UNMANNED AIRLIFT:

A VIABLE OPTION FOR MEETING

THE STRATEGIC AIRLIFT SHORTFALL

BY

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DISCLAIMER

ABOUT THE AUTHOR

Lieutenant Colonel Chad T. Manske received a commission through the Air Force Reserve Officer Corps from Michigan State University in June 1989. After graduation from Undergraduate Pilot Training at Columbus Air Force Base (AFB), Mississippi in 1991, he was assigned to Malmstrom AFB, Montana from January 1992 to January 1994 as a KC-135 pilot. In February 1994 was reassigned to Barksdale AFB, Louisiana as a KC-10 pilot for 10 months in lieu of the Base Realignment and Closure (BRAC) unit move to McGuire AFB, New Jersey. Serving at McGuire from October 1994 to May 1998, Colonel Manske left as a KC-10 instructor pilot. He was subsequently selected for reassignment as a C-17 pilot to Charleston AFB, South Carolina where he served from June 1998 until July 2000. Colonel Manske is a senior pilot with over 3,100 flying hours. and 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, and a master's degree in Operational Art and Science from the Air Command and Staff College. He is a Distinguished Graduate of Squadron Officer School and a graduate of the Air War College and the School of Advanced Airpower Studies. In July 2002, Colonel Manske was assigned as the Air Force Special Assistant to the Commander of United States Joint Forces Command in Norfolk, Virginia. Colonel Manske is married to the former Stacey LoPrete; and they have three girls, Taylor, Madison, and Reilly.

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ABSTRACT

This study examines whether there is a suitable role for unmanned airlifters in the USAF. A three-pronged approach is undertaken to make this determination: 1) an examination of the operational requirements that justify unmanned airlifters, 2) an investigation into current and emerging UAV technologies that are likely to meet the operational requirements, and 3) an analysis of the cost effectiveness of unmanned airlift. The author begins by establishing the fact that a strategic airlift shortfall exists. Mobility requirements studies conducted over the past 20 years illustrate the point that if the nation were called upon to fulfill the wartime requirements outlined in the National Security and Military Strategies to fight one major theater war and multiple small-scale conflicts, the Air Force would be woefully short of strategic airlift. The author postulates the concept of unmanned airlift as a potential solution for meeting the gap between requirements and existing capability. The author concludes that operational requirements for airlift could be satisfied within 10 to 20 years, and that technologies essential to unmanned airlift are indeed both a technological feasible and cost effective alternative for complementing and augmenting the USAF's fleet of venerable airlifters.

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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

Over the last decade, the United States Air Force (USAF) has become increasingly aware of the utility of unmanned aerial vehicles (UAV). Positive experiences with UAV employment in the Gulf War and subsequent conflicts have highlighted the ability of these platforms to perform difficult missions with reduced human risk, generating increased demand among Air Force leaders. These experiences provide a foundation for rational steps forward into an extrapolated future. Both the Predator and Global Hawk UAV platforms have proven their ability to provide decision makers with accurate and timely intelligence, surveillance, and reconnaissance data and are becoming firmly established within the USAF force structure. The success of these programs has led to the development and testing of uninhabited combat aerial vehicles (UCAVs) designed to suppress enemy air defenses on the battlefield. The current successes enjoyed by the UCAV development program will likely lead to questions about the utility of UAVs in other roles. One such role that merits investigation is airlift. This leads to the primary research question of this study: Is there a suitable role for unmanned airlifters in the USAF?

To discover whether such a role exists, this study will examine the extant body of literature on the history, development, and future of UAVs. The framework of analysis for this study uses 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]

The analysis first addresses the US strategic airlift shortfall, then examines the research question by dividing it into three major sub-questions using Howard's criteria. First, it examines operational airlift requirements to discern the status of airlift for the DOD (Department of Defense) and United States (US) security and interests. A synthesis of National Security Strategy (NSS) and National Military Strategy (NMS) documents and other strategic level defense guidance is used to link the requirement for airlift to national security. The study next postulates UAV requirements pertaining to airlift. The discussion then begins building a foundation for using unmanned airlift vehicles (UALVs) as a means to satisfy airlift requirements. USAF Scientific Advisory Board (SAB) studies on future force structure requirements contribute insights into this issue and aid in establishing a notional requirement for UALVs for the USAF.

[1] Michael Howard, "Military Science in an Age of Peace" (*Journal of the Royal United Services Institute for Defence Studies*, March 1974): 5.

The study then investigates the issue of UALV technological feasibility. Current and emerging technologies are assessed to determine if, when, and under what conditions it will be possible to develop a prototype unmanned airlift vehicle.

Finally, this thesis addresses the question of financial capability by synthesizing the various cost and UAV acquisition processes to determine the fiscal advantages and disadvantages of UALV development. In short, the three big sub-questions are as follows:

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

This paper uses some terms that 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 and unmanned airlift are used interchangeably to denote the aerial movement of cargo, supplies and equipment without a human operator aboard. Finally, several times throughout this study the following terms are used to designate specific periods of the future: short-term: 2002-2012; mid-term: 2012-2022; long-term: 2022-2032.

Background and Significance of the Problem

[2] Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms* (Washington D.C.: 12 April 2002), 450. On-line, Internet, 6 May 2002, available from http://www.dtic.mil/doctrine/jel/doddict/.

UAVs provide significant advantages over manned aircraft platforms in some mission areas. Thus, given the strategic airlift shortfall chronically experienced by the DOD, the development of an unmanned airlift vehicle may provide the capability to reduce the shortfall within existing funding levels. According to the DOD's 2001 UAV Roadmap, the document used to assist the DOD in developing a long-term strategy for UAV development between the years 2000 and 2025, UAVs are force multipliers that can increase unit effectiveness in an era of decreasing force size.[3] This study 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, and of unmanned transport, in particular.[4] When the USAF Scientific Advisory Board penned these studies six-to-seven years ago, its evaluation of unmanned transport 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 study titled *New World Vistas* contained several volumes specifically investigating widespread UAV applicability to meet future Air Force roles and missions.

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[3] Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap: 2000-2025* (Washington, D.C., April 2001), ii. On-line, Internet, 25 April 2002, available from http://www.acq.osd.mil/usd/uav_roadmap.pdf.

[4] See the following studies for more in-depth information: United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations*, Volume I, 1996. On-line, Internet, 7 December 2001, available from http://www.fas.org/man/dod-101/sys/ac/docs/ucav96/index.html; United States Air Force Scientific Advisory Board, *Report on UAV Technologies and Combat Operations,* Volume II: Summary (November 1996); Lt Col James A. Fellows, LCDR Michael H. Harner, Maj Jennifer L. Pickett, and Maj Michael F. Welch, "Airlift 2025: The First with the Most" (Maxwell AFB, Ala.: Air University, August 1996). On-line, Internet, 10 April 2002, available from http://www.au.af.mil/au/2025/volume2/chap04/v2c4-1.htm; and United States Air Force Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, Mobility Volume (Washington D.C.: USAF Scientific Advisory Board, 1995). *New World Vistas* in further citations.

One volume of this study focused on mobility. The mobility panel, which wrote that volume, 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 solely military technologies.[5] The mobility panel identified nineteen mission areas in which future technologies could influence mobility applications.

The panel rank-ordered the list of missions using another set of evaluative criteria and concluded that unmanned transport ranked 12th of 18 on the list.[6] The panel 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 unmanned airlift.[7] However, 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 unmanned transport 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 enthusiasm today.

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[5] *New World Vistas*, A-1.
[6] Ibid., 31.
[7] Ibid., 19.
[8] Ibid.

WHY DO WE HAVE UAVS?

UAVs have been considered a practical alternative to manned reconnaissance flight ever since Francis Gary Powers's 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. However, therein lies the difficulty in determining operational requirements for unmanned airlift roles and missions. The need to mitigate risk to accomplish a very 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. However, as with all Air Force missions, risk management procedures will dictate acceptable levels of risk. Nevertheless, if one is to make a case for unmanned flight operations of any kind, the reasons must be sound before the DOD will provide funding.

UAVs have been very popular instruments of war for the last dozen 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 begun to drive even better capabilities than were previously thought possible.[10] In many ways, rapid advancements in UAV

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[9] Thomas E. Ricks and Anne Marie Squeo, "Why the Pentagon is Often Slow to Pursue Promising New Weapons" (*Wall Street Journal*, 12 October 1999), 1.

[10] R. Barry Walden, "The Use of Modeling and Simulation in the Systems Engineering of Unmanned Aerial Vehicles" (Fall 1998), par 1.0. On-line, Internet, 24 October 2001, available from http://www.glue.umd.edu/~bwalden/project.html.

technologies created by this circular process make for "technologically ambitious" UAV programs that also turn out to be very affordable.[11]

ASSUMPTIONS

A couple of assumptions are made at the outset of this study.

1. The first assumption is that no passengers will be carried on the unmanned airlifters discussed in this study. If UALVs become a reality, they will likely only carry cargo until they have been proven extremely safe. The idea of carrying passengers in an aircraft with no pilots aboard is fraught with moral and ethical issues that cannot be addressed at this time. In the future, when technology matures to a sufficiently safe level, UALV passenger craft may become a reality.

2. The second assumption is that 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. They will also be needed to perform complex and specialized missions in 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 examines the chronic strategic airlift shortfall that unmanned airlift can potentially solve. This review highlights the importance of strategic airlift in the execution of national security and military strategy. Arguably, US strategy cannot be

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[11] Ibid.

[12] Lt Col Dana A. Longino, "Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios" (Maxwell AFB, Ala.: Air University Press, December 1994), xi; and, Clayton K. S. Chun, *Aerospace Power in the Twenty-First Century* (Colorado Springs, Colo and Maxwell AFB, Ala.: United States Air Force Academy in cooperation with Air University Press, July 2001), 295.

promulgated without adequate strategic airlift in sufficient quantities. The constant airlift shortfall can be overcome with UALVs.

Chapter 3 examines 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 fifteen years.

Chapter 4 assesses the technological feasibility of unmanned airlift. An evaluation of current, emerging, and conceptual technologies is placed into a mosaic 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 examines financial capability with respect to UAVs as a measure to alleviate the nation's strategic airlift shortfall. Analysis of costs associated with UAV development are examined and comparisons, when applicable, are made between manned and unmanned aircraft costs. The costs of decreasing readiness levels and the lack of retaining enough quality people to carry out our national objectives are probed. These costs increase the risk to securing our national interests while simultaneously placing a burden on our men and women who seem to be in short supply.

Chapter 6 summarizes and synthesizes the findings of the previous chapters. It then assesses the implications of the study for the future of UALVs.

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, USAAF, 1945

With the onset of the 1948 Berlin Airlift, US airlift forces gained new prominence in the eyes of national policymakers as they sustained a besieged city for nearly a year. Because of its decisiveness in affecting political opinion, policy makers enthusiastically embraced airlift during the Korean War. Its use was sorely needed in Korea because the force structure and logistical posture in theater were inadequate, and because Korea itself was distant from the continental US. To facilitate an adequate force structure for the war, Air Force Gen William H. Tunner in 1950 consolidated control of all Air Force airlift, to include its operations, support, and maintenance functions. General Tunner's reorganization optimized airlift's ability to support rapid troop movements and faster resupply of 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.[13] Although a major part of the debate revolved around the allocations of the declining military budget, none of the participants was willing 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.

[13] Col Robert C. Owen, "The Rise of Global Airlift In the United States Air Force 1919-1977: A Relationship of Doctrine, Power, and Policy," work in progress, 97.

Consequently, the airlift fleet underwent an unprecedented peacetime expansion.[14] The Vietnam War further highlighted the increasing utility of strategic airlift through the transport of record-breaking tonnages.[15] The trend toward greater requirements for airlift continued up to the Gulf War and beyond.

Even as political decision makers, military strategists, and theater commanders became more reliant on strategic airlift to deliver large tonnages in short time spans, the requirements for this capability always exceeded its supply. Despite airlift's higher profile, lawmakers never allocated enough capability to meet stated national security strategies and objectives. Recent commanders of America's airlift forces argued forcefully to acquire more capability to meet those objectives, but pleas for more assets have received mixed responses in spite of Congressionally mandated studies calling for more aircraft.

Statements made by the former and current USTRANSCOM commanders highlight both 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."[16]

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[14] Ibid., 101.

[15] Keith A. Hutcheson, *Air Mobility: The Evolution of Global Reach* (Beltsville, Md.: Point One Inc., 1999), 14.

[16] Quoted by Gen Charles T. Robertson, Jr., then CINCTRANSCOM and Commander, USAF Air Mobility Command, from Christian Lowe, "Military Not Able to Meet Airlift Requirement for War" (*Defense Week*, 18 December 2000), 12.

Similarly, General Handy, the current USTRANSCOM combatant commander, 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."[17] These statements, backed up by comprehensive studies on the issue, should not be taken lightly.

When terrorists struck the US homeland on 11 September 2001, the US 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 capability necessary to begin those operations. After a few months of extremely high tempo operations conducted 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, argued that the operations punctuated the need for more airlift.[18] C-5 and C-17 airlifters transported most of the equipment that went by air. With regard to the high utilization rate of C-17s in the war, Bowlds maintained that, "like any weapon system, in times when you're using them at higher rates than anticipated, they tend to wear out faster."[19]

Because of the war against terrorism, which is expected to "last as long as it takes," and the emphasis on homeland security measures, Congress budgeted an

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[17] Quoted by Gen John W. Handy, USTRANSCOM combatant commander, and Commander, USAF Air Mobility Command from, Harry Levins, "Transportation Command's Chief Emphasizes the Need for More C-17 Cargo Planes" (*St. Louis Dispatch*, 2 February 2002), 9.
[18] "With C-17 Negotiations Final, Air Force Mulls Expanding New Contract" (*Inside the Air Force*, 18 January 2002), 1. This statement was quoted by then Col Ted Bowlds, in a 14 January 2002 interview with Inside the Air Force.
[19] Ibid.

unprecedented $379 billion to defense programs for FY 2003.[20] Furthermore, the Air Force expects to sign a contract with Boeing in the spring of 2003 for an additional 60 C-17s, bringing the purchase total to 180 aircraft.[21] Thus, it is important for the DOD and the Air Force to consider long-term alternatives for increasing airlift capacity while the Congress and American people seem willing to open the nation's pocketbook for national defense.

Since 11 September 2001, the Pentagon has initiated a comprehensive review of its mobility requirements to reflect the demands applied to the defense transportation system. The DOD review will be based on the updated operational scenario described in the September 2001 release of the Pentagon's Quadrennial Defense Review (QDR). The previous scenario assumed nearly simultaneous conflicts in Southwest Asia and on the Korean peninsula, otherwise known as a two major theater war (MTW) scenario. This taxed airlift forces to the extent that deploying forces were put at risk. The most recent QDR established scenarios far more difficult to define than the two MTW scenario, which means an even greater need for airlift capability.[22]

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. Subsequently, risk was assessed in the Mobility Requirements Study 2005 (MRS-05) through assessments evaluating "the ability of US/coalition forces to achieve measurable warfighting

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[20] Department of Defense, "2003 Defense Budget is Investment in Transformation" 4 February 2002. On-line, Internet, 21 February 2002, available from http://www.dtic.mil/comptroller/fy2003budget/fy03budget1.doc.
[21] Robert Wall, "Pentagon Scrubs Airlift Needs for Homeland Defense, War Effort" (*Aviation Week and Space Technology*, 28 January 2002), 62.
[22] Ibid.

objectives."[23] MRS-05 examined airlift requirements from top to bottom, making considerations for both inter- and intra-theater strategic airlift capability, while also investigating continental US (CONUS) airlift requirements.[24] The results of these assessments are examined in Chapter 3.

