42. Wilson, "Pilots! Unman Your Airplanes!" 3692; and DARPA-USAF, "Unmanned Combat Air Vehicle (UCAV) Demonstration Program: UCAV Overview," 3. The UCAV program makes this claim based on "an 80 percent cost confidence in the affordability projections."

43. DARPA-USAF, "UCAV Program Overview," 4–5.

44. Ibid.

45. DOD, *Commercial Operations and Support Savings Initiative, Frequently Asked Questions.*

46. Flade, "Teaching a New Dog Old Tricks," 8; Reinhardt, James, and Flanagan, "Future Employment of UAVs," 38; Wilson, "Pilots! Unman Your Airplanes!," 3692; and DARPA-USAF, "Unmanned Combat Air Vehicle (UCAV) Program Overview," 2.

47. Reinhardt et al., 38.

48. USAF-SAB, *UAV Technologies and Combat Operations*, par. 4-6.

49. Up to 95 percent of peacetime manned aircraft training occurs in the aircraft.

50. CBO, *Options for Enhancing the Department of Defense's Unmanned Aerial Vehicle Programs*, 32.

51. Ibid.

52. Barry and Zimet, "UCAVs," 1–8.

53. Maj Shawn D. Nelson, HQ Air Combat Command, Predator UAV action officer, interview by the author, 11 April 2002.

54. Mr. Mark Parsons, Air Education and Training Command, interview by the author 11 April 2002.

55. Ibid.

56. Ibid. FY00 dollars.

57. Tobin, "Piloting the USAF's UAV Fleet," 17.

58. As noted at the beginning of this chapter, 30 to 40 percent of any aircraft program costs were personnel expenses. This percentage increases as the number of crewmembers operating the aircraft increase (e.g., navigators, additional pilots, flight engineers, loadmasters, scanners, and flying crew chiefs).

59. Nelson interview, 12 April 2002. The FY02 contract cost was approximately $1.7 million and included a full year's worth of training for 36 basic vehicle operators, 16 instructor operator upgrades, 48 payload sensor operators, and 20 instructor sensor operator upgrades. Divided evenly, though by no means an accurate measure, the per operator cost comes out to $14,242.

60. Hoffman, "Non-SUPT Pilots to Control UAVs."

61. Slagel, "Point Paper on Mobility Pilot Retention."

62. Ibid. FY01 data reflects all eligible USAF pilots. Rates for AMC pilots mirror the USAF rate at 18 percent (122 accepted of 679 total).

63. Ibid.

64. Flade, "Teaching a New Dog Old Tricks," 7.

65. Taylor, Moore, and Roll, *The Air Force Pilot Shortage*, 5.

66. Tirpak, "The Robotic Air Force," 71; and Noguier, 105.

67. CBO, *Options for Enhancing the Department of Defense's Unmanned Aerial Vehicle Programs*, 33.

68. DARPA-USAF, "UCAV Program Overview," 18. The UCAV CONOPS employs a mission control system (operator station) driven by a 1553 data bus and operated through a 100 megabits per second network switch and global positioning system time server. The UCAV CONOPS also stated that operators will monitor/control multiple UCAVs, which would amount to additional manpower savings.

69. Noguier, "Next Mission Unmanned," 105.

70. Ibid.

71. DOD, *Defense Budget for Fiscal Year 2003*, 20.

72. Ibid., 12.

73. Wall and Fulghum, "Military Budget Boost Yields Marginal Change," 24.

74. The FY03 defense budget request totaled $379 billion—an increase of nearly 20 percent over the FY02 budget and at the time, the second largest annual increase in 20 years.

75. Air Force Link, "USAF C-17." http//www.af.mil/news/factsheets/C_17_Globemaster_III.html.

76. Boeing Company Phantom Works, "Advanced Theater Transport Fact Sheet."

77. DARPA-USAF, "UCAV Program Overview," 28. The UCAV CONOPS stated that UCAVs would be placed in long-term storage when not in use to lower maintenance and life-cycle costs.

