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UNMANNED AIRLIFT: HOW SHOULD WE PROCEED?

by

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Abstract

In 1996, the U.S. Air Force Scientific Advisory Board identified 22 missions that might be accomplished by UAVs. Of the identified missions, there have been many studies conducted on the use of UAVs for intelligence, surveillance, and even combat applications, but none have been completed about the use of UAVs for air mobility roles, either tanker or airlift aircraft. This study seeks to break new ground by trying to answer the question, “How should we proceed?” to make the concept of unmanned airlift a reality. To this end, this study provides a conceptual survey of the strategic need for unmanned airlift, it discusses how operational pressures on the National Aerospace System (NAS) are driving the advancement of automating technologies, and it shows how this drive toward automation is laying the foundation for unmanned airlift. Based upon this foundation, this paper will sketch a path to the future, identifying critical requirements, studies, and technologies that will help make unmanned airlift a reality.

Chapter 1

Introduction

Imagine the following types of UAVs, mention of which is intended to stimulate the reader to look beyond the near-term to the far future: a Conus-based, hypersonic transatmospheric aerospace plane capable of overflying any location in the world and returning to base in less than two hours; a high altitude, global range, indefinite loiter VLO combat UAV; or a very large global range transport capable of providing emergency humanitarian aid without exposing an aircrew to danger.

-- USAF Scientific Advisory Board, 1996

The concept of unmanned airlift is not new. In 1995, General Ronald R. Fogleman, then Chief of Staff, USAF, chartered *Air Force 2025*, a project directed to determine what capabilities the USAF would need in the future.¹ When completed, the report identified uninhabited air vehicles (UAV) as one of 10 critical leverage systems crucial to the defense of our nation. Additionally, the authors of *Airlift 2025* (the air mobility piece of 2025) concluded the most appropriate global mobility system may be airships used in conjunction with powered and unpowered UAV delivery platforms.² Shortly after the presentation of *Airlift 2025*, the USAF's Scientific Advisory Board (SAB) released its study on UAVs and combat operations. Having reviewed the Air Force's roles and missions to determine how UAVs might contribute to the Service's capabilities, the SAB identified 22 relevant missions, including Refueling Tanker and Cargo Transport, that were applicable for UAV development.³ Based on their assessment

of technology, the SAB projected Tanker aircraft might develop between 2005-2015 and Cargo aircraft between 2015-2025.⁴ Given the level of interest UAV development has received, one might expect that some study of unmanned airlift might have been accomplished by now, but there has not. Therefore, based upon recent advancements in technology, coupled with the changes in the security, economic, and strategic environments, this paper seeks to answer the question, “How should we proceed?” to make unmanned airlift a reality.

To answer this question, this paper surveys the strategic requirements that suggest there is a need for unmanned airlift and identifies the fact that the U.S. Air Force does not currently have a vision for operating cargo aircraft “automatically.” However, as the research shows, the pressure of more and more passenger aircraft competing for limited airspace may soon overwhelm the National Airspace System (NAS).

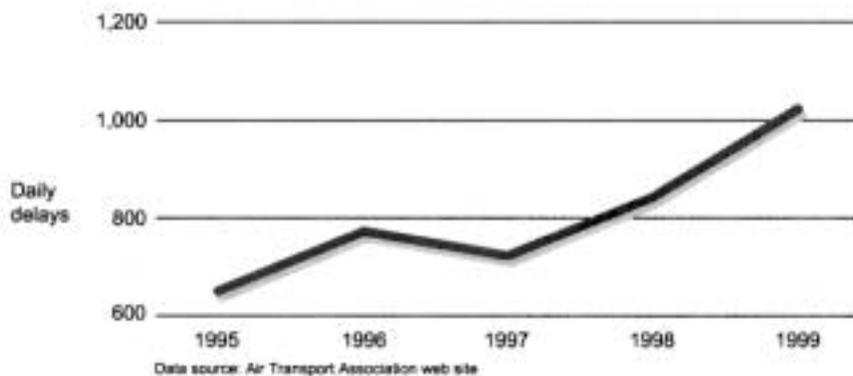


Figure 1-1: Increasing Air Traffic Delays

To ease the pressure, The Federal Aviation Administration (FAA) and NASA are developing new concepts, technologies and procedures that will help lay the foundation for unmanned airlift. This paper will review these concepts, technologies, and

procedures to support the thesis that one *can* suggest a path to the future, and it includes developing: a vision, certain specific technologies, and moving to capitalize on the great advancements that are currently under development.