One of the alternatives to the airlift shortfall suggested by some is to increase the number of Civil Reserve Air Fleet (CRAF) participants. However, according to one report, "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."[25] These limitations have fueled a controversy over a satisfactory solution to the nation's airlift shortfall. On the one hand, it seems that by contracting more CRAF carriers, the problem lessens. However, the US requires specialized military airlift for transport into potentially hostile areas, a capability the CRAF does not possess. Increasing CRAF carrier participation is not the right answer to these woes. 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."[26] While CRAF is an extremely important component of American airlift capability, without a robust organic airlift fleet to move oversized and outsized cargo, as well as the capability to

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[23] John A. Tirpak, "The Airlift Shortfall Deepens" (*Air Force Magazine*, April 2001), 58. On-line, Internet, 24 January 2002, available from http://www.afa.org/magazine/April2001/0401airlift.html.
[24] See Office of the Joint Staff, "Mobility Requirements Study 2005 Executive Summary," (December 2000). On-line, Internet, 25 April 2002, available from http://www.dtic.mil/jcs/j4/projects/mobility/execsummrs05.pdf.
[25] Interview with Maj Victor DelMoral, Headquarters, AMC/DOF, 9 June 2000, paraphrased in Col Robert C. Owen and Capt Todd A. Fogle, "Air Mobility Command and the Objective Force: A Case for Cooperative Revolution," January/February 2001, On-line Internet, 26 November 2001. Available from http://www.cgsc.army.mil/milrev/English/JanFeb01/owen.htm.
[26] Gen Charles T. Robertson, Jr., "Statement Before the Senate Armed Services Sea Power Committee on Strategic and Tactical Lift in the 21st Century," 10 March 1999, 13.

transport it far closer to hostilities than CRAF aircraft are able, the credibility of US national security and military strategy is in jeopardy.

In short, the nation is experiencing a strategic airlift shortfall. Despite the Air Force's potential purchase of 60 more C-17s, bringing the total acquisition up to MRS-05 required levels, a new national strategy has been published by the Secretary of Defense. The new strategy dispenses with the former two MTW scenario, and substitutes for it a much broader, capabilities-based approach requiring "planning for a wider range of contingencies."[27] This suggests that the airlift we have on order is probably not enough to meet operational requirements. In addition, procuring significant airlift capability to meet requirements is likely to cost more than the DOD has or is willing to spend. Additionally, building a capabilities-based airlift force for broad, unknown, and potentially hostile situations will likely make implementing the strategy a difficult and risky proposition at best, let alone a cost-effective one. The idea of increasing airlift capability cost effectively, with significantly reduced risks, combined with advances in unmanned aircraft technology, yields a potential vision for unmanned air transport.

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[27] Department of Defense, *Quadrennial Defense Review Report*, 30 September 2001, 61. On-line, Internet, 10 April 2002, available from http://www.defenselink.mil/pubs/qdr2001.pdf.

CHAPTER 3

OPERATIONAL REQUIREMENTS

In view of the information GAO developed and DOD's position, the Congress should scrutinize proposed manned aircraft developments to assure that 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

As lead command for the DOD's airlift program, AMC is charged with 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 Air Mobility Strategic Plan. The executive summary of the Strategic Plan states that airlift forces play a fundamental role in US national security through their conduct of operations other than war, power projection, and force sustainment.[28] However, the plan cautions that more effort must be expended to increase airlift capacity in order "to meet future capability requirements."[29] How did airlift become such an important component of US security and where does the strategic guidance originate for outlining airlift requirements?

This chapter provides a top-down survey of rapid global mobility's critical role in the achieving national objectives. This survey allows one to deduce how airlift requirements are generated. Next, UAV requirements processes are examined to

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[28] Air Mobility Command, "Air Mobility Strategic Plan 2002 Executive Summary," October 2001; and On-line, Internet, 15 January 2002, available from https://amc.scott.af.mil/xp/xpx/STRATPLAN2002FOUO/Executive_Summary.htm.
[29] Ibid.

demonstrate the increasing reliance on UAVs to fulfill a growing list of unified combatant commander missions. Finally, airlift requirements and needs are combined with the growing list of UAV capabilities to conceptualize an unmanned airlift vehicle. The argument then leads to a determination of possible requirements for unmanned airlift vehicles in support of national strategy.

STRATEGIC DOCUMENT REVIEW

US national strategic level guidance originates with the President's NSS. It is then filtered down through the Chairman of the Joint Chiefs of Staff's (CJCS's) National Military Strategy (NMS). Strategic airlift forces are important enablers of this strategy. As a force operating around the world and around the clock, strategic airlift capabilities show American resolve and presence through the rapid aerial delivery of combat troops and equipment.

For the sake of argument, this thesis uses national security strategy examples from the most recently published NSS, that issued in 2000. 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 US must transform capabilities, technologies and organizations that meet tomorrow's challenges. According to the 2000 NSS, this requires an investment in focused science and technology efforts, concept development, and experimentation.[30]

[30] United States, Executive Office of the President, *A National Security Strategy for a Global Age* (White House, December 2000), 1.

NATIONAL SECURITY STRATEGY

The NSS's primary function is to provide high-level guidance leading to the accomplishment of national objectives. The latest NSS makes clear the significance of strategic lift: "strategic mobility is critical to our ability to augment forces already present in the [sic] region with the projection of additional forces for both domestic and international crisis response. This agility in response is key to successful American leadership and engagement."[31] Without a robust strategic airlift fleet, America lacks the credibility to fulfill commitments in support of its interests. The NMS further elucidates airlift's critical role as an integral part of the CJCS strategy to support the NSS.

NATIONAL MILITARY STRATEGY

Similar in organization to the NSS, the NMS furnishes advice from the CJCS in conjunction with the Joint Chiefs of Staff (JCS) and unified combatant commanders for the strategic direction of the services.[32] The NMS also outlines the US national military objectives, the international strategic environment, and how US military capabilities fulfill the strategy to achieve those objectives.[33] Three distinct objectives are articulated in the NMS. The objectives are to shape, to respond, and to prepare now for an uncertain future. The NMS objectives parallel those in the NSS, but are narrower in scope and focus specifically on military matters.

For strategic airlift, the "respond" objective means responding "to crises across the full range of military operations, from humanitarian assistance to fighting and

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[31] Ibid., 20.
[32] Office of the Chairman of the Joint Chiefs of Staff, *National Military Strategy of the United States of America* (Washington, D.C., September 1997), 1. On-line, Internet, 22 February 2002, available from http://www.dtic.mil/jcs/nms.
[33] Ibid., 5.

winning MTWs and conducting concurrent smaller-scale contingencies."[34] Failing to meet that requirement has dire implications for the security of the nation. Although mandated to prepare for two nearly simultaneous MTWs by the NMS, the DOD arguably has never possessed the strategic airlift required to meet this goal.[35] It is vital for US military forces, as an international power with global interests, to deter and defeat cross-border aggression around the globe. A deficiency in this capability "would signal to key allies our inability to help defend mutual interests, thus weakening our alliances and coalitions."[36] 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 is the functional unified command, and the parent command to AMC, charged with managing the Defense Transportation System. It is accountable for generating 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.[37] Like the NSS and NMS, the USTRANSCOM Strategic Guidance outlines its strategy in parallel to the "shape, respond and prepare now for an uncertain future" paradigm mentioned previously. To shape the environment, the command provides properly trained mobility forces.[38] It responds by mobilizing those

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[34] Ibid., 15.

[35] Interview with Col Michael Fricano, Chief, AMC Studies and Analysis Division (AMC/XPY), on 1 March 2002. Col Fricano's division was responsible for providing the Joint Staff data for consideration in the Mobility Requirements Study 2005 described later in this chapter. Col Fricano stated that US organic airlift forces are sized to accommodate only one MTW at this time.

[36] Ibid.

[37] United States Transportation Command, "Strategic Guidance FY 2002" (2001), 3. On-line, Internet, 2 May 2002, available from http://www.transcom.mil/J5/fy02sg.pdf.

[38] Ibid., 4.

forces to transport mission essential personnel and equipment where needed. USTRANSCOM prepares now for an uncertain future through an enterprising modernization program guaranteeing US technological superiority in selected war fighting capabilities.[39] To attain these goals, the command strives to achieve defense transformation in accordance with Secretary of Defense Rumsfeld's vision for 21st century military forces.[40]

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 21st century.[41] But, the command also acknowledges difficulties in fulfilling national goals and objectives of future military forces: "The challenge is to exploit future technological advances, foresee the obsolescence of current systems, and plan for their replacement."[42] It is this challenge that is the basis for this thesis.

A CORE COMPETENCY: RAPID GLOBAL MOBILITY

The Air Force professes expertise in six core competencies. They are air and space superiority, precision engagement, rapid global mobility, information superiority, global attack, and agile combat support. Of the six, rapid global mobility allows the movement of troops and equipment required to accomplish the objectives of the national strategy. With regard to airlift requirements, the US must possess sufficient capability to account for the decreased access to overseas bases that has occurred over the last decade.

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[39] Ibid.
[40] Ibid.
[41] Ibid., 5.
[42] Ibid.

It also means possessing the economic strength to finance that capability. Because core competencies define the USAF's greatest attributes and are imperative for the application of airpower, sufficient airlift forces are required to enable them. Defining what constitutes sufficient, however, has been no easy task.

Airlift Requirements

For more than 20 years, the US has attempted to quantify its airlift needs. The Congressionally Mandated Mobility Study published in 1981 was the first of several assessments. It set a strategic airlift objective for the transport of 66 million tons miles of cargo per day (MTM/D) to meet the requirements of the unified commanders in addition to published national security and military strategies.[43] In 1992, after the collapse of the Soviet Union, the Mobility Requirements Study (MRS) was published. It set an objective of 57 MTM/D resulting from the NSS mandate to fight two MTWs.[44] Three years later the MRS Bottom Up Review Update (BURU) was published, this time reducing the airlift requirement to 49.7 MTM/D.[45] This study, for the first time, accounted for the contributions of organic airlift and contracted commercial aircraft known as the Civil Reserve Airlift Fleet (CRAF). A small portion of the airlift requirement, approximately 20.7 MTM/D, was designated for CRAF, while the rest was made the responsibility of the USAF.[46]

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[43] United States General Accounting Office, *Military Readiness: Air Transport Capability Falls Short of Requirements* (Washington D.C., June 2000), 27. On-line, Internet, 2 May 2002, available from http://www.intellnet.org/documents/200/060/261.pdf. MTM/D is a measurement of airlift capacity roughly translating to transporting a given amount of cargo over a given distance. Air Mobility Command computes the measure using a formula of the product of an aircraft's available flying hours per day, nautical miles per hour, expected average load in short tons, and a factor that accounts for returning empty, and divides the factor by one million.
[44] Ibid.
[45] Ibid.
[46] Ibid.

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 major theater wars occurring nearly simultaneously.[47] MRS-05 attempted to account more precisely for some of the factors not considered in previous mobility studies by including them in its assumptions. These factors included requirements such as intra-theater airlift and special airlift missions flown in excess of those supporting the two MTW scenario. These refinements better approximate actual airlift operations than do previous studies.[48]

MRS-05 also accounted for other significant factors affecting airlift operations not previously considered. Figure 1 depicts the airlift requirements derived from MRS-05 and warrants some explanation. As a minimum, 51.1 MTM/D is required to prosecute the intra-theater movement of equipment from one MTW to another. 1.6 MTM/D is required to support special operations, .9 MTM/D was added to support theater combatant commander requirements and the transport of missile defenses to a combat theater, and another .9 MTM/D was added to support theaters not engaged in combat, but nonetheless requiring airlift support. This increased the total requirement to 54.5 MTM/D, which is the minimum necessary established to transport wartime equipment and troops between two theaters of war.

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[47] Ibid., 6.

[48] Office of the Joint Staff, *Mobility Requirements Study 2005 Executive Summary* (Washington D.C., December 2000), 4. On-line, Internet, 25 April 2002, available from http://www.dtic.mil/jcs/j4/projects/mobility/execsummrs05.pdf. *MRS 2005* in further citations.

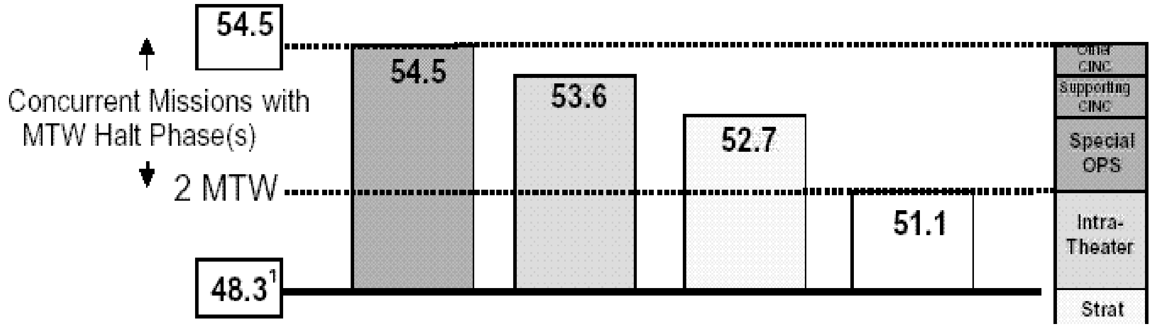

Figure 1. MRS-05 Airlift Requirements

[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.[49]

Source: Office of the Joint Staff, *Mobility Requirements Study 2005 Executive Summary* (Washington D.C., December 2000), 5. On-line, Internet, 25 April 2002, available from http://www.dtic.mil/jcs/j4/projects/mobility/execsummrs05.pdf.

Finally, under other various credible scenarios, an airlift requirement of 67.0 MTM/D was established.[50] Altogether, these requirements were, and still are, well beyond the capability of US airlift.[51] The CRAF can feasibly handle 20.5 MTM/D of the requirement, while AMC organic airlift can only transport approximately 19.4 MTM/D.[52] More recent estimates set the organic capability at 24.7 MTM/D, increasing the combined

[49] Fricano interview, 1 March 2002.
[50] *MRS 2005*, 4.
[51] Based on AMC news reports in mid-March 2002, the combined CRAF and AMC organic airlift capability amounted to 45.2 MTM/D. AMC's intent to purchase 60 additional C-17s beyond the 120 already contracted adds another 6.7 MTM/D for a total of 51.9 MTM/D. This number still falls short of the 54.5 called for in MRS-05.
[52] United States General Accounting Office, *Updated Readiness Status of U.S. Air Transport Capability* (Washington D.C., 16 March 2001), 12. On-line, Internet, 2 May 2002, available from http://www.aviationtoday.com/reports/air0327.pdf ; and Ibid., 11. 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; but it does account for the KC-10 additive capability of 3.0 MTM/D since MRS-05 did account for its limited cargo contributions.

USAF and CRAF capability to 45.2 MTM/D.[53] Based on a requirement of 54.5 MTM/D, this results in a 9.3 MTM/D capability gap, which is 17.1 percent short of required capability.

This chronic capability gap suggests two things. First, feasible solutions must be addressed to close the gap. If defense planners establish realistic assumptions regarding future defense scenarios, capabilities should match requirements. Next, if meeting the requirement is completely out of reach, the strategy should reflect that reality. Stretching US airlift forces beyond their limits will result in their eventual failure. Realistically, DOD will opt to reduce the gap by increasing capability in accommodation of the strategy. The GAO, the independent auditing arm of Congress, addressed the implications of ignoring the shortfall.

In a 2000 study on air transport readiness, the GAO validated what Air Force officials had been saying for some time about the state of the airlift fleet and its capabilities.[54] The study maintained the shortfall was not due solely to a lack of capability, but to additional factors as well. For instance, between fiscal years (FY) 1997 and 1999, only 55 percent of the C-5 fleet, on average, was mission capable.[55] This implied that merely possessing airlift capacity alone did not guarantee its availability for a crisis or contingency. Other variables also affect the mission capability rate. One is the lack of available aircraft spare parts for the airlift fleet. Another is the amount of time spent undergoing depot maintenance. Yet another is the simple reduction of aircraft

[53] Ibid, 12. As of the writing of this thesis, total USAF airlift capability, based on AMC news reports, was 45.2 MTM/D. The increased capability results from the addition of C-17s coming off the assembly line.
[54] United States General Accounting Office, *Military Readiness*, 50.
[55] Ibid., 5.

resulting from procuring only half as many C-17s to replace retiring C-141s.[56] Cumulatively, the significance of these variables suggests the existing airlift force structure cannot support the NSS and NMS. As the airlift fleet continues to age, its capability will continue 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	FY1997-99 Average* peacetime rates	FY 2000 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 fiscal years 1997 – 99. Average mission capable rates for the C-141 and C-17 were based on fourth quarter fiscal year 1999 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.

Source: United States General Accounting Office, "Updated Readiness Status of U.S.