78. Ibid., 4.

79. AMC, *Air Mobility Strategic Plan 2002 C-141 Roadmap* (U). (Secret). Information extracted is unclassified.

80. AMC, *Air Mobility Strategic Plan 2002 C-5 Roadmap* (U). (Secret). Information extracted is unclassified. The threshold figure of 180,000 pounds is based on a range of 3,200 nautical miles.

81. This figure assumes CRAF provides 20.5 MTM/D and that 180 C-17s provide 20.1 MTM/D. The rate of 20 to 31 UALV per year is based on the retirement of 17.2 C-5s per year (which provide an aggregate of approximately 3.1 MTM per year). Lastly, fleet size will vary depending on the existing airlift requirement, CRAF commitment, and maintenance state of the C-5 and the C-17.

Chapter 6

Analysis, Conclusions, and Implications

> *Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.*
>
> —Guilio Douhet

Analysis

The author began this paper by asking if there is a suitable role for unmanned airlifters in the USAF. A framework from historian Michael Howard was used as a way to break the question down into three subquestions. Each of the subquestions examined an important factor essential to determine if a role could exist for unmanned airlifters in the USAF. The subquestions follow:

1. What operational requirements justify unmanned airlifters?
2. Are current and emerging technologies likely to meet these potential operational requirements?
3. Are the concepts cost-effective?

Each subquestion was examined in-depth using primary and secondary evidence for determining the answer to the research question. Before the examination of each subquestion, however, a justification for UA was established under the guise of the US strategic airlift shortfall.

For more than 20 years, and perhaps longer, the United States has experienced an airlift shortfall. Several mobility requirements studies commissioned by the DOD over this period have openly acknowledged and quantified the nature of the shortage. Evidence was presented from the highest levels of the government and military via national strategic documents such as the NSS and NMS, characterizing airlift as the cornerstone of national and military power. Yet, the DOD has done little to ensure the nation has enough airlift to meet stated wartime requirements.

Although operational requirements do not presently exist for UA, unified combatant commanders and defense planners must first be made aware of its potential. Defense planners, for sound reasons, only think about capabilities available in the present with little regard paid to future requirements and capabilities. Furthermore, if it could be proven to unified combatant commanders that they could get sufficient airlift capability to fulfill wartime requirements in their areas of responsibility and get it less expensively, they would likely be interested.

Experience with unproven aircraft concepts implies a high reluctance on the part of the DOD and senior military leaders to commit to programs that show little near-term prospects of success. In the examination of airlift requirements, the author found that the DOD would lack sufficient capability should it have to implement the limits of the NMS outlined in the *QDR*. Because airlift has historically been an under-funded requirement, it was observed that alternatives to expensive airlift procurement programs providing equivalent capabilities at professed savings would merit DOD attention. Lack of sufficient aircrew, progress in emerging unmanned aircraft technologies, and increases in UAV R&D funding all provide the impetus to investigate the UA concept. Therefore, there must be reasonable assurances that UA could demonstrate a requisite level of technological feasibility before DOD officials commit to its procurement and acquisition.

Once operational requirements were established for UA, the next question to be answered was, "Are current and emerging technologies critical to UA likely to meet potential operational requirements?" The 2001 *UAV Roadmap* defined sufficient criteria necessary to evaluate technologies essential for the feasibility of any DOD unmanned aircraft program. These criteria—reliability, survivability, and autonomy—were adopted in this paper as the framework for analyzing the measures of merit, technologies, concepts, and support systems critical to the success of UA program. The examination revealed that UALVs should conceptually be employed in formations of up to six vehicles controlled and monitored by a manned airlifter "mother ship" housing mission control stations in the cargo compartment. The number of vehicles employed in the formation will undoubtedly be driven by operator span of control and aircraft maximum-on-the-ground considerations at operating airfields. Each operator could potentially be responsible for monitoring the flight progress of multiple UALVs. These determinations were made on the basis that airspace and air traffic management procedures cannot yet adequately accommodate autonomously employed UAVs through controlled airspace shared by manned aircraft, military or civilian. The prognosis was made that within the next decade air traffic management procedures might indeed be able to support autonomous UAV operations without difficulty.