Scope, Limitations, and Assumptions

This paper is not meant to be a history of the development of UAVs, nor is it a survey of all possible technologies that could enable unmanned airlift. Furthermore, this report is not a feasibility study, as most of the technologies discussed are under development, and will not be in widespread use until 2010. That said, this paper focuses on NAS evolution and NASA's Small Aircraft Transportation System (SATS), because integrating UAVs in the national and global airspace systems represents one of the most significant hurdles to be overcome. For UAV flight outside restricted airspace, the FAA currently requires 60 days prior notice and a detailed explanation of coordination, communication, route and altitude, and lost link/mission abort procedures.⁵ NAS evolution and SATS developments will help provide a path toward seamless UAV operation. However, in addition to NAS evolution and SATS, this paper will examine several other key enabling technologies. Finally, this study assumes the reader has an understanding of aviation terminology and is familiar with the purposes of major aviation organizations.

Use Of Terms

Different organizations refer to UAVs in different ways. For example, the FAA used to refer to UAVs as Remotely Piloted Vehicles (RPV) but has changed to Remotely Operated Aircraft (ROA). To avoid creating yet another term for pilotless aircraft and to

be consistent with current Air Force terminology, this paper uses “UAV,” “unmanned airlift” and “automated airlift” synonymously to indicate an aircraft that carries cargo and/or passengers, but does not require pilots in their seats to perform basic flight functions: takeoff, en route control, and landing. Therefore, although “UAV” and “unmanned” are used throughout this paper, the envisioned “unmanned” airlifter would routinely carry personnel as auxiliary crew or as passengers. Also, this study applies equally to tanker and cargo aircraft. Since NASA and the Air Force Research Laboratory are developing an automatic refueling capability that would allow aircraft to refuel without the receiver being able to see the tanker,⁶ unmanned airlift also implies unmanned tanker.

Notes

¹ Maj Thomas G. O’Reilly, “Uninhabited Air Vehicle: Critical Leverage System for Our Nation’s Defense in 2025,” Research Report no.99-152 (Maxwell AFB, Ala.: Air Command and Staff College, 1999), v.

² James A. Fellows et al., *Airlift 2025: The First With the Most*, (paper presented to Air Force 2025, August 1996), 44, on-line, Internet, 25 Jan 2002, available from <http://research.maxwell.af.mil/papers/spacecast/volume2/chap04/vol2ch04.pdf>.

³ United States Air Force Scientific Advisory Board, *UAV Technologies and Combat Operations*, vol. 1, *Summary*, SAB Report SAB-TR-96-01 (Washington, D.C.: Department of the Air Force, AF/SB, 1996), 3-1.

⁴ *Ibid*, p. 10-2.

⁵ US Department of Transportation, memorandum of understanding with Department of Defense. Subject: Department of Defense (DoD) Remotely Operated Aircraft (ROA) Operations, 19 March 1999.

⁶ Barth Shenk, Air Force Research Laboratory, interviewed by author, 6 January 2002.

Chapter 2

The Impetus for Automation

Based upon the strategic outlook of the most recent Quadrennial Defense Review (QDR), the need for unmanned airlift is becoming more apparent. The QDR acknowledges capabilities and forces located in the continental U.S. will be critical to our future military posture, and future expeditionary and forced entry missions may depend upon rapidly deployable, highly lethal and sustainable forces that may come from outside a theater of operations.¹ Furthermore, DoD will need to provide sufficient mobility, including airlift, to conduct expeditionary operations in distant theaters against adversaries armed with weapons of mass destruction and other means to deny access to U.S. forces.² However, the QDR points out, “The U.S. military has an existing shortfall in strategic transport aircraft.”³ With the need to provide more power projection and more airlift in the face of greater threats, unmanned airlift may help provide the force enhancements, risk reduction and deterrent capabilities the QDR is seeking.

Here is how unmanned airlift can help. First, unmanned airlift/tanker aircraft won't have a limited crew-duty day, so they can project power farther, without direct crew constraints. Furthermore, we can increase their operational tempo without putting a tremendous strain on limited numbers of aircrew. Second, our nations political leaders will have a more flexible military instrument of power if they know they can project

power without risk to aircrews. This would occur when we marry unmanned tankers to unmanned combat aerial vehicles (UCAV), or when we send airlift aircraft to airdrop supplies during humanitarian relief efforts when the threat is unknown. Finally, unmanned power projection should serve as a meaningful deterrent. Hopefully, knowing the U.S. can strike precisely across almost any distance, with a whole spectrum of force (instead of just cruise or ballistic missiles), will dissuade adversaries from using force against America or its allies. Surprisingly, however interesting these concepts sound, there has been no planned progress toward unmanned airlift.