Air Transport

Capability," 16 March 2001, 10. On-line, Internet, 2 May 2002, available from http://www.aviationtoday.com/reports/air0327.pdf.

[56] Ibid., 9.

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

CAPABILITY SOLUTIONS

The shortfall capability gap is likely to expand depending on the outcome of a new mobility requirements study. Emerging homeland security requirements are further exacerbating the airlift shortage.[57] In addition, the global war on terrorism is also having an adverse effect on the shortage.[58] The Joint Staff obviously did not account for either of these factors in MRS-05 because they had not occurred. But they are, and remain, open-ended commitments that airlift forces must support. Long-term solutions are something that must be considered.[59]

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

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[57] This statement was made by Gen John W. Handy as reported in: Frank Wolfe, "Air Force Seeks to Allay Concerns of DoD, Hill on Multiyear Financing for C-17s" (*Defense Daily*, 19 February 2002), 4.
[58] Robert Wall, "Pentagon Scrubs Airlift Needs for Homeland Defense, War Effort" (*Aviation Week and Space Technology*, 28 January 2002), 62.
[59] Ibid.

4. Prioritize funding for airlift…operations and modernization to…levels commensurate with achieving and sustaining the desired capability levels[60]

Option one is unrealistic in comparison to the other three because of the dynamic nature of the strategic environment and American unwillingness to accept unnecessary risk. Option two has been implemented by the QDR as referenced earlier. Option three, like option one, is also unrealistic, especially in light of the events that have occurred since 11 September 2001. Both the DOD and the Air Force, through additional C-17 acquisition and C-5 modernization, are pursuing option four, albeit at great expense.

It is difficult to quantify the requirements necessary to satisfy the seemingly endless number of operations tasked for airlift forces over the last decade.[61] The number of military operations other than war (MOOTW) the US may become involved with, including small-scale contingencies (SSCs), is expected to rise, hailing a call for increased mid-term airlift capability.

Requirements for wartime air transportation cannot be met with existing capabilities. If airlift is indeed the "foundation of US national security at the strategic level," DOD must adequately fund it.[62] In lieu of adequate funding, alternative cost effective measures must be examined to increase capability to 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

[60] United States General Accounting Office, *Military Readiness*, 19.
[61] Ibid.
[62] United States Air Force, *Air Force Doctrine Document 2-1: Air Warfare* (Washington D.C., 22 January 2000), 17. On-line, Internet, 5 May 2002, available from http://afpubs.hq.af.mil/pubfiles/af/dd/afdd2-1/afdd2-1.pdf.

yield a solution for closing the airlift capability gap. Examining the UAV requirements process illuminates this investigation.

UAV requirements

Until recently, UAV requirements have grown out of a demand for persistent, systematic intelligence, surveillance, and reconnaissance at lower risk to aircraft operators. The demand for UAV systems comes primarily from defense users. This demand, in turn, drives requirements and the acquisition of UAV systems. Yet, how does demand for UAVs become a requirement? A researcher who authored a study on 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, 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.[63]

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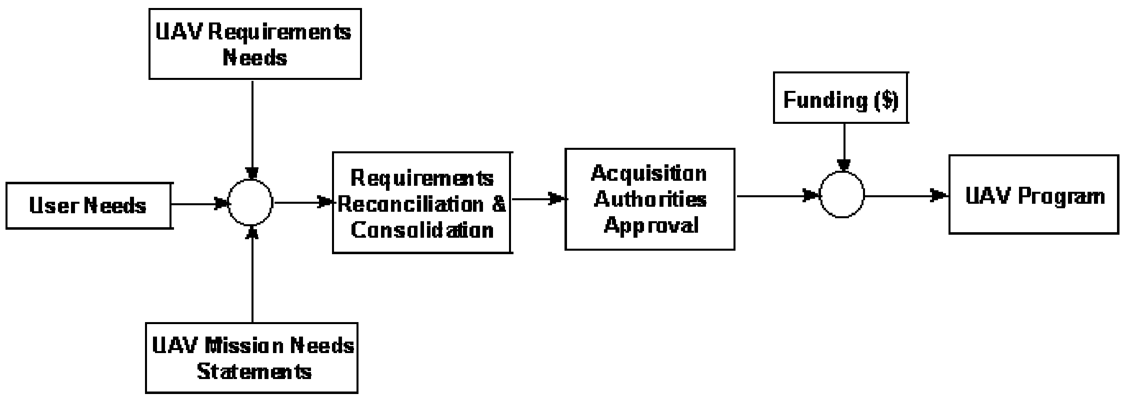
[63] R. Barry Walden, "The Use of Modeling and Simulation in the Systems Engineering of Unmanned Aerial Vehicles," Fall 1998. On-line, Internet, 24 October 2001, available from http://www.glue.umd.edu/~bwalden/project.html.

This process relies on inputs from potential users as well as from developed mission needs statements.[64] Subsequently, the inputs are reconciled and consolidated to avoid duplication. They are then processed and approved by the acquisition authority, after which the UAV program is funded and the system is built. Figure 2 provides an illustration of the requirements generation process.[65]



Source: R. Barry Walden, "The Use of Modeling and Simulation in the Systems Engineering of Unmanned Aerial Vehicles," Fall 1998, on-line, Internet, 24 October 2001, available from http://www.glue.umd.edu/~bwalden/project.html.
Figure 2. Requirements Generation and UAV Program Development Process

IDENTIFYING UAV REQUIREMENTS

Within the DOD, UAV requirements are identified via Integrated Priority Lists (IPLs). 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 IPLs for funding in the FY02-

[64] The Mission Needs Statement is a document used within 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. *Source*: United States General Accounting Office, *DoD's Use of Remotely Piloted Vehicle Technology Offers Opportunities for Saving Lives and Dollars* (Washington D.C., 3 April 1981), 15.
[65] Walden, "The Use of Modeling and Simulation."

07 Future Year Defense Plan (FYDP), 57 (39 percent) identified 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."[66] Technology is the primary impetus behind UAV requirements-generation.[67] UAV users want them to go "farther, faster, and do more things for low-cost and simplicity."[68] Using available and relevant technologies simplifies the UAV system yet requires a major investment.[69] In order to meet users' requirements, a technology push is needed. But, a major problem with a technology push is the underestimation of the technological challenges in developing UAV systems. Technology limitations withstanding, the USAF is embarking on a path toward developing and building combat UAVs. This developmental methodology is a natural extension of the risk-eliminating characteristics inherent with UAVs.

As recently as a few years ago, many in the defense industry and Congress could not envision unmanned combat systems development and testing until at least a decade into the 21st century. Several factors have come together to change that mentality. First, Operation Allied Force confirmed the notion 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 have

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[66] Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000-2025* (Washington, D.C., April 2001), 13. On-line, Internet, 25 April 2002, available from http://www.acq.osd.mil/usd/uav_roadmap.pdf. *UAV Roadmap* in further citations.
[67] Walden, "The Use of Modeling and Simulation."
[68] Ibid.
[69] Ibid.

fueled renewed interest in the possibility of sending armed unmanned combat aircraft into hostilities where risk is unknown or potentially high. Third, Congress has felt compelled to respond to increased awareness among America's desire for reduced combat casualties as a result of advances in precision weaponry over the last dozen years. The response from Congress came in the form of initiatives in the Fiscal Year 2001 Defense Authorization Bill that steeply increased previously meager funding for research and development of unmanned combat systems.

The JCS began reviewing requirements for UAV programs in 1984. They determined at that time that sensors, electronics, and vehicle design had sufficiently matured to transcend the technical problems plaguing previous efforts.[70] The JCS supported a vision for the advancement of UAV concepts, which fueled renewed interest in previously lackluster 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."[71] UAVs are now a normal aspect of Air Force operations.

Many considerations contribute to the decision to fulfill operational requirements with a UAV. But, deciding whether to fulfill a requirement with UAVs, manned aircraft, or both requires thoughtful consideration of several factors. Among them are "the

[70] Steven Kosiak and Elizabeth Heeter, "Unmanned Aerial Vehicles: Current Plans and Prospects for the Future" (Center for Strategic and Budgetary Assessments, 11 July 1997), On-line, Internet, 24 October 2001, available from http://www.csbaonline.org.
[71] Ibid.

scenarios to be encountered, the missions and tasks, the alternatives, the relative risks, the relative costs of the tasks and the maturity of the technologies."[72] Each must be weighed against the requirement to ensure UAVs are the right tool. According to the USAF SAB, the right combination of manned and unmanned aircraft platforms is decided after operational validation and use of the aircraft and the associated concepts of operation.[73] It took time to alter an institutional outlook once opposed to replacing pilots with UAVs. A similar process must take place for unmanned airlift to be accepted and proven feasible.

Determining Requirements for UALVs

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 unmanned reconnaissance and uninhabited combat aerial vehicle (UCAV) development are indicative of the evolutionary paths that must be forged to encourage requirements development. In order for them to be developed, UALVs must prove feasible. Feasibility requires an objective determination of what is technologically possible, which is the topic of the next chapter. Therefore, a bona fide need and justification for UALVs must exist before they are pursued. One example of the lack of adequate UAV requirements despite the ongoing development of a UAV program was reflected in a 1981 GAO report: "The Air Force had an advanced 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

[72] United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations Volume I* (Washington D.C., 1996), par 2-2. On-line, Internet, 7 December 2001, available from http://www.fas.org/man/dod-101/sys/ac/docs/ucav96/index.html.
[73] Ibid.

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."[74] Therefore, a declared and supported operational requirement for unmanned airlift from a potential user must be submitted to proceed past conceptualization.

Furthermore, for UALVs to be viable candidates for the airlift mission, they must have roughly equivalent capabilities to manned airlifters. According to one GAO report, UALVs must demonstrate the ability to compete with other systems attempting to meet the same requirement.[75] However, UAVs "will be unable to compete successfully as a system because no [UAV] exists that can be used for comparative purposes."[76] Thus, an interesting paradox develops for UALVs and other emerging unmanned aircraft roles. How does one support an emerging UAV requirement if a prototype is not, or cannot be, built and tested![77] If UALVs can justify and prove themselves feasible, airlift customers may find them particularly useful.

In this vein, Robert Owen, a retired Air Force officer with wide knowledge of airlift history, hints at the possibility of future aircraft concepts to support 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 is considering an advanced theater transport," an airlifter concept examined as a candidate UALV in the next

[74] United States General Accounting Office, *DoD's Use of Remotely Piloted Vehicle Technology*, 12.
[75] Ibid., 15.
[76] Ibid., 15.
[77] This topic is addressed in Chapter 5 when UAV acquisition programs are examined in detail.

chapter.[78] 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.[79] 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. It may also help in another area where the Air Force has a shortfall—pilots.

INSUFFICIENT AIRCREWS

DOD's UAV Roadmap IPL analysis concluded that future UAVs should address the shortfall of sufficient aircrews.[80] The Air Force has invested millions of dollars to train pilots because of a pilot shortage. This examination serves to illuminate the point that this money could be invested in unmanned aircraft research, and eventually, the aircraft themselves. In time, this will 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 utilization of the air and space environment, or 2) the lack of 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 separation rates of eligible pilots,

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[78] Col Robert C. Owen and Capt Todd A. Fogle, "Air Mobility Command and the Objective Force: A Case for Cooperative Revolution" (January/February 2001), On-line, Internet, 26 November 2001, available from http://www-cgsc.army.mil/milrev/English/JanFeb01/owen.htm. This statement was paraphrased from from AMC's *Air Mobility Strategic Master Plan 2000*, par 1.7.6, available On-line at www.amc.af.mil/xp/index.htm.
[79] Ibid.
[80] *UAV Roadmap*, 41.

posting an 81% separation rate through spring 2001.[81] Unmanned airlift can potentially ameliorate this problem without interruption of the conduct of airlift missions. Two solutions could abate this situation to some degree. One is to increase the number of personnel required for the kind of strategy being pursued, which may reduce the length of time personnel are deployed. Another is to increase airlift capacity without significantly increasing the number of personnel required to operate the additional lift. Considering the fact the economy ebbs and flows in cycles but the commitment of personnel to the NSS remains static, an unmanned airlift platform that 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, this importance is called into question by a lack of capability to match requirements. Despite studies setting wartime airlift requirements at unattainable levels, USAF airlift forces have always attempted to fulfill them. Fortunately, since WWII, the US has never had to respond 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.

The war on terrorism begun in Afghanistan in 2001 has aged AMC airlifters faster than programmed, prompting many calls for additional airlift capacity. So far, lawmakers have responded by funding additional C-17s and by considering upgrades to portions of the C-5 fleet. These initiatives are expensive and are likely to put a severe

[81] Capt Angela Slagel, "Point Paper on Mobility Pilot Retention," HQ AMC/DPXPA, 2 October 2001, On-line, Internet, 28 February 2002, available from http://amc.scott.af.mil/dp/dpx/dpxp/dpxpa/retention/retention.htm.

drain on the defense budget. Cost-efficient alternatives to expensive manned airlift matching capability requirements should be studied and proposals forwarded.

Operational requirements do not yet exist for unmanned airlift. Unmanned airlift must demonstrate the potential to perform the airlift mission as good as, or better than, manned airlifters before it is given serious consideration for augmentation of the manned fleet. Several types of missions have been identified as ideal candidates for fulfillment by UAVs, and the list is growing. 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 either exist or emerge sufficiently to invest the necessary research funding for them.

CHAPTER 4
TECHNOLOGICAL FEASIBILITY

In the development of air power, one has to look ahead and not backwards and figure out what is going to happen, not too much what has happened.

--William Mitchell

Over the last ten to fifteen years, the United States has made enormous advances in unmanned aircraft technology. These advancements have proceeded considerably faster than expected, in part because of the demand for UAVs from commanders. Nevertheless, one must still ask whether future UAV capabilities will be sufficiently well developed to support the airlift mission. This chapter investigates that question.

First, a brief history of UAV developments is provided to establish context for the development and administration of past and current UAV programs. This also serves as a baseline for future unmanned aircraft development and administration. Following that, several unmanned aircraft measures of merit deemed essential to the success of unmanned airlift are examined to determine technological feasibility. Standard DOD UAV feasibility criteria are applied to each measure of merit to establish a technological foundation for unmanned airlift. Additionally, a reasonable prognosis of development for the next 20 years is made for each measure of merit to determine unmanned airlift feasibility. Next, additional UALV considerations pertinent to the successful development of UALVs are reviewed, including UCAV development practices, which are construed as a potential developmental template for future UALV development. The chapter concludes with an analysis of technological feasibility challenges and a table that summarizes the evaluation of each measure of merit.

Brief History of UAV Development

Unmanned flight has existed in some form or another for centuries. For example, two thousand years ago in China, kites, controlled by string essentially functioned as remotely controlled vehicles.[82] Much more recently, armed forces achieved unmanned flight with varying degrees of success in World War I, World War II, the Vietnam War, and Operation Desert Storm. Before discussing UAV history further, we must distinguish between the various terms used to describe UAVs.

The terms cruise missile, guided missile, remotely piloted vehicle (RPV), drone and unmanned aerial vehicle are used to describe classes of vehicles that operate without a human aboard. Unmanned aerial vehicles are classified as either expendable or recoverable. Cruise and guided missiles are expendable, one-way vehicles used for the purpose of destruction. RPV is an older, now rarely used, term for UAV, although the two are interchangeable. Many consider drones recoverable vehicles. Michael Armitage, author of *Unmanned Aircraft*, makes the following succinct distinction between drones and RPVs/UAVs, which is accepted by this thesis: "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, on the other hand, is a pilotless aircraft that transmits mission related data to a remote controller and reacts to his commands as well

[82] William Wagner and William P. Sloan, *Fireflies and Other UAVs* (Arlington, Tex.: Midland Publishing, 1992), 15.

as to other control inputs."[83] Today, UAVs can be generally divided into four categories: tactical reconnaissance vehicles, strategic reconnaissance vehicles, target drones, and UCAVs.[84]

Wars of the last century have witnessed the use of UAVs in varying degrees over the battlefield. During WW 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.[85] After a series of failed tests, however, the program was cancelled after only completing eight of 36 scheduled flights.[86] During WW II, the US Army Air Forces attempted a handful of glide bomb missions and converted worn-out B-17s and B-24s into primitive cruise missiles.[87] During the Vietnam War, the Pentagon deployed UAVs called Lightning Bugs over North Vietnam and Southeast China to reduce pilot losses.[88] Additionally, Firebee UAVs were employed in Vietnam for surveillance and reconnaissance gathering beginning in 1964.[89] Although the Firebees enjoyed moderate success and a loss rate of only four percent, DOD terminated the program a few years after the war ended.[90] The reason for Firebee's termination was a supposed cessation of its mission to perform tactical unmanned reconnaissance.