The author determined that UA technological feasibility is dependent on strictly defined capability requirements, which the DOD must clearly articulate if the UA program is to have a chance of succeeding. For example, if a requirement to incorporate a fully ACHS is required onboard unmanned airlifters, timelines must be established at which point a defined capability demonstration occurs. The degree of success or failure in meeting demonstration goals will determine how the program will proceed. Extensive R&D is required for many of the technologies examined. However, technological development will proceed along evolutionary lines rather than revolutionary ones. One of the biggest technological hurdles to cross with UA is the issue of control mechanisms required to physically direct the movements of the vehicles. Whether control will be exercised remotely from ground stations or through technology similar to that used for existing formation station keeping is a question for developers and users. Employing airlifters in a constellation of aircraft simplifies command and control of the vehicles while drastically reducing difficult airspace management problems associated with integrating manned and unmanned aircraft in the same airspace.

Table 3 in chapter 4 summarizes the results of various measures of merit and concepts and provides a total technological feasibility estimate. The results suggest that an UA program is technologically feasible in the short-term to midterm, that is by 2022. Given clear operational requirements and borrowing from the best practices gained from successful UAV ACTD programs, it is conceivable to develop and design UALVs to augment the USAF manned airlifter fleet.

Finally, the overriding consideration behind any new defense program will be the issue of cost. Whereas current thinking about UAVs centers on the reduction of risk as a driving factor behind development, reduction of cost is the strongest argument for pursuing UA. Cost comparisons between manned reconnaissance aircraft and ISR UAVs, manned fighters and developing J-UCAS, and manned airlifters and notional UALVs revealed significant cost advantages in favor of unmanned platforms. Therefore, assuming technological feasibility of UA, a comparison of costs between manned and unmanned airlifters was extrapolated to reveal cost advantages of UA. In nearly every financial category, unmanned aircraft displayed the potential to meet or better the acquisition and life-cycle costs of manned aircraft. Initial projected UALV life-cycle costs should strive to be less than two-thirds that of manned aircraft life-cycle costs. This will allow for what UAV development history has shown, unanticipated cost growth. If cost growth extends beyond the costs of manned airlift programs, a reevaluation of the UALV program should be performed to ensure the effort is worth the investment. Even if costs grow, technological progress in the program will likely be applicable to other UAV roles and missions, thus advancing unmanned programs at-large. Keys to the financial capability of unmanned aircraft development programs of the future will be the avoidance of requirements creep, establishing firm timelines for the demonstration of key and critical technologies, and eventually, a potential to amortize high development costs over the life of a fleet. ACTD practices will allow potential UAV users to determine the viability and feasibility of UA with only a marginal up-front investment made to the program.

Conclusion

The author began this paper investigating whether a suitable role could exist for unmanned airlifters in the USAF. Evidence disclosed that in the short-term to midterm time frame, UA concepts and technologies would reach levels of maturity worth pursuing at this time.

A chronic strategic airlift shortfall exists if the US Strategic airlift forces are not properly sized to meet the needs of the NMS, which results in unnecessary risk to deploying troops ordered to distant theaters of conflict. UA offers the potential to reduce the airlift shortfall gap while reducing expensive training costs of flight personnel required to perform the mission. Given operational requirements and a mission need, the technological feasibility of UA is assured if directed efforts to improve existing technologies are made. Present and future potential characteristics of UAVs would suggest that unmanned aircraft are very likely to be used in future operations.[1] By capitalizing on the explosion of existing and emerging unmanned technology with the need for viable, cost-effective solutions to the airlift shortfall, the potential for unmanned airlifters is promising.

The conclusions of this study are,

1. There is an operational requirement for UALVs,
2. UALVs are technologically feasible within the next 20 years, and
3. UALVs offer a cost-effective solution to meeting the chronic shortfall in strategic airlift capability.

These findings are provisional and must be validated by more in-depth investigation. However, there is enough analysis behind them to make them strongly suggestive. At this point, one can only hope that continued thought about needed UAVs encourages defense officials, decision makers, and industry to consider future possibilities with an open mind-set. If not, this effort has at least broadened thinking about the alternatives to solve future defense issues. America needs alternatives to complement and augment expensive manned airlift to meet the strategic airlift shortfall.