Currently, neither the Air Force nor the aviation community at large has a vision for unmanned airlift. According to Maj Grant Dick in Air Mobility Command's (AMC) long range planning branch, AMC's strategic plan extends to 2018 and does not include the concept of unmanned airlift.⁴ Maj Lenny Richoux, the air mobility officer at the Headquarters USAF strategic plans division, confirmed that the Air Force is not currently pursuing pilotless tanker or airlift aircraft.⁵ Furthermore, Mr. Barth Shenk of the Air Force Research Lab acknowledged that the lab has had no requests to do studies into automated airlift.⁶ Widening the search, Mr. Bob Hilb, Manager of Advanced flight Systems and Future Technologies at United Parcel Service (UPS), stated UPS was "not considering it."⁷ Surprisingly, the only agency this author could find with an active interest in automated airlift was NASA. In November 2001, NASA contracted with the Applied Research Laboratory at Pennsylvania State University (PSU) to study the requirements of automated airlift. Mr. Ed Crow, Head of the Systems and Operation Automation Division at PSU, began the study by trying to find an agency (government or industry) that had a desire to actively pursue unmanned, automated airlift. He found

none.⁸ This is not to say there is no interest in the subject. Anecdotally, many agencies are talking about it, but if there is someone out there with a vision for unmanned airlift, they are keeping it to themselves. To some degree this reticence is understandable, and worthy of brief investigation.

There appears to be five main reasons why no one has a vision for unmanned airlift, and a short discussion will help clarify the direction of this report. Both Majors Richoux and Grant identified the first reason—no military requirement. Since the Air Force has no specific mission that requires unmanned airlift for completion, it has no vision which includes unmanned airlift.⁹ Bob Hilb from UPS identified the second reason—cost/payoff. Mr. Hilb relayed that UPS only invested in technologies that would be cost effective in the near term, and the possibility of unmanned cargo-carrying aircraft lies too far in the future.¹⁰ The third and fourth reasons are intuitive—safety and cultural concerns. How receptive will the public be toward getting on aircraft with no pilot, or just having them fly overhead? The final reason is one already discussed in this paper—integrating UAV operations in the national and global airspace systems. Currently, there are so many different communication, navigation, and surveillance systems, each with varying degrees of coverage, that one cannot construct a single, straightforward operating procedure. When combined, these five reasons create a significant obstacle. No one organization can provide the funding, direction, or operational procedures to overcome them all. However, there are economic and security pressures on the NAS that are driving technical, cultural, and organizational revolutions which will redefine how we think about aviation. The planned response to these revolutions will help pave the way for unmanned airlift.

The pressure of more aircraft competing for limited airspace is driving significant changes to the NAS. To quantify the problem, Boeing compiled the following statistics (based upon pre 9/11 observations): between 1995 and 1999, the US Department of Transportation (DOT) saw a 58% increase in aircraft departure delays, and cancellations grew even faster, increasing 68%; during the first 7 months of 2000, over 90 million passengers arrived late to their destinations or had their flight canceled; and the Air Transport Association (ATA) estimates that delays cost the US industry, shippers, and passengers more than \$5 billion per year—about \$3 billion in direct airline operating costs and at least \$2 billion in the value of passengers' time.¹¹ According to John Marburger, the President's Director of the Office of Science and Technology Policy, "our air traffic system – based on 1960's technology and management ideas – [is] approaching gridlock, [and] . . . the current system cannot simply be scaled up to meet projected future growth, especially given the additional measures required to enhance its security."¹² To meet the needs of the 21st century, Mr. Marburger argued the aviation system must include a common infrastructure of communications, navigation, and surveillance equipment that would be secure and allow "all classes of aircraft, from airlines to unpiloted vehicles to operate safely, securely, and efficiently from thousands of communities based on market size and demand."¹³ To meet these requirements, the Federal Aviation Administration (FAA), in conjunction with the International Civil Aviation Organization (ICAO) and the aviation industry, is implementing Free Flight and its Operational Evolution Program (OEP).