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[83] Michael Armitage, *Unmanned Aircraft* (London: Brassey's Defence Publishers, 1988), xi.
[84] Don Herskovitz, "A Sampling of Unmanned Aerial Vehicles" (*Journal of Electronic Defense*, March 2001): 66.
[85] John W.R. Taylor and Kenneth Munson, *Jane's Pocket Book of Remotely Piloted Vehicles: Robot Aircraft Today* (New York: Collier Books, 1977), 18.
[86] Lt Col Richard M. Clark, "Uninhabited Combat Aerial Vehicles: Airpower by the People, For the People, But Not with the People" (Maxwell AFB, Ala.: Air University Press, August 2000), 8.
[87] Maj Dennis Larm, "Expendable Remotely Piloted Vehicles for Strategic Offensive Airpower Roles" (Maxwell AFB, Ala.: School of Advanced Airpower Studies, June 1996), 14-15.
[88] Thomas E. Ricks, and Anne Marie Squeo, "Why the Pentagon is Often Slow to Pursue Promising New Weapons" (*Wall Street Journal*, 12 October 1999), 8.
[89] Eric H. Biass and Roy Braybrook, "The UAV as a Sensor Platform: From Pioneer to Global Hawk" (*Armada International*, October-November 2001), 4.
[90] Ibid.

In the last dozen years, UAVs have been primarily used for reconnaissance, surveillance, and attacks against fixed ground targets. Operation Desert Storm saw the first successful large-scale use of reconnaissance UAVs. The principal UAV employed in Desert Storm was the Pioneer, operated by the United States Marine Corps (USMC). Six Pioneer units that included approximately 30 aircraft were deployed: three with USMC ground units, one with the US Army and two on Navy battleships. Two Pioneers were destroyed by anti-aircraft artillery fire while five perished due to non-combat causes.[91]

CURRENT UAV PROGRAMS

The Department of Defense operates three current and three developmental UAV programs. Current programs include the Pioneer, Predator, and Hunter. Developmental programs include Global Hawk, Fire Scout, and Shadow 200. Table 2 provides a summarized history of recent UAV programs.

Pioneer

The Pioneer system has served the Army, Navy, and Marine Corps for over 17 years. It has been used both 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 the Pioneer in Desert Storm, the RQ-1 Predator joined the fleet and provided real-time imagery of Bosnia for the North Atlantic Treaty Organization peacekeeping forces.[92]

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[91] Ibid., 2.
[92] LTC James R. Reinhardt, Maj Jonathan E. James, and CDR Edward M. Flanagan, "Future Employment of UAVs: Issues of Jointness" (*Joint Force Quarterly*, Summer 1999), 37. On-line, Internet, 2 May 2002, available from http://www.dtic.mil/doctrine/jel/jfq_pubs/0822b.pdf.

Predator

The Predator performs a variety of functions with regard to American reconnaissance and surveillance missions. It is equipped with an electro-optical/infrared (EO/IR) sensor and a synthetic aperture radar (SAR), giving it a day/night all-weather reconnaissance capability. The Air Force anticipates using Predators for an extended period and expects an Initial Operating Capability (IOC) some time in 2003.[93] In addition to the much-employed Pioneer and Predator platforms acquired by the Navy and Air Force respectively, the Army has fielded the Hunter UAV.[94]

Hunter

The Hunter UAV system is particularly noteworthy among existing unmanned ISR platforms. Hunter's mission is day/night reconnaissance, intelligence, surveillance, and target acquisition for corps commanders.[95] Although Hunter has performed to standards, it has encountered technical problems. Its software data link capabilities and engines suffered from technical defects that have proven too expensive to fix.[96] Thus, Hunter is reaching the end of its service life. Despite production cancellation in 1996, seven low-rate initial production systems comprising eight aircraft each were acquired in spite of cancellation in 1996, and four of the systems are still in service.[97]

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[93] Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000-2025* (Washington, D.C., April 2001), 4. On-line, Internet, 25 April 2002, available from http://www.acq.osd.mil/usd/uav_roadmap.pdf. *UAV Roadmap* in further citations.
[94] Biass and Braybrook, "The UAV as a Sensor Platform," 2.
[95] United States General Accounting Office, *Unmanned Aerial Vehicles: DoD's Acquisition Efforts* (Washington D.C., 9 April 1997), 4.
[96] Brendan P. Rivers, "UAVs: 100 Eyes in the Sky" (*The Journal of Electronic Defense*, June 1999): 45.
[97] *UAV Roadmap*, 4.

Global Hawk

The Global Hawk is a high altitude, long endurance surveillance and reconnaissance UAV. It has a wingspan of over 116 feet and endurance exceeding 36 hours. Like the Predator, it carries an EO/IR sensor and SAR, but it also has a moving target indicator. Global Hawk is currently a developmental program until IOC is achieved. IOC is expected by fiscal year 2005 or sooner.[98]

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 fielding before 2010. Among them is the Air Force's UCAV, dubbed the X-45, designed for the suppression of enemy air defenses (SEAD) role.

Table 2. Summary History of Recent UAV Programs

System	Lead Manufacturer	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 '93

[98] Ibid.

RQ-3/ Dark Star	Lockheed Martin	Air Force	1996	n/a	3	0	Cancelled '99
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 Techsystems	Army	1997	n/a	19	0	Cancelled '99
RQ-7/Shadow	AAI	Army	1991	2003	8	0	176 planned
Fire Scout	Northrop Grumman	Navy	1999	2003	1	0	75 planned

Source: Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000-2025* (Washington, D.C., April 2001), 6. On-line, Internet, 25 April 2002, available from http://www.acq.osd.mil/usd/uav_roadmap.pdf.

PROMOTING UAV DEVELOPMENT

Currently, the following three organizations manage 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

3. Joint Chiefs of Staff/Joint Requirements Oversight Council: Unified CinC priorities evaluation and requirements formulation[99]

Before the current arrangement, the Defense Airborne Reconnaissance Office served as a single focal point for UAV administration from 1993 to 1998.[100]

Congress has generally provided support for the DOD's UAV programs. However, it has exercised extensive oversight, reflecting concerns and differences within the DOD over the cost, speed, and direction of UAV programs.[101] After cancellation of the Army's Aquila UAV program in 1987 due to requirements growth, high costs, and technical difficulties, Congress directed the DOD to establish a centralized UAV program, which was activated as the UAV Joint Program Office (JPO). 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."[102] Testing failures were not conducive to fostering the innovation required to investigate new and viable roles and missions for UAVs. Therefore, support waned.

In 1988, Congress acted to rectify UAV program failures. Specifically, the FY 1988 Continuing Appropriations Act required DOD to submit a UAV master plan for execution under centralized direction. The act stipulated that, "the conferees [should strive] to eliminate funding within the services' separate RDT&E [research, development, training and evaluation] accounts for individual RPV[s], and to consolidate these efforts

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[99] *UAV Roadmap*, 58.
[100] Ibid.
[101] Steven Kosiak and Elizabeth Heeter, "Unmanned Aerial Vehicles: Current Plans and Prospects for the Future," 11 July 1997, On-line, Internet, 24 Oct 2001, available from http://www.csbaonline.org.
[102] United States General Accounting Office, *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.

in a Joint RPV program."[103] In other words, the act legislated inter-service coordination in the UAV developmental process.

In implementing the act, the DOD organized the UAV JPO under the auspices of the Navy's Air Systems Command to simplify all services' UAV developmental efforts.[104] The goal of the JPO was to incorporate as much commercial technology as practicable to foster development of UAVs while shortening the fielding time for UAV operational employment.[105] 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."[106] Nevertheless, the enormous expansion of UAVs eventually became too much for the JPO to manage. Therefore, the current UAV oversight structure, manned through strong, independent organizations within the DOD and JCS, seems adequate to foster UAV development programs.

In sum, UAVs have existed in some form or another for thousands of years. The US has employed UAVs with varying degrees of success in a variety of roles in wars since World War I. Current and past UAV programs have provided mixed results in an effort to perfect the technology that inevitably drives their design. Developmental programs show reasonable promise as efforts to hasten IOC of the Predator and Global Hawk, and accelerate testing of the X-45 UCAV, continue.

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[103] Kosiak and Heeter, Unmanned Aerial Vehicles.
[104] Ibid., and Lt Col Dana A. Longino, "Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios" (Maxwell AFB, Ala.: Air University Press, December 1994), 15.
[105] Kosiak and Heeter, "Unmanned Aerial Vehicles."
[106] Longino, "Role of Unmanned Aerial Vehicles," 15.

Evaluating UAV Technological Feasibility

According to the 2001 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."[107] These criteria are necessary for the success of any future UAV program and will be used as a starting point for analysis. However, these criteria alone are not sufficient. Other criteria are applied that are pertinent to the successful employment of UALVs. At the end of the chapter, a table summarizing the evaluation of each measure of merit and technological consideration is included. The focus for much of the rest of the chapter is devoted to analyzing whether each measure of merit offers sufficient reliability, survivability, and autonomy with respect to UALVs. The product of this analysis (i.e. the table at the end of the chapter) is an aggregate determination of the technological feasibility of UALVs for the USAF.

Reliability, Survivability, and Autonomy

The reliability of a system consists of several components. According to the *UAV Roadmap*, reliability is "a product of technology and training" and is a vital part of increased UAV mission availability.[108] Designing reliability enhancements into UAVs primarily involves consideration of the trade-offs between a minimum level of redundancy required and costs. Components installed on UAVs may not necessarily be appropriate for use in manned aircraft, because of less-than-thorough testing with humans, etc. but must be sufficiently reliable for mission accomplishment. Determining the proper level of reliability for UAVs is still a challenge today.

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[107] *UAV Roadmap*, 17.
[108] Ibid.

Survivability generally refers to an unmanned vehicle's ability to depart on a mission, complete it, and land safely.[109] Survivability is both a product of tactics and technology in which aircraft defensive systems play an important role.[110] Air Force Manual 1-1, published in 1992, stated that "logistics capabilities must be designed to survive and operate under attack; that is, they must be designed for combat effectiveness, not peacetime efficiency."[111] This is true today because existing USAF airlifters incorporate state-of-the-art defensive systems for self-protection. For UALVs, in the absence of a human operator, defensive functions, such as rapidly 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 sufficient self-reliance to permit mission accomplishment. Autonomy is highly dependent on jam-proof navigation and communication systems that facilitate mission completion. It is also dependent upon automated decision logic capable of performing routine operator functions requiring minimum operator input.

A middle ground must be found regarding the degree of control man will have in future UAV operations. Humans are limited in the number of parameters they can attend to, as well as the speed with which they control them; but they have unique cognitive skills that cannot be duplicated by machines.[112] Man will likely want to exercise tight control over UAVs, but how much is the question. How much autonomy should UALVs

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[109] Lt Col James A. Fellows, LCDR Michael H. Harner, Maj Jennifer L. Pickett, and Maj Michael F. Welch, "Airlift 2025: The First with the Most" (Maxwell AFB, Ala.: Air University, August 1996), 11. On-line, Internet, 10 April 2002, available from http://www.au.af.mil/au/2025/volume2/chap04/v2c4-1.htm.
[110] *UAV Roadmap*, 17.
[111] Air Force Manual 1-1, *Basic Aerospace Doctrine of the United States Air Force*, Vol 1 (Washington D.C., March 1992), 15.
[112] United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations*, Volume I (Washington D.C., 1996), 4-3. On-line, Internet, 7 December 2001, available from http://www.fas.org/man/dod-101/sys/ac/docs/ucav96/index.html.

be ceded 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 the importance of the human operators was minimized, owing to the assumption that most of the UAV functions would be automated.[113] However, the study's authors postulated that rather than being minimized, man's role in unmanned aircraft operations would increase and perhaps be more important because of automation.[114] The authors summarized their position regarding man's role as follows: "The human is not replaced by automation but is freed from simple and boring tasks to accomplish those functions most suited to human intellect."[115] However, the simple and boring tasks accomplished by humans may be beyond the capacity of UAVs to perform.[116] It is easy to overlook the human-machine interface given UAV technology progression because complex machines such as unmanned aircraft rely on advanced engineering concepts still in early stages of maturity.

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 employment environment relies on pilots to perform complex tasks not yet possible with automated systems, such as monitoring navigational aid outages and

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[113] Ibid, 7-1.
[114] Ibid, 7-1.
[115] Ibid., 7-2.
[116] Ibid., 7-1.

responding to airfield restrictions.[117] It is both feasible and conceivable, though, that if requirements existed for machines to perform these functions, algorithms could be designed to assimilate and apply this information as required. If UALVs are employed in formation, as this thesis advocates, these functions will be handled and applied by the aircrew of the manned airlifter.

"AIRLIFT 2025"

Before examining the various technologies and measures of merit, it is worthwhile to mention the work of an Air Force sponsored study from 1996 intended to chart a path for airlift's future. The study's authors examined desired airlift attributes for the year 2025 and wrote it 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 as a function of the predicted national security environment in 2025, available technologies at the time the study was written in 1996, and emerging technologies likely available by 2025.[118]

It is important to note that when then Air Force Chief of Staff Gen Ronald Fogleman commissioned the "Airlift 2025" study, power projection was an important facet of US national security. Realizing airlift's role in national security, it became apparent to him 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, including cargo payload point-of-use delivery and extraction, long unrefueled vehicle range, total resource visibility, inter-

[117] Maj Keith E. Tobin, "Piloting the USAF's UAV Fleet: Pilots, Non-Rated Officers, Enlisted, or Contractors?" (Maxwell AFB, Ala.: School of Advanced Airpower Studies, June 1999), 27. On-line. Internet, 2 May 2002, available from http://papers.maxwell.af.mil/projects/ay1999/saas/tobin.pdf.
[118] Fellows, et al., "Airlift 2025," vi.

modality, modularity, interoperability, responsiveness, and cost.[119] The study's authors concluded that each of these capabilities was required to meet national objectives forecast for 2025.[120] 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 section evaluates the most important of these measures to include payload capacity; range; command, control, communication and information systems; navigation systems, and defensive systems. A prognosis of development for unmanned airlift in each measure of merit is accomplished at the end of each section to determine technological feasibility; and as stated previously, a table at the end of the chapter sums up these results, providing a total technological feasibility estimate.

Before this, however, an examination of UAV airspace management must be conducted. UAV airspace issues affect all UAVs; but more importantly, the progress made in better managing airspace will have significant impacts on the design of future UAVs. Thus, the following brief section provides the conceptual employment foundation for UALVs, around which the successive measures of merit will be designed.

UAV 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 US, and its international counterpart, the

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[119] Ibid., 16.
[120] Ibid.

International Civil Aviation Organization (ICAO), are working 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 has been accomplished."[121]

The US is just beginning to consider solutions regarding the difficulties associated with airspace management. The UAV Roadmap prescribes actions US airspace managers must consider to facilitate integration: "Standards must be established to allow UAVs to operate flexibly within the NAS [National Airspace System], even for high altitude missions involving flight above all civil traffic, because UAVs reach such altitudes only after climbing through potentially crowded airspace. Such transits through the NAS while enroute from 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."[122] Potential solutions must be developed and implemented in such a way that they do not disrupt civil aviation safety and operations.[123]

As UAV use expands, it is inevitable that these vehicles will operate in the same airspace as manned aircraft; and the safety of the people aboard manned aircraft remains

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[121] Tobin, "Piloting the USAF's UAV Fleet," 9.
[122] *UAV Roadmap,* 56.
[123] Charles L. Barry and Elihu Zimet, "UCAVs: Technological, Policy, and Operational Challenges" (*Defense Horizons*, October 2001), On-line, Internet, 19 November 2001, available from http://www.ndu.edu/inss/DefHor/DH3/DH3.htm.

the greatest concern. Currently, UAVs operate in restricted airspace independent of civil traffic "with significant advanced written notification that can be widely disseminated."[124] They are de-conflicted in both time and space via specifically designated airspace such as special corridors and restricted operational zones.[125] Yet, with UAVs like the UCAV joining the fight, cooperation and integration with manned aircraft, as well as new methods of integration, must be devised. Joint Pub 3-55.1, *Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles*, recognized the complexity of this issue well before the widespread use of ISR UAVs in Operation Allied Force. It stated that "UAV operations must be coordinated with the ACA [airspace control authority] to provide safe separation of UAVs and manned aircraft and to prevent engagement by friendly air defense systems."[126] 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.[127] Overcoming these challenges will be the key to more widespread use of UAVs in other roles and missions. It will do no good if the US fields an armada of UAVs that can perform every role and mission the Air Force conducts unless the support infrastructure is capable of integrating UAVs with manned aircraft.