For the ideas on the preceding pages to entertain reality, UAVs must surmount the current perception that they are only capable of successfully fulfilling and complementing the ISR role, and perhaps the air superiority and suppression of enemy air defenses roles. Planting the seeds now and considering what is possible in the future is a requirement for making it real. UA has sufficiently answered each research subquestion and in doing so has answered the primary research question: there unequivocally exists a role for unmanned airlifters in the Air Force.

Implications

The above conclusions suggest the following implications for various DOD agencies:

1. The DOD or their executive agents must perform a detailed cost-benefit analysis of all the factors examined in this paper to determine if the findings of this study are indeed valid. Afterwards, employ the best practices and lessons learned from the J-UCAS and other successful UAV programs to embark upon a moderate course of development.
2. Charge DARPA with the responsibility of investigating the feasibility of concepts for UA. As a conduit between USTRANSCOM, United States Joint Forces Command, the Air Force, the UAV Battlelab, and industry, DARPA should determine the viability of UA and assist in determining if it has potential to augment current airlift forces. Ensure technological integration efforts address the problems of past programs in which UAVs experienced uncontrollable cost growth and requirements creep.
3. War-game scenarios with unmanned airlifters. Establish a feasible CONOPS and employment in war games that exposes the strengths and weaknesses of UA for consideration in each phase of design, development, testing, evaluation, acquisition, and fielding.

Notes

1. Noguier, "Next Mission Unmanned," 113.

Glossary

ACH	automated cargo handling system
ACP	aviator continuation pay
ACTD	acquisition concept technology demonstration
AI	artificial intelligence
airlifter	plane used in the aerial movement of cargo, supplies and equipment
AMC	Air Mobility Command
ATT	advanced theater transport
BURU	Bottom-Up Review Update
C3I	command, control, communication, and information
CJCS	Chairman of the Joint Chiefs of Staff
CMDS	countermeasures dispense sets
CBO	Congressional Budget Office
CONOPS	concept of operations
CONUS	continental United States
CRAF	Civil Reserve Air Fleet
DARPA	Defense Advanced Research Projects Agency
DGPS	differential GPS
DPG	Defense Planning Guide
DOD	Department of Defense
EO	electro-optical
FAA	Federal Aviation Administration
FY	fiscal year
GAO	General Accounting Office
GPS	global positioning system
HLS	homeland security
ICAO	International Civil Aviation Organization
IOC	initial operational capability
IPL	integrated priority lists
IR	infrared
ISR	intelligence, surveillance and reconnaissance
JCS	Joint Chiefs of Staff

JPALS	Joint Precision Approach and Landing System
JPO-UAV	Joint Program Office for Unmanned Aerial Vehicles
JSF	Joint Strike Fighter
J-UCAS	Joint Unmanned Combat Air Systems
LAIRCM	large aircraft infrared countermeasures
Lasercom	ground-based laser communications
MANPAD	man-portable air defense
MITL	man in the loop
MQW	multiple quantum well (laser communications)
MRS	Mobility Requirements Study
MRS-05	Mobility Requirements Study 2005
MTM/D	"million ton miles per day"
MTW	major theater war
NAS	National Airspace System
NATO	North Atlantic Treaty Organization
NAVAIR-SYSCOM	Naval Air Systems Command (Also called NAVAIR)
NMS	National Military Strategy
NSS	National Security Strategy
O&S	operations and support
QDR	Quadrennial Defense Review
R&D	research and development
RAIM	receiver autonomous integrity monitoring
RDT&E	research, development, training, and evaluation
RF	radio frequency
RPV	remotely piloted vehicle
SAB	Scientific Advisory Board
SAR	synthetic aperture radar
SATS	Small Aircraft Transportation System
SEAD	suppression of enemy air defense
SUPT	Specialized Undergraduate Pilot Training

Tbps	terabits/second
TCAS	traffic collision and avoidance system
TPSA	technology, process, and system attributes
UA	unmanned airlift
UALV	unmanned airlift vehicle
UAV	unmanned aerial vehicle
UCAV	unmanned combat aerial vehicle
USTRANSCOM	United States Transportation Command
UT	unmanned transport
VHF	very high frequency

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