Free Flight and the OEP will change the air traffic control paradigm with new concepts, technology, and operating procedures. Expected to be in place by 2010, the

OEP envisions greater airspace access through reduced vertical separation between aircraft, reduced lateral separation between aircraft, increased RNAV or point-to-point navigation, and more informed decision making through increased situational awareness for pilots and air traffic controllers.¹⁴ The industry is so enthusiastic about these changes that UPS is busily equipping its aircraft with Automatic Dependent Surveillance—Broadcast (ADS-B) (an OEP enabling device to be discussed in the next chapter). Fed Ex has issued “challenges” to the aviation industry and the FAA to speed up the process.¹⁵ Furthermore, Boeing has created new corporate division for ATM development, and has already received permission from the FCC to build a medium earth orbit constellation of satellites to support the common information network.¹⁶

To achieve the OEP’s goals, there are three core upgrades that must be made to the airspace system: trajectory based air traffic management, reliance on a common information network, and airspace redesign. Although Boeing’s vision goes a bit further than the FAA’s, Boeing’s depiction of how the airspace system should evolve is extremely illuminating. Referring to the figure on the next page, trajectory-based flow management allows air traffic controllers to predict aircraft flight paths and make adjustments as necessary. With older systems, the controller had no way to foresee congested airspace or the impact changed routing would have on other traffic. Trajectory-based flow management will allow controllers to view predicted flight paths up to 40 minutes into the future. This will make potential conflicts much easier to spot and resolve while giving controllers the information and the time to plan for safe avoidance of congestion and delays.¹⁷ Next, we’ll look at the common information network (CIN).