Therefore, UAVs must be positioned in flight such that their performance is optimized.[128] "This positioning will range from station keeping in wide spread

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[124] Ibid.
[125] Lt Col A. Noguier, "Next Mission Unmanned: The Human Factor" (*Royal Air Force Air Power Review*, Winter 1999), 109.
[126] Joint Publication 3-55.1, *Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles* (Washington D.C., 27 August 1993), II-6. On-line, Internet, 2 May 2002, available from http://www.dtic.mil/doctrine/jel/new_pubs/jp3_55_1.pdf.
[127] Ibid.
[128] *UAV Roadmap*, 47.

constellations to close formation with other UAVs and/or manned aircraft."[129] Optimally, the best positioning is one that balances 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 has conducted experiments testing the feasibility of UAV formation flight and has successfully applied the use of traffic collision and avoidance system (TCAS) "to better integrate manned and unmanned flight operations."[130] However, this is but the first step of a program that must go beyond using TCAS as a de-confliction measure.

So far, this examination of airspace management has focused primarily on US efforts. Arguably, American UALVs will likely be actively operating in territories throughout the world. Therefore, actions initiated by ICAO nation airspace managers are of consequence to the US. For instance, European airspace managers have already made a serious effort to ensure safe UAV operations on the continent, to include airspace integration policies mirroring the FAA's.[131] UCAV integration test trials in European airspace are ongoing and "will evaluate whether UCAVs and UAVs can be certified to operate safely alongside manned aircraft in Europe's crowded skies."[132]

A potential solution to unmanned airspace management difficulties is on the horizon. The National Aeronautics and Space Administration and the FAA are working on a program called the Small Aircraft Transportation System (SATS) that "will help

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[129] Ibid.
[130] Ibid., 43.
[131] Nick Cook, "Europe's Dilemma: Manned or Unmanned?" (*Interavia*, June 2000), 43.
[132] Ibid., 44.

provide a path toward seamless UAV operation" with manned aircraft.[133] SATS will function to provide integration of the currently disparate communication, navigation, and surveillance measures employed by manned aircraft, which will be a step closer to autonomous aircraft operations in restricted airspace.

In sum, current airspace management efforts are less than optimal for autonomous UAV users. Although, specific UAV airspace is allocated for operations, it comes at the expense of employment flexibility. It also limits the potential for new UAV roles and missions. Safety is the most important factor when determining how to integrate unmanned aircraft into manned airspace. For the UCAV, integration with manned aircraft is a vital objective it must attain to operate among manned aircraft. Airspace de-confliction 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, this thesis 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 greatest factor affecting UALV design and development will be the ability to transport sufficient quantities of cargo to offset wartime airlift requirements. To maximize flexibility, UALVs must have the ability to transport palletized cargo, oversized and outsized cargo loads, and rolling stock exceeding the size of standard

[133] Maj John T. Budd, "Unmanned Airlift: How Should We Proceed?" (Maxwell AFB, Ala.: Air Command and Staff College, April 2002), 3. This paper goes into great depth on the SATS concept, revealing an implementation window in the United States between 2005 and 2010.

aircraft pallets.[134] To be an effective complement to augment manned strategic airlifters, UALVs should possess the ability 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 wider range of airfields, while sufficiently meeting requirements to transport both oversize and outsize cargo.[135] If the payload capacity is much smaller than that, the vehicle risks the inability to transport bulky oversize cargo, a requirement of any future airlifter.[136] If the payload capacity is much larger than that, the vehicle risks denied access to a greater number of airfields due to landing weight restrictions.[137] There are no known technological barriers to designing an unmanned airlifter fuselage to accommodate the stated capacity requirements. However, if an autonomous cargo handling capability is required for aerial delivery of cargo, maturity of this emerging technology is required.

The degree of autonomy in cargo handling systems for unmanned airlifters will depend on their intended function. If UALVs are employed in formation with manned

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[134] Only the C-5 and C-17 possess the capability to transport bulky outsize cargo--a critical US requirement for airlift.

[135] 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, which could transport its payload 2,400 nautical miles un-refueled, down to 110,000 pounds, which could nominally transport its payload 3,200 nautical miles un-refueled. The latter distance is significant as described in the next section on range. *Source*: A. Lee Battershell, *The DoD C-17 versus the Boeing 777* (Washington D.C.: National Defense University Press, October 1999), 72-3.

[136] Approximately 70 percent of the cargo required to fulfill the requirements of existing wartime scenarios in the first month is oversize and outsize. With unreliable C-5s (less than 60 percent by most estimates), and the slow accession of C-17s to nearly twice as many retiring C-141s, the next strategic airlifter must possess oversize and outsize capability to avoid a high level of warfighting risk. *Source*: Air Mobility Command. *Air Mobility Strategic Plan 2002 Executive Summary* (U). October 2001. On-line. Internet, 15 January 2002. (For Official Use Only) Available from https://amc.scott.af.mil/xp/xpx/STRATPLAN2002FOUO/Executive_Summary.htm.

[137] Added to these payload capacities are fuel and vehicle fuselage weights, the sum of which can restrict operations.

aircraft, the cargo handling system does not have to be very autonomous. However, if UALVs are employed independently of manned aircraft, a higher degree of autonomy is required. In addition, if UALVs are employed exclusively to major hub regions where logistics support is extensive, cargo-handling systems do not need to be automated. However, if UALVs are employed to austere regions to on- and off-load their cargo, highly ACHSs are required.[138] The technological feasibility of UALVs is simplified and less expensive by employing the vehicles in formations with manned aircraft. If ACHSs are capable of in-flight internal movement of cargo containers and equipment, a system to maintain vehicle center-of-gravity within structural airframe limits must be incorporated. This system may also assist in optimizing cargo on- and off-load at the destination, reducing the number of loading and unloading personnel required.[139]

One ACHS currently available employs a roller system that hydraulically maneuvers palletized cargo within the fuselage, which could greatly assist in the aerial delivery of cargo.[140] This system uses a conveyor belt to move cargo back and forth on the cargo floor, while the rest of the system employs a hook device that assists in securing cargo to the floor.[141] This system will work in concert with rollers and a conveyor belt to control movement of cargo in and out of the aircraft.[142] Other designs in various stages of development also exist for ACHSs that may offer greater degrees of

[138] United States Air Force Scientific Advisory Board, *Report on UAV Technologies and Combat Operations Volume II: Panel Reports* (Washington D.C., December 1996), 2-34.
[139] Fellows, et al., "Airlift 2025," 41.
[140] Mitchell Industries, "Feasibility of Modular Unmanned Logistics Express" Final Proposal, 27 April 1998, n.p. On-line, Internet, 2 May 2002, available from http://www.eb.uah.edu/ipt/files/1998/IPT1998_Final_Report_Team_1_Final.pdf.
[141] Ibid.
[142] Ibid.

autonomy for the airdrop mission.[143] If UALVs require automated cargo handling systems in fulfillment of aerial delivery missions, however, this technology must continue to mature, which will result in greater vehicle viability. Reliable, semi-autonomous cargo handling systems should be available for aerial delivery use in the short- to mid-term depending on the degree of autonomy required.

RANGE

Another developmental factor of great importance for strategic UALVs is sufficient range. The conflicts US forces have taken part in over the last decade have stretched the US airlift system. Additionally, tanker aircraft required to support the movement of airlifters have also been spread thinly, signifying the need for additional tankers in the US fleet. In order to reduce the dependency on tankers, any future airlift aircraft should have sufficient range to conduct global operations with minimal dependency on these scarce resources. To increase flexibility of use, however, UALVs should incorporate an automatic in flight air refueling capability, with feasible procedures of employment.[144] If the 2002 war on terrorism in Afghanistan is any indication of wars in the future, there will be greater reliance on air refueling tankers to accomplish the mission. In Afghanistan, every mission in the early stages of the war required air refueling.[145]

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[143] See Lt Col David W. Allvin, "Paradigm Lost: Rethinking Theater Airlift to Support the Army After Next" (Maxwell AFB, Ala.: Air University Press, September 2000), 56-59. On-line, Internet, 7 May 2002, available from http://research.maxwell.af.mil/Papers/special_collection/CAD-PAP/allvin.pdf, for an illuminating description of several automated cargo handling technologies developed by Wright Laboratory at Wright-Patterson Air Force Base, Ohio.

[144] "Automated Aerial Refueling (AAR)," Air Force Research Laboratory (PowerPoint presentation, 26 March 2002), slide number 3.

[145] Vernon Loeb, "Fill 'er Up; In the Nation's First 'Tanker War' Every Mission Needs Midair Refueling" (Washington Post, 21 April 2002), F01.

The USAF SAB advocated future 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 continental US basing without relying on tanker aircraft support.[146] However, a radius of this magnitude would require more fuel on-board the vehicle, which in turn would decrease the available payload capacity. To put this 6,000 nm radius in perspective with existing strategic airlifters, the C-5, the USAF's largest cargo aircraft, possesses an un-refueled range of approximately 2,650 nm while transporting its maximum payload of 270,000 pounds.[147] By comparison, the smaller C-17 possesses an un-refueled range of approximately 2,400 nm while transporting a payload of 160,000 pounds.[148] 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."[149] Therefore, strategic UALVs should possess an un-refueled range of 3,000 nm or greater. This figure is both 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, however, the lesser the dependence on in-flight aerial refueling, which is merely a concept, and ground refueling at en route locations. According to one Air University thesis, "a reduced requirement for aerial refueling of airlifters will free up tanker assets for other

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[146] United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations*, 4-2.
[147] "C-5 Galaxy Fact Sheet," On-line. Internet, 30 May 2002. Available from http://www.af.mil/news/factsheets/C_5_Galaxy.html.
[148] "C-17 Globemaster III Fact Sheet," On-line. Internet, 30 May 2002. Available from http://www.af.mil/news/factsheets/C_17_Globemaster_III.html. The C-17 has a maximum payload capacity of 170,900 pounds.
[149] United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations*, 4-2.

missions already in demand," while "a reduced requirement for en route refueling will alleviate the bottlenecks already prevalent in AMC's en route infrastructure."[150] UALVs should incorporate receiver aerial refueling capability for maximum flexibility and extended operational range, if possible.[151] If automated air refueling technology is 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 electro-optical) data. Existing methods of UAV command and control consist of satellite-dependent radio frequency (RF) communication links using bandwidth as conduits. An example of the near future of UAV command and control capability will be embodied in the UCAV.

Effective command and control will be the *sine qua non* for UCAV 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 missions in which the tasks are dull and the risk is low. A disadvantage of this type of control system, though, is its inability to account for

[150] Maj Richard J. Hazdra, "Air Mobility: The Key to the United States National Security Strategy" (Maxwell AFB, Ala.: Air University Press, August 2001), 95.
[151] Any future UAV program requiring automated in-flight aerial refueling will depend on the tests conducted within the next six years with the UCAV X-45 advanced technology demonstrator. *Source*: Defense Advanced Research Projects Agency (DARPA)/United States Air Force (USAF). "Unmanned Combat Air Vehicle System Demonstration Program: UCAV Program Overview" (28 November 2001), slide 44.

emergencies or fast-changing combat environments in which the decision logic software is not resident within the vehicle's avionics suite.[152] Because of the unique aspects of the SEAD mission, UCAV decision-making logic will be the most complex system of its kind.

Although the command and control goal for the UCAV is autonomous operations, they will likely 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.[153] The Global Hawk employs somewhat of a hybrid between operator controlled and autonomously controlled UAV C2 systems that allows for limited dynamic re-tasking in-flight. The Predator is controlled through a MITL system, which 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 has reduced situational awareness with respect to the vehicle's external environment, making the task difficult. Complicating the task further is the fact that feedback mechanisms on the UAV are unable to provide the operator with situational cues normally perceived by an aircrew aboard an aircraft. The situation becomes acute if the operator is unaware of potential threats such as terrain, weather, ground fire, or enemy aircraft.

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[152] Clayton K. S. Chun, *Aerospace Power in the Twenty-First Century* (Colorado Springs and Maxwell AFB, Ala.: United States Air Force Academy in cooperation with Air University Press, July 2001), 296.
[153] Ibid.

UALVs would require less sophisticated decision logic than UCAVs because by mission design airlifters do not face the array of threats associated with the SEAD mission. 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, or maneuver rapidly in all flight axes to evade the threat. Additionally, UALVs will potentially require less bandwidth than existing ISR UAVs. This is because they will not be employed to receive and send bandwidth-consuming imagery like ISR UAVs.[154] If UALVs are employed independently of manned airlifters they will require the same connectivity to command and control agencies on a one-for-one basis, as is currently performed by existing UAVs. If UALVs are employed in formations with manned aircraft, bandwidth requirements will decrease because only the manned airlifter in the formation needs to have long-range connectivity with a controlling agency. The unmanned airlifters will only need to have 'local' connectivity with the manned airlifter in this instance, monitoring and controlling its actions, if necessary.

One of the primary things to consider when designing and developing C3I for UALVs is the degree of control operators will possess over the vehicles. Because UAVs rely on sensors and data links for the transfer of information, they are susceptible to jamming. If numerous UAVs are employed simultaneously, operators may lack the bandwidth necessary to conduct safe operations.[155] According to one Air University

[154] 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 Gen John 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 new tankers with sensor equipment. *Source*: Gen John Jumper, "Chief's Sight Picture" (7 March 2002), 1, On-line, Internet, 27 May 2002, available from http://www.afpc.randolph.af.mil/pubaffairs/comm/comm2002/03/March7/Editorial.htm.
[155] Chun, *Aerospace Power*, 296.

research paper, "data link or radio controlled transmissions create a vulnerability. An adversary could jam or engage these signals or take command of the aircraft or at least intercept the downlink."[156] Therefore, counters to these jammers must be developed. UAVs are also vulnerable to the loss of the electronic link that controls their movements. Currently, the US 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, new protective solutions must be found.

One new, inexpensive, and innovative data link technology offers increased bandwidth capability, while also providing better communications security. According to the UAV Roadmap, the Naval Research Laboratory has "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.[157] One disadvantage to the MQW technology, though, is its range, which is limited to only a few kilometers.[158] 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.

In addition, several new and potentially revolutionary technologies are in various stages of development to alleviate the effects of RF congestion. According to the UAV Roadmap, "the key trend in…future airborne communication systems is increasing data rates…primarily brought on by migration towards higher RF frequencies and the

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[156] Maj Robert C. Nolan, "The Pilotless Air Force? A Look at Replacing Human Operators with Advanced Technology" (Maxwell AFB, Ala.: Air Command and Staff College, March 1997), 28. On-line, Internet, 25 April 2002, available from http://research.maxwell.af.mil/papers/student/ay1997/acsc/97-0530.pdf.
[157] *UAV Roadmap*, 34.
[158] Ibid.

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."[159] Until then, "both RF and optical technology development will continue to progress out to 2025."[160]

The fundamental consideration of C3 systems is that the more autonomy is relinquished to command and control UALVs, the lower becomes the reliability of current technologies to accommodate them. If a human controls every UALV action, MITL technologies are both adequately autonomous and reliable for use in the short- to mid-term timeframe. However, if UALVs are to 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 are critical to the success of any unmanned aircraft required to execute tasks that result from complex human decision-making processes. An example includes the decision a fighter makes when determining whether to engage a target. Much research has already been 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, though, this technology is expensive

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[159] Ibid., 32.
[160] Ibid.

and must advance significantly before being incorporated into UAVs.[161] Perfecting adequate AI technology will remain a future challenge as UAVs are vested with greater autonomy over traditional human functions. As a key TPSA (technology, process, and system attribute) for the UCAV, AI progress should be monitored for potential application to other UAV programs. AI should be sufficiently reliable and autonomous for the use in unmanned airlifters by the mid-term timeframe.

NAVIGATION SYSTEMS

Reliable navigation systems are vital to the function of all aircraft. With respect to UALVs, though, a higher degree of both reliability and autonomy are required. 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) that works with global positioning system (GPS) receivers can 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."[162] RAIM, or its updated successor, will likely be available for UALVs, providing them the required degree of reliability for autonomous operations. However, even RAIM faces challenges. Among those challenges is the need to develop an anti-jam GPS system.[163] GPS jammers are potentially destructive devices capable of interrupting the navigation signal many aircraft rely upon for primary navigation. Precise

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[161] Michael Puttre and Kenneth B. Sherman, "A Little Payload Goes a Long Way" (*The Journal of Electronic Defense*, July 2001): 42; and Lt Col David Glade, "Unmanned Aerial Vehicles: Implications for Military Operations" (Maxwell AFB, Ala.: Air University, July 2001), 10.
[162] Maj Chad T. Manske, "Looking Ahead at the Future of Airlift: A Capabilities-Based Approach to Designing the Next Generation Strategic Airlifter" (Maxwell AFB, Ala.: Air Command and Staff College, April 2001), 9.
[163] Barry and Zimet, "UCAVs."

and reliable navigation systems are required for precision airdrop missions UALVs may undertake to enhance point-of-use delivery capabilities.[164] Advances being pursued by Air Mobility Command for point-of-use standoff delivery, such as automatic steering parachutes, are expected to be reliable at the beginning of the mid-term timeframe.

Another navigation system important to the feasibility of UALVs is automatic approach and landing systems. Raytheon, an aerospace products company under Air Force contract, has been working on a precise automated landing system for manned aircraft that has potential applications for unmanned aircraft. The Air Force already uses an electronic navigation and landing system for the 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, both 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 then uplinks this data to VHF receivers aboard aircraft flying in the terminal area, providing very precise position information.[165] This capability allows for the execution of precise approaches and safe landings on the surface.[166]

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[164] United States Air Force Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, Summary Volume (Washington D.C.: USAF Scientific Advisory Board, 1995), 65. On-line, Internet, 22 January 2002, available from http://www.au.af.mil/au/awc/awcgate/vistas/vistas.htm.
[165] Bruce Solomon, program director for Raytheon Company's JPALS. Interviewed by author, 30 January 2002.
[166] Ibid.

So far, more than 200 precision approaches with a military test aircraft have been flown with JPALS. Some of the tests were accomplished with a specially configured Boeing 727 aircraft, signifying its potential application to large unmanned aircraft. In addition, JPALS meets the DOD's need for an anti-jam and secure approach and landing system capable of operation in a hostile environment.[167] Because of JPALS and technologies like it, UAV mishaps in the landing phase should be drastically reduced. As an emerging technology, the JPALS enhances the reliability, survivability, and autonomy of potential UALVs.

In sum, navigation systems for both 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 anti-access challenges to UALVs, leaving questions of their survivability in a wartime environment unanswered. In addition, technological feasibility is not assured for the precision airdrop mission, as it 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

Because UALVs are likely to be employed in hostile conditions, just as manned airlifters are, it is necessary to ensure the vehicles are protected from potential threats. Existing ISR UAVs do not have active defensive systems to protect them, but there are reasons for this. First, ISR UAVs are generally less expensive compared to their manned

[167] Ibid.

counterparts.[168] Their primary purpose is to collect information in the face of potential threats otherwise incurred by humans. Active defensive systems unnecessarily add costs to these UAVs. Second, ISR UAVs have small payloads (most are less than 3,000 pounds) in comparison to potential payloads for UALVs. Their payloads consist primarily of sensors needed to execute the vehicle's mission. Third, it is much harder to target a small UAV than a larger, less maneuverable one. For the reasons contrasting those above (e.g. higher expense, larger payload, larger size, less maneuverability, and greater vulnerability), UALVs should incorporate defensive capabilities.

During Operation Allied Force, Serbian air defenses forced the inefficient routing of many AMC sorties. In this context CINCTRANS 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."[169] Furthermore, he declared, "as the 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."[170] 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.[171] He argued that countermeasures were "not worthwhile for small tactical UAVs that are

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[168] An exception to this statement is the Global Hawk.
[169] Gen Charles T. Robertson, Jr., "Submitted Written Statement to the House Armed Services Readiness Subcommittee," 26 October 1999. On-line, Internet, 8 February 2002, available from http://www.transcom.mil/speeches/991108-3.html.
[170] Ibid.
[171] Steven Zaloga, "Conflicts Underscore UAV Value, Vulnerability" (*Aviation Week and Space Technology*, 17 January 2000), 103.

much smaller than contemporary fighter aircraft, but they might be considered on large, high-cost systems."[172] If the US 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 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 were necessary.[173] Yet, the plan also 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."[174] In order 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 the USAF's research labs and AMC leadership. Former CINCTRANSCOM 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.[175]

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[172] Ibid.
[173] Air Mobility Command, "Air Mobility Strategic Plan 2002 Executive Summary."
[174] Ibid.
[175] Air Mobility Command, "Air Mobility Strategic Plan 2002 Executive Summary."

What kind of defensive systems, then, should UALVs possess? It really depends on how much value is placed on the UALV as a transporter of valuable cargo. As a minimum, they should include the large aircraft infrared countermeasures (LAIRCM) system. The purpose of LAIRCM is to protect large, vulnerable aircraft from MANPADS and to counter advanced infrared missile systems.[176] According to one fact sheet about the system, "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."[177] Based on the experiences of airlifters in Operation Allied Force, AMC placed LAIRCM number one on its list of acquisition priorities.[178] In addition, potential threats also necessitate the use of countermeasures dispense sets (CMDS) possessing the capability to eject flares and chaff, which are standard equipment on existing airlifters.

Should stealth technology be adapted to UALVs 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 also serves a similar purpose for the high-risk SEAD mission of the UCAV. However, stealth is 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.

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[176] "Large Aircraft Infrared Countermeasures (LAIRCM)," On-line, Internet, 22 May 2002, available from http://www.fas.org/man/dod-101/sys/a/equip/laircm.htm.
[177] Ibid.
[178] Ibid.

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, however, provide an adequate degree of reliability and survivability protection for both the current and next generation of airlift vehicles, manned or unmanned. Because the operational requirement for UALVs is for strategic (inter-theater) airlift and not intra-theater airlift, it may not be necessary to equip unmanned airlifters with the same degree of defensive capability as manned airlifters. UALVs are unlikely to be operated at small, unimproved airfields because the technological feasibility required to invest them with that capability would be cost-prohibitive. Therefore, the author argues that to retain maximum mission flexibility with UALVs, a minimum active defensive system should be installed on the vehicle.[179]

Additional UALV 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. The first is system redundancy. System redundancy in the design of any unmanned aircraft, including UALVs, will necessitate a tradeoff between reliability, survivability, and autonomy. Tradeoffs will also exist between cost and technological feasibility, as they are inextricably linked. Therefore, incorporating the appropriate level of redundancy in UALVs will be key to their efficiency. The second consideration is the role of simulation

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[179] The cost-benefit tradeoff between whether to equip UALVs with defensive systems or whether not to, dictates the former. By equipping UALVs with a minimum of defensive capability, the vehicle and its cargo are preserved from destruction from both airborne and ground threats. Since technological feasibility and cost are inextricably linked to one another in all UAV programs, cost of defensive capabilities will ultimately determine their inclusion.

in unmanned aircraft design, development, training, and operations. Simulation will 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 is presented to illustrate the latest in UAV developmental practices. Many of these practices will set a new standard for UAV development and bear a direct relationship to the technological feasibility of UALVs. Finally, the chapter will conclude with general comments on the technological feasibility obstacles UALV developers may face and a reasonable prognosis for surmounting them.

SYSTEM REDUNDANCY

System redundancy is a key component of feasibility. Most manned aircraft built today incorporate triple redundancy in their major systems. The hydraulic, electrical, avionic, and environmental systems are those most often made redundant. Redundancy reduces the potential for loss of life that typically results from the failure of major systems, and is incorporated for safety and liability reasons. Although manned aircraft must be built with high levels of redundancy, UALVs do not require the same high degree of redundancy essential for manned aircraft because 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 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.[180] Simulation must accurately duplicate the conditions it is designed to emulate. 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."[181] In other words, simulation can help determine if a concept for unmanned aircraft operations is feasible in the first place.

Simulation also provides a means by which UAV operators are trained, making UAVs inexpensive alternatives to manned aircraft.[182] According to the *UAV Roadmap*, "today's *manned* [emphasis added] 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."[183] 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

[180] United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations*, 7-3.
[181] Ibid., 7-3 to 7-4.
[182] Predator UAV training consists of 50 classroom hours, 28.5 simulator hours, and 34.5 hours spent flying 15 missions. Gail Kaufman, "Predator UAV Operators take Distance Learning to Challenging Heights" (*Defense News*, 26 November-2 December 2001), 3. 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 the Global Hawk and UCAV, requiring less user/operator intervention.
[183] *UAV Roadmap*, 45

achieved."[184] Because UALVs will likely be employed in formations with a manned airlifter, the manned airlifter could have UALV control stations in the cargo area in which vehicle operators monitor their flight status. The Global Hawk already employs this method of vehicle control, using operators to monitor both flight progress and vehicle status. In UALVs, each operator could be responsible for monitoring two or more of the vehicles much the same way as the UCAV.[185]

UCAV PROGRAM DEVELOPMENT PRACTICES

If unmanned airlift development is to flourish, successful development practices from other successful UAV programs must be adopted. So far, the UCAV program is demonstrating success. The UCAV was conceived though a defined requirement to perform the SEAD mission. According to DARPA, the objective of the UCAV program "is to design, develop, integrate, and demonstrate the critical and key technologies, processes, and systems attributes (TPSAs) pertaining to an operational UCAV system."[186] TPSAs are critical technology areas of the program that include adaptive autonomous control, advanced cognitive aids integration, secure robust command, control and communications, and compatibility with integrated battle space.[187] In a general sense, they are necessary technological attributes for all UAVs. DARPA plans on developing and demonstrating 15 key and critical TPSAs during a series of 150 ground, flight, and simulation tests.[188] "Collectively, these activities will demonstrate the technical feasibility, validate mission effectiveness projections, and provide an 80% cost

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184 *UAV Roadmap*, 55.
185 Block five highlights of the UCAV concept of operations calls for single operators to control multiple vehicles by mid-FY06. Source: DARPA-USAF, "UCAV Overview" (28 November 2001), slide numbers 6 and 40. Therefore, UALVs should be able to use this technology for their own concept of operations.
186 DARPA-USAF, "UCAV Overview" (28 November 2001), slide number 3.
187 Ibid.
188 Ibid.

confidence in the affordability projections" of the UCAV.[189] DARPA has 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

System integration

6. Advanced targeting and engagement process
7. Compatibility with integrated battlespace
8. Secure, robust communication capability
9. Adaptive, autonomous operations
10. Affordable large scale software integration
11. Coordinated multivehicle flight motion

Support system

12. Affordable OSS
13. Prognostics and health management

[189] Ibid.

14. Mobility, rapid deployment and footprint

15. Sortie rate, turn time and ground ops[190]

Of these 15, numbers one, four, five, and seven through fifteen, have direct applicability to UALV program development. Processes and lessons learned from the integration of these TPSAs should be used in all future UAV developmental efforts. Additionally, each of these TPSAs should be 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 should be realistic and tailored according to a specified timeline, as is the case with the UCAV program.[191] Although the UCAV program is an excellent example to model UALV development, many of its objectives are focused strictly on combat strike operations. What will be needed is the application of those ideas and technologies to unmanned airlift. However, despite the progress and technological advancements made to develop more reliable, survivable, and autonomous UAVs, they must surmount formidable obstacles.

Thus far, this chapter has demonstrated that essential UALV technologies exist or will reasonably emerge, yielding the potential for unmanned airlifters in the mid-term. 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 prognosticates possible solutions.

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[190] Ibid.

[191] The timeline for each of the TPSAs denotes a realistic expectation for availability and inclusion into the UCAV program.

TECHNOLOGICAL FEASIBILITY CHALLENGES

Advancements in sensors, propulsion, and navigation technologies, among others, have led to capabilities never before imagined for UAVs. Yet, skepticism of the DOD's efforts toward UAV feasibility abound. The CBO has been 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."[192] These are problems not likely 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 has outlined the technological mandate for future UAV programs, juxtaposing the exploitation of a strong science and technology program with "evolving military needs" designed to defeat potential adversaries.[193]

UAVs have experienced mishap rates 10 to 100 times greater than manned aircraft.[194] 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. However, at what point in program development should this decision be made? The cost of frequently destroyed user cargo, let alone the cost of destroyed vehicles, may

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[192] Congressional Budget Office, *Options for Enhancing the Department of Defense's Unmanned Aerial Vehicle Programs* (Washington D.C., September 1998), 18. On-line, Internet, 17 December 2001. Available from http://www.cbo.gov/showdoc.cfm?index=917&sequence=0.
[193] Department of Defense, *Quadrennial Defense Review Report* (Washington D.C., 30 September 2001), 41. On-line, Internet, 10 April 2002, available from http://www.defenselink.mil/pubs/qdr2001.pdf.
[194] Ibid.

be reason enough to consider whether to continue supporting a UALV program. There must be reasonable assurances that mishap rates for UALVs are comparable to manned aircraft before significant investment will be made in their future.

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

Israel has had 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 is at the 50,000 hour mark) showed three reliability-related areas--flight control systems, propulsion, and operator training--accounted for 75 percent of the mishaps.[195] "The potential savings from improvements in these three areas make a strong case for identifying and incorporating such reliability enhancements in existing and all future UAV designs."[196] 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.[197]

Advancements in the three reliability-related areas above provide sufficient assurances that lend themselves to acceptable parameters for UALVs in the short- to mid-term timeframe. In other words, UAV mishap rates over the next 10 to 20 years will

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[195] *UAV Roadmap*, 45.
[196] Ibid.
[197] Ibid.

likely *equal or better* those of manned aircraft. Increased experience with UAVs has 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. First, 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.[198] Second, the propulsion-related mishaps in the Israeli experience, in the case of the Pioneer, as well as the US experience with both the Pioneer and Predator, are mostly a function of less reliable propeller-driven engine UAVs. UALVs will use more-reliable jet engines to transport their larger payloads, or their successor propulsion technology, significantly reducing propulsion-related mishaps. Third, operator training must focus more closely on mishap causes in the same way that aircrew study manned aircraft accident reports. This is the best way to lessen the occurrence of operator-related mishaps and enhance the feasibility of UALVs.

Lastly, in order for future UAV programs to succeed, the most technologically advanced nation in the world must overcome the challenge of successfully *integrating* UAV technologies to employ them to their fullest potential. Individually feasible technologies are 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.

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[198] Jennifer Evans, William Hodge, Judy Liebman, Claire J. Tomlin, and Bradford W. Parkinson, "Flight Tests of an Unmanned Air Vehicle with Integrated Multi-Antenna GPS Receiver and IMU: Towards a Testbed for Distributed Control and Formation Flight," (Stanford University, 1999), 9. On-line, Internet, 30 May 2002. Available from http://sun-valley,stanford.edu/~tomlin/papers/longps99.pdf.

SUMMARY

This chapter examined the technological feasibility of unmanned airlift as a potential future function of the USAF. The chapter began with a history of UAV developments after which current DOD UAV programs were reviewed. The evidence indicated that throughout the last century UAV development has favorably progressed in response to operational requirements and available technologies. Technological feasibility was evaluated 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 that establish a new and improved paradigm for UAV evolvement. Lastly, technological feasibility challenges were examined to caution against what some experts perceive are obstacles to future UAV development. In this regard, however, it was demonstrated that technological progress is advancing such that in the near future, these obstacles will be surmounted.

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 indicates that there is reasonable assurance to design, develop, and field a functional UALV in the short- to mid-term timeframe.

Table 3. Evaluation of Essential UALV Measures of Merit and Concepts

	PROJECTED AVAILABILITY*			**R,S, A ****	**REMARKS**
MEASURE OF MERIT OR CONCEPT	*SHORT TERM '02-'12*	*MID TERM '12-'22*	*LONG TERM '22-'32*		
Airspace Management	X			A,R	Assumes UALVs in formation with a manned airlifter. Otherwise, capability not available until mid- 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
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	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.