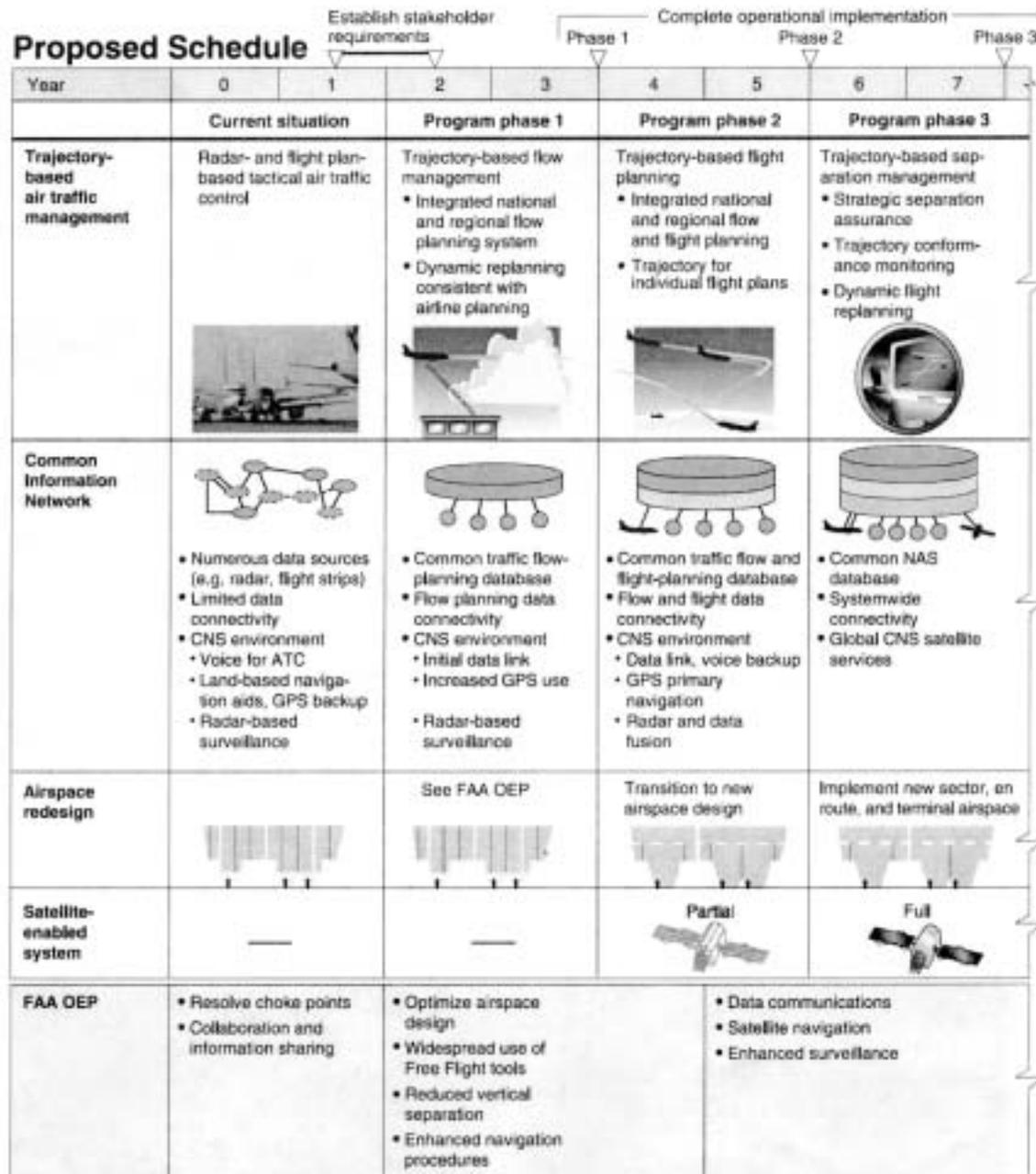


Figure 2-1: Boeing’s Vision for the Evolution of the Air Traffic Management System

The CIN is the backbone of the new airspace system. The basic concept is to integrate the communication, navigation, and surveillance (CNS) systems that service the air traffic management environment. In Boeing’s vision, the CIN will use secure and encrypted communication links between aircraft, advanced (CNS) satellites, and ground-

based users to provide real-time information about aircraft trajectories, weather, and traffic flow.¹⁸ To better visualize this concept, Boeing provided the graphic in figure 2-2.

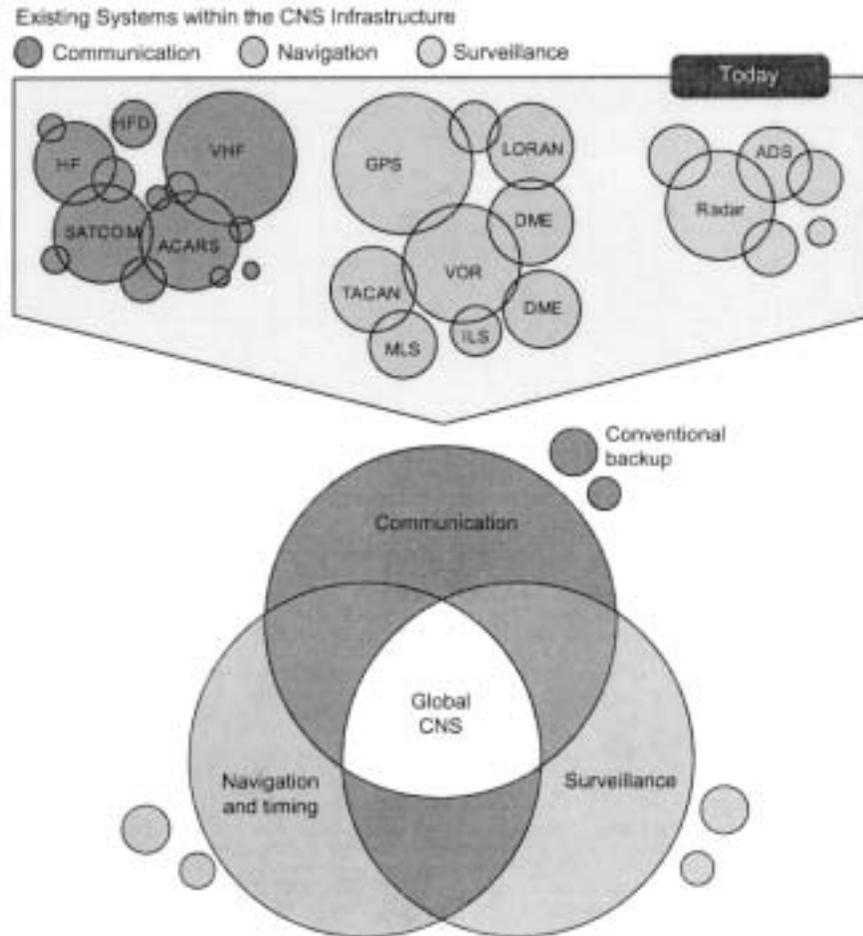
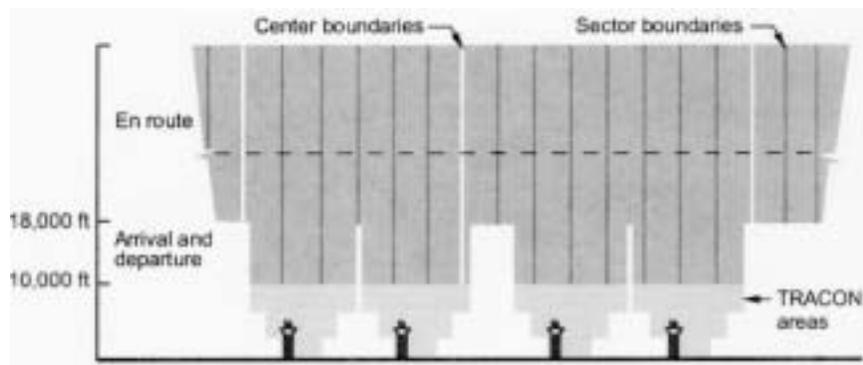