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.[199] US ISR UAV programs administered over the last ten years have striven to keep the development, procurement and acquisition, operations and support, 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. High overhead costs in many cases 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 USAF, this chapter examines 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

[199] Lt Col A. Noguier, "Next Mission Unmanned: The Human Factor," (*Royal Air Force Air Power Review*, Winter 1999), 105.

both exist and if unmanned aircraft programs can demonstrate financial cost effectiveness over manned programs, a role does exist for UALVs in the USAF.

It is incumbent upon the US to 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 mid- and long-term capabilities to meet those requirements.[200] Increased operating costs have been the result of an airlift fleet averaging nearly 25 years old and suffering from poor reliability and extensive maintenance.[201] 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.[202]

The chapter begins by analyzing the development, procurement, operations and support, 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.

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[200] Office of the Secretary of Defense, *Quadrennial Defense Review Report* (Washington D.C.: Department of Defense, 30 September 2001), 68. On-line, Internet, 2 May 2002, available from http://www.defenselink.mil/pubs/qdr2001.pdf. *QDR* in further citations.
[201] Gen Charles T. Robertson, "Statement Before the Senate Armed Services Sea Power Committee on Strategic and Tactical Lift in the 21st Century" (10 March 1999), 12-3.
[202] Air Mobility Command, *Air Mobility Strategic Plan 2002 Executive Summary* (October 2001), On-line, Internet, 15 January 2002, available from https://amc.scott.af.mil/xp/xpx/STRATPLAN2002FOUO/Executive_Summary.htm.

Costs and Comparisons

Cost is an important consideration in the development of future airlift platforms and their support systems.[203] Determining the cost effectiveness of unmanned aircraft systems requires a balanced comparison between manned and unmanned systems. The *UAV Roadmap* defined 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."[204] It is beyond the scope of this thesis to provide a definitive cost-benefit analysis of manned versus unmanned aircraft vehicles. However, the cost comparisons presented here should be sufficiently suggestive to answer the research question regarding the overall financial soundness of the UALV concept.

UAV Funding and the Defense Budget

Over the last several years, the DOD has steadily increased the budget for UAV programs. In FY99, the DOD invested approximately $115 million, which accounted for less than one percent of its acquisition budget.[205] For FY03, the DOD has budgeted $189

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[203] Lt Col James A. Fellows, LCDR Michael H. Harner, Maj Jennifer L. Pickett, and Maj Michael F. Welch, "Airlift 2025: The First with the Most" (Maxwell.AFB, Ala.: Air University, August 1996), 14. On-line, Internet, 10 April 2002, available from http://www.au.af.mil/au/2025/volume2/chap04/v2c4-1.htm.

[204] *QDR*, 51.

[205] Maj Thomas G. O'Reilly, "Uninhabited Air Vehicles: Critical Leverage Systems for Our Nation's Defense in 2025" (Maxwell AFB, Ala.: Air Command and Staff College, April 1999), 19. On-line. Internet, 25 April 2002, available from http://research.maxwell.af.mil/papers/student/ay1999/acsc/99-152.pdf.; and Congressional Budget Office, *Options for Enhancing the Department of Defense's Unmanned Aerial Vehicle Programs* (September 1998), 56. On-line, Internet, 17 December 2001, available from http://www.cbo.gov/showdoc.cfm?index=917&sequence=0. *Options* in further citations.

million for UAV programs, planning higher increases of funding beyond that.[206] In addition, it has allocated $339 million for 2004, $366 million for 2005, and $392 million for 2006.[207] 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. It is not known with absolute certainty how much it costs to operate them.[208] Until recently, this uncertainty was exacerbated by a fiscally constrained funding environment that focused funding on higher priority USAF aircraft programs, which left strategic airlift funding, especially for the procurement of the expensive but capable C-17, and upgrades for the unreliable C-5, sorely absent.

Before the events of 11 September 2001, there was a struggle to procure badly needed airlift to meet the requirements and conditions established by MRS-05. As described in Chapter 2, MRS-05 recommended purchase of between 170 and 180 C-17s to close the airlift gap and fulfill wartime airlift requirements.[209] USAF officials are lobbying for an additional 42 C-17s beyond that, for a total inventory of 222. The fundamental consideration is that if world events had not occurred as they did on 11 September 2001, the US airlift fleet would still be in jeopardy of failing to meet established requirements. Can the US get the same capability more cost effectively in the future? The Global Hawk provides one example.

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[206] Amy Svitak, "Pentagon Details Extra Money for War on Terror" (*Defense News*, 25 February 2002), 4.
[207] Ibid.
[208] Lt Col David Glade, "Unmanned Aerial Vehicles: Implications for Military Operations" (Maxwell AFB, Ala.: Air University, July 2001), 21.
[209] Office of the Joint Staff, *Mobility Requirements Study 2005 Executive Summary* (December 2000), 5. On-line, Internet, 25 April 2002, available from http://www.dtic.mil/jcs/j4/projects/mobility/execsummrs05.pdf. In MRS-05, this figure assumed no C-5 aircraft would go through the RERP modification.

The 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."[210] Currently, the DOD plans 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.[211] By comparison, these development costs are roughly *half* that of the U-2 aircraft the Global Hawk is designed to replace.[212] 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

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[210] *Options*, 14.
[211] Department of Defense, *Program Acquisition Costs by Weapon System: Department of Defense Budget for Fiscal Year 2003* (February 2002), 20. On-line, Internet, 10 April 2002, available from http://www.dtic.mil/comptroller/fy2003budget/fy2003weabook.pdf. *Defense Budget for Fiscal Year 2003* in further citations.
[212] Charles L. Barry and Elihu Zimet, "UCAVs: Technological, Policy, and Operational Challenges" (*Defense Horizons*, October 2001), On-line, Internet, 19 November 2001, available at http://www.ndu.edu/inss/DefHor/DH3/DH3.htm.

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.[213] 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."[214] Though written 14 years ago, these words are still true today. Otherwise, large, complex UAVs would have already been developed and fielded. How, then, should the US proceed in developing and procuring

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[213] Defense Acquisition Deskbook, On-line, Internet, 10 April 2002, available through http://web2.deskbook.osd.mil. These terms are usually grouped into the acronym RDT&E.
[214] Michael Armitage, *Unmanned Aircraft* (London: Brassey's Defence Publishers, 1988), 100-1.

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 UCAV, which will arguably be the most complex UAV developed to date. Many believe that although UCAVs will "cost less per unit to acquire, operate, and maintain than manned aircraft," they 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* [emphasis added]."[215] Just like the UCAV in which the mission and vehicle concept are unproven, the costs of developing UALVs are likely to be very high. R&D costs for UALVs will be dependent on the level of support the program garners, how effectively the program fulfills operational requirements, and how technologically feasible the vehicle proves to be. Over time, despite initially high R&D costs, UALVs should amortize their costs if procured in sufficient numbers. The 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 both the Global Hawk and U-2 were $205 million and $243 million, respectively.[216] Although not significantly less, the 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

[215] Barry and Zimet, "UCAVs: Technological, Policy, and Operational Challenges."
[216] Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap 2000-2025* (Washington, D.C., April 2001), 53. On-line, Internet, 25 April 2002, available from http://www.acq.osd.mil/usd/uav_roadmap.pdf. *UAV Roadmap* in further citations. These figures are both adjusted to FY00 dollars.

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 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 23-month period—a difference of $1 million.[217]

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 initial operating capability. In that period, developing the C-17 cost U.S. taxpayers $5.6 billion. McDonnell Douglas funded an additional $1.7 billion—bringing the total C-17 development cost to $7.3 billion."[218] Because there are no UALV R&D costs to compare with the C-17, this thesis 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.[219] 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 are used to 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

[217] Ibid. These figures are both adjusted to FY00 dollars.
[218] A. Lee Battershell, *The DoD C-17 versus the Boeing 777* (Washington D.C.: National Defense University Press, October 1999), 84.
[219] This also assumes the unmanned aircraft possesses equivalent capabilities to its manned counterpart.

manned counterparts, the comparison is not completely accurate. According to the *UAV Roadmap*, for example, "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."[220] In other words, consideration of support system costs must not be overlooked when comparing costs. In the case of UALVs, however, the last chapter posited that the best method for their employment was 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.[221] Unfortunately, similar procurement cost comparisons cannot be drawn between UCAVs and JSFs since both are still in the R&D phase.[222]

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."[223] Additionally, from "*10 to 15 percent* [emphasis added] of the manned aircraft's empty weight" is comprised of man-supportable mission equipment.[224] By applying the cost-to-weight methodology, a cost of $403,500 is derived from a 269,000-

[220] *UAV Roadmap*, ii.
[221] *Defense Budget for Fiscal Year 2003*, 20.
[222] Ibid., 20 and 19, respectively.
[223] *UAV Roadmap*, 53.
[224] Ibid.

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 for the same capability results.[225] When one considers the fact that Congress appropriated over $16.6 billion for

C-17 procurement between 1981 and 1995, the potential savings become readily apparent.[226] UALV procurement costs will be highly dependent 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.

UAV 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.

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[225] 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 unnamed others. Tradeoffs in weight may result if additional sensors, automated cargo handling systems, etc., are added to the aircraft empty weight. *Source*: The staff of the Secretary of the Air Force for Acquisition (SAF/AQ) and BGen Ted F. Bowlds, Air Force Program Executive Officer for Airlift and Tanker aircraft (AFPEO/AT), interviewed by author via email, 12 April 2002.

[226] Battershell, *The DoD C-17*, 85. By applying the '10 to 15 percent' rule, UALV procurement savings could potentially amount to between $1.67 and $2.5 billion.

Three major acquisition anomalies must be avoided for future UAV acquisition programs to succeed. The first is requirements creep.[227] Also known as "gold-plating," requirements creep means "trying to make the UAV do too much too soon."[228] 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.[229]

Second, "available" UAV technologies should be considered "capable" technologies.[230] Many times commercial-off-the-shelf technology, dubbed non-developmental, is incorporated into UAVs without undergoing sufficient testing. Often, it is assumed these technologies are mature enough for the UAV system they are installed in but GAO studies have shown otherwise.[231] For example, the Army's Hunter UAV incorporated stand-alone software, data link equipment, and engines that before installation met standards. 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.[232] In past UAV programs, "available" technologies were assumed mature enough for program incorporation. Nevertheless, costs increased out of control,

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[227] R. Barry Walden, "The Use of Modeling and Simulation in the Systems Engineering of Unmanned Aerial Vehicles" (Fall 1998), par 1-0. On-line Internet, 24 October 2001, available from http://www.glue.umd.edu/~bwalden/project.html.
[228] LTC Daniel T. Morris, "Unmanned Aerial Vehicles: Options for the Operational Commander" (Newport, RI.: Naval War College, 18 May 1992), 5.
[229] Walden, par 1-0.
[230] United States General Accounting Office, *Unmanned Aerial Vehicles: DoD's Acquisition Efforts* (Washington D.C., 9 April 1997), 6-7.
[231] Ibid., 7.
[232] Ibid., 9.

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 an entire system of integrated components, including the maintenance, training, air vehicle operator stations, and ground operator manpower costs are also acquired. The US GAO, in a 1997 report on the DOD's acquisition efforts, cautioned that potential UAV users and developers must keep in mind that UAV systems are not cheap, and that prudent cost efficiency should drive the development strategy.[233]

Advanced Concept Technology Demonstration Acquisition

The USAF acquires its UAVs through advanced concept technology demonstration (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."[234] 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.[235]

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

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[233] Ibid., 7.
[234] Maj Christopher A. Jones, "Unmanned Aerial Vehicles: An Assessment of Historical Operations and Future Possibilities" (Maxwell AFB, Ala.: Air Command and Staff College, March 1997), 43. On-line, Internet, 2 May 2002, available from http://research.maxwell.af.mil/papers/student/ay1997/acsc/97-0230D.pdf.
[235] *Options*, 25

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.[236]

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
4) Transition to procurement[237]

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.[238]

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

[236] Ibid., 21.
[237] Ibid., 23.
[238] Ibid.

procurement.[239] These advantages are the cornerstone of the efficient financial utility of UAVs, fostering improved cost effectiveness over manned aircraft acquisition methods and strategies.

UCAV ACQUISITION

UALVs are likely to follow the same developmental path as UCAVs, owing to the unproven technology development similarities of both. Therefore, successful UCAV acquisition processes should be replicated for other developing UAV programs. For example, the Defense Advanced Research Projects Agency (DARPA), the DOD's advanced research arm responsible for UCAV development, "firmly believes that the unit…cost of the UCAV weapon system will be *one-third* [emphasis added] that of the Joint Strike Fighter," according to the director of the Pentagon's Operational Test and Evaluation Office.[240] 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, DOD would acquire dozens of them. Unfortunately, the comparison is not that simple. It is much easier to compare the size and projected capabilities of UCAVs with Joint Strike Fighters (JSFs), than it is to compare C-17s with unknown, unproven unmanned airlift vehicles.

How is the UCAV assuring its development and acquisition costs stay one-third of the JSF? The approach, not unlike the ACTD process utilized for both the Predator

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[239] Jones, "Unmanned Aerial Vehicles," 43.

[240] George C. Wilson, "Pilots! Unman Your Airplanes!" (*National Journal*, 1 December 2001), 3692; and Defense Advanced Research Projects Agency (DARPA)-United States Air Force (USAF), "Unmanned Combat Air Vehicle (UCAV) Program Overview" (September 2001), 3. The UCAV program makes this claim based on "an 80% cost confidence in the affordability projections." *Source*: DARPA/USAF, "UCAV Program Overview," (September 2001), 3.

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.[241] The implementation of this strategy will provide decision makers with the technical and financial feasibility information required to make an informed procurement decision.[242] It is incumbent upon future UAV developers to extract the UCAV 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

Operations and support costs are costs associated with owning, operating, maintaining, and supporting a fielded DOD system.[243] They include fuel, pay for unit personnel, and pay for indirect support personnel. Preliminary studies of UCAV O&S costs suggest they will be 75 percent lower than both F-16 and JSF O&S costs.[244] Others have estimated the cost savings potential close to 90 percent as calculated for peacetime

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[241] DARPA-USAF, "UCAV Program Overview" (September 2001), 4-5.
[242] Ibid.
[243] Department of Defense, *Commercial Operations and Support Savings Initiative Frequently Asked Questions*, On-line, Internet, 10 April 2002, available from http://www.acq.osd.mil/es/dut/cossi/faqs.html.
[244] Lt Col John W. Flade, "Teaching a New Dog Old Tricks: Replacing Man with Artificial Intelligence in Combat Aircraft" (Carlisle Barracks, Pa.: US Army War College, 1 April 2000), 8; Lt Col James R. Reinhardt, Maj Jonathan E. James, and CDR Edward M. Flanagan, "Future Employment of UAVs: Issues of Jointness" (*Joint Force Quarterly*, Summer 1999), 38. On-line, Internet, 2 May 2002, available from http://www.dtic.mil/doctrine/jel/jfq_pubs/0822b.pdf; and Wilson, "Pilots! Unman Your Airplanes!," 3692; and Defense Advanced Research Projects Agency (DARPA)-United States Air Force (USAF), "Unmanned Combat Air Vehicle (UCAV) Program Overview" (28 November 2001), 2.

operations.[245] The potential savings in O&S costs in unmanned aircraft result from two observations: the need in manned aircraft to fly costly training and pilot proficiency sorties, and the fact that some, if not the majority of, the training in a UAV can be conducted without the vehicle actually in flight.[246] In other words, simulators offer training to pilots at substantially lower costs than training in actual aircraft.[247]

Though training costs are lower for unmanned aircraft, requirements creep contributes to increases.[248] 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."[249] 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, though, an investigation of UAV ground system support costs must be done.[250]

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

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[245] Reinhardt, et al., "Future Employment of UAVs: Issues of Jointness," 38.
[246] United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations Volume I* (1996), par 4-6. On-line, Internet, 7 December 2001, available from http://www.fas.org/man/dod-101/sys/ac/docs/ucav96/index.html.
[247] Recall an earlier statistic in which up to *95 percent* of peacetime manned aircraft training occurs in the aircraft.
[248] *Options*, 32.
[249] Ibid.
[250] Barry and Zimet, "UCAVs: Technological, Policy, and Operational Challenges."

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 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.[251] 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 is to compare Predator UAV training costs directly with Specialized Undergraduate Pilot Training (SUPT) costs. SUPT is the method used to initially train USAF pilots. The FY00 cost of putting a newly trained pilot through a year of USAF SUPT was $472,920.[252] This figure includes flying hours, manpower costs, student pay, non-personnel, and command-support costs.[253] However, more costs are incurred from training required in the follow-on weapon system. For example, it cost an additional $129,316 to train a C-17 copilot.[254] There are numerous other costs implied in making a pilot fully qualified and mission-ready, such as mobility, life support, aircrew chemical

[251] Maj Shawn D. Nelson, HQ ACC/DOTR, Predator UAV action officer. Interviewed by the author on 11 April 2002.
[252] Mr Mark Parsons, AETC/FMAF. Interviewed by author 11 April 2002.
[253] Ibid.
[254] Ibid. FY00 dollars.

defense, aircrew tactics, and continuation training costs.[255] UAV operators do not receive these kinds of training; therefore, these costs are not incurred. Another important cost consideration, particularly with airlifters, is the fact there are multiple crewmembers onboard essential to the mission. The cost to train and equip them adds expenses beyond single operator programs.[256] Due to the complexities of the current Predator training contract, it is difficult to give an exact cost for each individual operator.[257] However, a proposal by Air Combat Command projects initial Predator operator training costs, under a non-pilot training program, to be $12,000 per operator.[258]

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. USAF data indicates that 78 percent of non-retirement eligible pilots separated from the USAF in FY01. This is despite the fact the USAF has improved aviator continuation pay (ACP) incentives over the last four years amounting to the "most robust compensation program to date."[259] These incentives include up-front payment increases from between $100,000 to $150,000, including increases in annual bonuses from $12,000 to $25,000. Pilots can

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[255] Maj Keith E. Tobin, "Piloting the USAF's UAV Fleet: Pilots, Non-Rated Officers, Enlisted, or Contractors?" (Maxwell AFB, Ala.: School of Advanced Airpower Studies, June 1999), 17. On-line, Internet, 2 May 2002, available from http://papers.maxwell.af.mil/projects/ay1999/saas/tobin.pdf.

[256] At the outset of the chapter, it was noted that 30 to 40 percent of any aircraft program were personnel costs. 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).

[257] Nelson interview, 12 April 2002. The FY02 contract cost was approximately $1,709 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.

[258] Capt Hoffman, HQ ACC/XRMS bullet background paper on "Non-SUPT Pilots to Control UAVs," 19 April 2000.

[259] Capt Angela Slagel. HQ AMC/DPXPA point paper on "Mobility Pilot Retention," 2 October 2001.

also choose from varying service commitment lengths. Yet, even ACP acceptance rates among eligible pilots have plunged to an Air Force-wide low of only 18 percent.[260] This figure represents a mere 470 out of 2,629 total USAF pilots eligible to accept the bonus.[261] These are disheartening figures considering the Air Force has increased flight training rates and raised the active duty service commitment length to ten years from eight. Four years ago, the pilot retention situation became acute. In 1998, "efforts left the USAF 648 pilots short of its 13,986 [pilot] requirements."[262] By 2007, the USAF will be approximately 2,300 pilots short.[263] Figure 3 below 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 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 take into account a summation of all the cost concepts examined thus far, and are concerned primarily with the long-term amortization of weapon system

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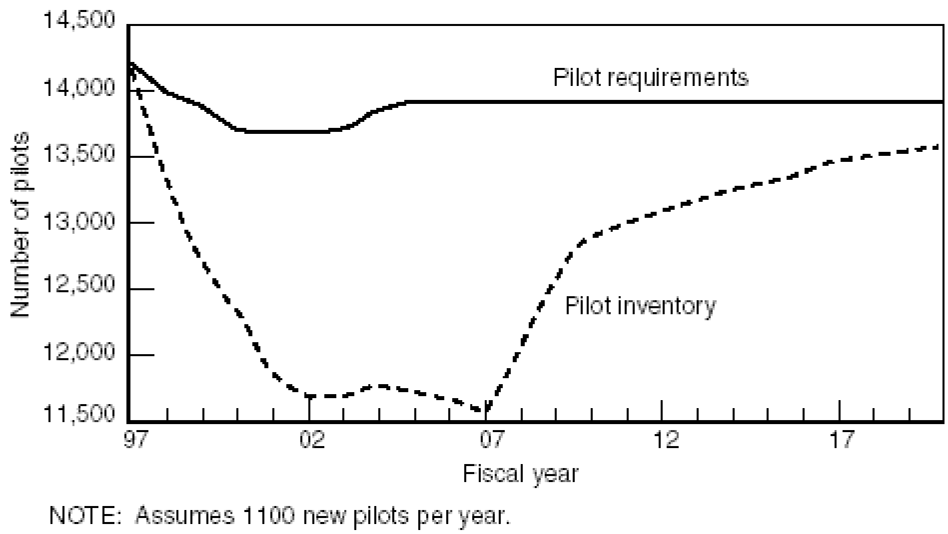
[260] Ibid. FY01 data reflecting all eligible USAF pilots. Rates for AMC pilots mirror the USAF rate at 18 percent (122 accepted of 679 total).
[261] Ibid.
[262] Flade, "Teaching a New Dog Old Tricks," 7.
[263] William W. Taylor, Craig Moore, and C. Robert Roll, Jr., *The Air Force Pilot Shortage: A Crisis for Operational Units?* (Santa Monica, CA: RAND, 2000), 5. On-line, Internet, 21 March 2002, available from http://www.rand.org/publications/MR/MR1204/.

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.[264] 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.[265]



Source: William W. Taylor, Craig Moore, and C. Robert Roll, Jr, *The Air Force Pilot Shortage: A Crisis for Operational Units?* (Santa Monica, CA: RAND, 2000), 5. On-line, Internet, 21 March 2002, available from http://www.rand.org/publications/MR/MR1204/.

[264] John A. Tirpak, "The Robotic Air Force" (*Air Force Magazine*, September 1997), 71. On-line, Internet, 22 January 2002, available from http://www.afa.org/magazine/Sept1997/0997robot.html, and Noguier, "Next Mission Unmanned," 105.
[265] *Options*, 33.

Figure 3. Predicted USAF Pilot Requirements versus Pilot Inventory

Unmanned Aircraft Cost Savings

Up to this point a great deal has been written about unmanned aircraft and their cost advantages over manned aircraft systems. The following section examines additional generalized savings.

OTHER UAV 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.[266] Depending on the level of sophistication and automation, there are tremendous costs associated with today's manned aircraft glass cockpits that disappear. 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."[267] A different writer noted that by removing the pilot, the possibility of being taken prisoner or becoming a casualty of war is also removed. A reduction in search and rescue forces also results.[268] A third advantage results from a decrease in base infrastructure otherwise needed to support manned aircraft operations (altitude chambers, life support organizations, etc.), which are used to support manned aircraft operators.

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266 DARPA-USAF, "UCAV Program Overview" (28 November 2001), 18. The UCAV concept of operations (CONOPS) employs a mission control system (operator station) driven by a 1553 data bus and operated through a 100 Mb/s (megabits per second) network switch and global positioning system time server. The UCAV CONOPS also states that operators will monitor/control multiple UCAVs, which amount to additional manpower savings.

267 Noguier, "Next Mission Unmanned," 105.

268 Ibid.

Yet, these generalized savings over manned aircraft are overshadowed by other factors associated with UAVs. 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, though, as 22 are budgeted for FY03, along with the 16 budgeted in FY02 and seven in FY01.[269] These vehicles should pay for themselves quickly because the acquisition costs will be amortized over the larger fleet. Another factor to consider is that UAVs have extremely high accident rates over manned aircraft, which is accounted for based on the 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 UALV 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, is $3.826 billion.[270] That calculation puts the per price procurement for each aircraft at roughly $318 million. The RDT&E costs accompanying procurement tops out at $157.2 million.[271] UALV costs in these areas must best that price while providing comparable cargo capabilities if the Air Force is to seriously consider UALVs.

Although the Air Force has committed to procuring 60 more C-17s in 2002, it is uncertain whether or not the Air Force would have made this is commitment prior to the terrorist attacks on America 11 September 2001. The constrained fiscal environment before that time focused acquisition priority on other platforms such as the F-22, creating

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[269] *Defense Budget for Fiscal Year 2003*, 20.
[270] Ibid., 12.
[271] Robert Wall and David A. Fulghum, "Military Budget Boost Yields Marginal Change" (*Aviation Week and Space Technology*, 11 February 2002), 24.

a budget battle to fund other important capabilities such as airlift.[272] A situational example of UALV cost savings below illustrates this point.

Assuming UALVs have defined operational requirements and are technologically feasible, and applying the same cost differential between UCAVs 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 recently contracted are procured for $318 million each. Applying the three-for-one cost difference one could either procure the same number of airplanes (60) for a third of the price ($106 million); or one could appropriate the $318 million to procure 180 UALVs. Now, the C-17 can transport roughly 170,000 pounds.[273] To be conservative, one may assume that the UALV has the same capacity as the Boeing ATT concept aircraft described in Chapter 4—80,000 pounds.[274] The total capacity of the 60 C-17s equates to 10.2 million pounds. If 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.

UALV Storage and Leasing

Because the DOD would probably employ UALVs primarily during contingency operations when airlift demand peaks, they might otherwise remain, except for those

[272] The FY03 defense budget request totaled $379B—an increase of nearly 20% over the FY02 budget and the second largest annual increase in 20 years.
[273] Department of the Air Force, "USAF C-17 Fact Sheet," on-line, Internet, 18 April 2002, available from http://www.af.mil/news/factsheets/C_17_Globemaster_III.html.
[274] Boeing Company Phantom Works, "Advanced Theater Transport Fact Sheet," on-line, Internet, 22 November 2001, available from http://www.boeing.com/phantom/att.html.

designated or required to retain system proficiency, idle.[275] 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 UCAV, 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 save both the Air Force and the commercial lessee a lot of money.

Regarding the UCAV program, storage is expected to result in a savings of 80% of life-cycle costs.[276] This is a key factor in reducing the overall life-cycle costs of UAVs, too. For example, in the war against terrorism in Afghanistan, the US 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. Keeping the UALVs in storage when not in use would save on O&S costs, and in the end would serve as a cost-effective solution to US airlift shortfall woes.

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[275] The UCAV CONOPS state that UCAVs will be placed in long-term storage when not in use to lower maintenance and life-cycle costs. *Source*: DARPA-USAF, "UCAV Program Overview" (28 November 2001), 28.

[276] DARPA-USAF, "Unmanned Combat Air Vehicle (UCAV) Program Overview" (September 2001), 4.

Fleet Size

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 illustrative example demonstrates a logical rationale for UALV fleet size.

C-5s are likely to begin retiring, based on forecast airframe structural service life estimates, near the end of the mid-term timeframe as defined by this thesis. 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, while at the end of 2002, 73 are forecast to remain. Beyond 2002, there are forecast to be 56 at the end of 2003, 31 at the end of 2004, and 22 at the end of 2005.[277] The average number of C-141s retiring over this five-year period is 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.[278] 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 calculated in Chapter 4 of between 100,000 and 160,000 pounds, and given the MRS-05 airlift requirement of 54.5 MTM/D as mentioned in Chapter 3, and a fleet of 180 C-17s providing 20.1 MTM/D, a

[277] Air Mobility Command, *Air Mobility Strategic Plan 2002 C-141 Roadmap* (October 2001). On-line, Internet, 31 May 2002. (For Official Use Only) Available from https://amc.scott.af.mil/xp/xpx/STRATPLAN2002FOUO/Roadmap/C-141_Roadmap.pdf.

[278] Air Mobility Command, *Air Mobility Strategic Plan 2002 C-5 Roadmap* (October 2001). On-line, Internet, 31 May 2002. (For Official Use Only) Available from https://amc.scott.af.mil/xp/xpx/STRATPLAN2002FOUO/Roadmap/C-5_Roadmap.pdf. The threshold figure of 180,000 pounds is based on a range of 3,200 nm.

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.[279]

SUMMARY

Estimating UAV program costs is a difficult task that must be performed with great care and judgment. This chapter has informed the reader that unmanned airlift offers distinct cost advantages over manned aircraft. It began with an examination on UAV funding and the defense budget and progressed through a series UAV program costs, including R&D, procurement, and acquisition costs. After that, the ACTD and UCAV 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 are reviewed with respect to UALVs. In every instance it was determined that unmanned aircraft, and possibly UALVs, demonstrate the potential ability to possess costs *equal or better than* their manned counterparts, answering the research sub-question, "are the concepts cost-effective?" in the affirmative.

[279] 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 UALVs 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 both 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

This thesis began 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 sub-questions. Each of the sub-questions examined an important factor essential to determine if a role could exist for unmanned airlifters in the USAF. The sub-questions were:

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

For more than 20 years, and perhaps longer, the US 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 unmanned airlift, 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 not only could they get sufficient airlift capability to fulfill wartime requirements in their areas of responsibility, but that they could also 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, this thesis found the DOD wanting of sufficient capability should it have to implement the limits of the national military strategy outlined in the QDR Report. 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 research and development funding all provide the impetus to investigate the unmanned airlift concept. Therefore, there must be reasonable assurances that unmanned airlift could demonstrate a requisite level of technological feasibility before DOD officials commit to its procurement and acquisition.

Once operational requirements are established for unmanned airlift, the next question this thesis sought to answer was, 'Are current and emerging technologies critical to unmanned airlift 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 by this thesis as the framework for analyzing the measures of merit, technologies, concepts, and support systems critical to the success of an unmanned airlift program. The examination revealed that UALVs should first 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. 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.

It was determined that unmanned airlift technological feasibility is dependent on strictly defined capability requirements, which DOD must clearly articulate, if an unmanned airlift program is to have a chance of succeeding. For example, if a requirement to incorporate a fully automated cargo handling system is required on board 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 research and development 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 unmanned airlift 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 summarized the results of various measures of merit and concepts, and provided a total technological feasibility estimate. The results suggest that an unmanned airlift program is technologically feasible in the short- to mid-term, 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 unmanned airlift. Cost comparisons between manned reconnaissance aircraft and ISR UAVs; manned fighters and developing UCAVs; and manned airlifters and notional UALVs reveal significant cost advantages in favor of unmanned platforms. Therefore, assuming technological feasibility of unmanned airlift, a comparison of costs between manned and unmanned airlifters was extrapolated to reveal cost advantages of unmanned airlift. 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 acquisition practices will allow potential UAV users to determine the viability and feasibility of unmanned airlift with only a marginal up-front investment made to the program.

Conclusion

This thesis began with an investigation into the question of whether a suitable role could exist for unmanned airlifters in the USAF. Evidence disclosed that in the short- to mid-term timeframe, unmanned airlift concepts and technologies would reach levels of maturity worth pursuing at this time. .

A chronic strategic airlift shortfall exists in the US. Strategic airlift forces are not properly sized to meet the needs of the national military strategy, which results in unnecessary risk to deploying troops ordered to distant theaters of conflict. Unmanned airlift 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 unmanned airlift is assured if directed efforts to improve existing technology are made. Present and future potential characteristics of UAVs would suggest that unmanned aircraft are very likely to be utilized in future operations.[280] 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 that:

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

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[280] Lt Col A. Noguier, "Next Mission Unmanned: The Human Factor" (*Royal Air Force Air Power Review*, Winter 1999), 113.

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 mindset. 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 airlift to meet the strategic airlift shortfall.

In order 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. Unmanned airlift has sufficiently answered each research sub-question and in doing so has answered the thesis question: there unequivocally exists a role for unmanned airlifters in the USAF. The United States needs unmanned airlifters!

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 thesis to determine if the findings of this study are indeed valid. Afterwards, employ the best practices and lessons learned from the UCAV 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 unmanned airlift. As a conduit between USTRANSCOM, United States Joint Forces Command, the Air Force, the UAV Battlelab, and industry, DARPA could determine the viability of unmanned airlift 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 concept of operations and employment in war games that exposes both the strengths and weaknesses of unmanned airlift for consideration in each phase of design, development, testing, evaluation, acquisition, and fielding.

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