Figure 2-2: Integration of the CNS Systems

With the CIN established, trajectory-based flight path management will be possible because controllers will receive real-time information about aircraft position, weather, and flight plans. This will also enable the redesign of airspace.

The concept of redesigned airspace is really a byproduct of trajectory-based flow management and the CIN. One of the tools being implemented under Free Flight is Collaborative Decision Making (CDM). CDM provides airline operations centers, air traffic controllers, and the FAA’s national control center with real-time access to NAS

status information, including weather, equipment availability, and delays. This collaboration helps manage the airspace more efficiently.¹⁹ As the support technologies for CDM mature, there will be less need for as many sector controllers managing airspace tactically. Collaboration at the national level and trajectory-based flow management should identify and eliminate congestion before it becomes a factor at the sector level. This is what is depicted in figure 2-1 next to airspace redesign. The following figure is included for clarification.



Before



After

Figure 2-3 Airspace Redesign

Taken together, trajectory-based flow control, CIN, and airspace redesign represent significant steps forward in airspace management. Since the technologies that will enable these steps will be crucial to the development of unmanned airlift, they will be discussed

in greater detail in the next chapter. However, there is another new concept in aviation that will be even more important to clearing the path toward unmanned airlift: NASA's Small Aircraft Transportation System (SATS).

Unlike Free Flight and the OEP, SATS represents a revolution in aviation. Currently, nearly 70% of domestic air travelers are forced to fly through fewer than 35 of the nation's more than 18,000 landing facilities. SATS hopes to demonstrate and produce the technology and training necessary for more passengers to travel via small aircraft, point-to-point, in almost any weather, and land at more airfields without the benefit of control towers, radar, or precision instrument approaches.²⁰ To make this possible, SATS intends to make the aircraft "smarter" by providing pilots with more intuitive guidance. The technologies necessary to accomplish this will be discussed in chapter 4. However, SATS has ambitious goals. One such goal is having (in terms of safety and reliability) one SATS pilot equal two Airline Transport Pilot (ATP) certified pilots—thus permitting commercial, single-pilot flight operations.²¹ Furthermore, SATS hopes to reduce inter-city doorstep-to-destination transportation time by 50% in 10 years and by 67% in 25 years, making SATS travel an attractive alternative to hub-and-spoke commercial air travel.²² As one can see, SATS represents a revolution in air travel concepts, and the technology necessary to deliver SATS will take unmanned airlift forward. However, there is another force that will help propel aviation toward unmanned airlift--the uncertain security environment.

After the tragic terrorist attack on New York and Washington, D.C. on 11 September 2001, the FAA and other agencies are looking for better ways to maintain control of the skies. According to the Aviation and Transportation Security Act, the

Transportation Security Administration (a division of the DOT) will be required to “identify and undertake research and development activities necessary to enhance transportation security.”²³ Steve Pansky, the FAA’s Manager for Research and Strategic Requirements, explained that this was initially interpreted as a call for better baggage screening and ground security measures. However, there are those who are now looking at monitoring flight conformance, and establishing parameters and procedures for taking control of an aircraft in flight, (or having the pilot transfer control to the ground) should an incident occur.²⁴ Although not going as far as taking control of the aircraft, Boeing’s air traffic management plan anticipates the need for improved security measures. With Boeing’s CIN in place, should a terrorist threat occur, a security administrator could restrict access to airspace by entering the restriction directly into the system, and the system would immediately respond and update the trajectories of all affected aircraft.²⁵ Since the terrorist attack is so recent, no one has fleshed out exactly how ground control would work, but security against terror in the sky presents another impetus for developing the technologies for unmanned airlift.

In summary, no one in the military or industry is willing to admit to a vision of unmanned airlift, so currently there is no well defined path. However, with the pressure to get more out of our available airspace, and do it safely, many exciting automation technologies will be developed over the next 3-7 years. We turn now to a closer look at some of those technologies and how they may influence the development of unmanned airlift.

Notes

¹ Department of Defense, *Quadrennial Defense Review*, 30 September 2001, on-line, Internet, 12 February 2002, p. 26, available from <http://www.defenselink.mil/pubs/qdr2001.pdf>.

² Ibid, p. 26.

³ Ibid, p. 8.

⁴ Major Grant Dick, Air Mobility Command, Long Range Planning Branch, interviewed by author, 9 January 2002.

⁵ Major Lenny Richoux, Headquarters US Air Force, Future Concept Development Office, interviewed by author, 25 January 2002.

⁶ Barth Shenk, Air Force Research Laboratory, interviewed by author, 6 January 2002.

⁷ Bob Hilb, Manager, Advanced Flight Systems and Future Technologies Office, UPS, interviewed by author, 10 January 2002.

⁸ Ed Crow, Systems and Operation Automation Division, Applied Research Laboratory, Pennsylvania State University, interviewed by author, 14 January 2002.

⁹ Richoux and Dick interviews.

¹⁰ Hilb interview.

¹¹ Boeing, "Quick Facts about Air Traffic and Its Economic Impact," on-line, Internet, 16 Jan 2002, available from www.boeing.com/atm/pdf/combinedfacts.pdf.

¹² John Marburger, "Presentation to the Commission on the Future of the United States Aerospace Industry," November 27, 2001, 1-2, on-line, Internet, 14 Jan 2002, available from <http://www.boeing.com/atm/pdf/sciadvpresentationtocommis.pdf>.

¹³ Ibid, p. 3.

¹⁴ Federal Aviation Administration, "Operational Evolution Plan Version 4.0," December 2001, on-line, Internet, available from <http://www.faa.gov/programs/oep>.

¹⁵ David Bond, "ATC Modernization: How Much, How Fast?" *Aviation Week and Space Technology*, 10 September 2001, 66.

¹⁶ Boeing, "Important Milestone for Boeing Air Traffic Management as FCC Grants Mobile Satellite Service Licenses," 18 July 2001, on-line, Internet, available from http://www.boeing.com/news/releases/2001/q3/nr_010718b.htm.

¹⁷ Boeing, "Boeing Air Traffic Management--Backgrounder," on-line, Internet, 8 Mar 2002, available from <http://www.boeing.com/news/feature/aa2002/pdf/ATM.PDF>.

¹⁸ Boeing, "Air Traffic Management – Safety and Security," on-line, Internet, 9 Jan 2002, available from <http://www.boeing.com/atm/safety/index.html>.

¹⁹ Federal Aviation Administration, "Free Flight Phase 1," on-line, Internet, 16 January 2002, available from http://ffp1.faa.gov/about/about_ffp1.asp.

²⁰ NASA, "Small Aircraft Transportation System Program, Program Plan V0.8, on-line, Internet, 22 Jan 2002, available from http://sats.larc.nasa.gov/downloads/SATS_Program_PlanV0.8.doc.

²¹ Ibid, p. 8.

²² Ibid, p. 4.

²³ US Senate, *Aviation and Transportation Security Act*, 117th Cong., 1st sess., 2001, S. Doc.1447, 2.

Notes

²⁴ Steve Pansky, Manager, Research and Strategic Requirements, Federal Aviation Administration, interviewed by author, 16 Jan 2002.

²⁵ Boeing, Air Traffic Management – Safety and Security.

Chapter 3

Command and Control of UAVs in the National Airspace System

The technologies and procedures being developed for the OEP will have a direct impact on two key issues facing UAVs operating in the NAS: maintaining positive control and maintaining proper aircraft separation. This chapter will discuss how emerging technology and procedures in communication, navigation, and surveillance will aid the transition to unmanned airlift.

Perhaps the most important development will be the integration and use of data links for several types of information transfer. First, the FAA and ICAO are introducing direct controller/pilot data link communications (CPDLC) to reduce voice traffic and time spent on routine actions. Eurocontrol completed its first test of CPDLC in the summer of 2001, and US agencies will initiate use of CPDLC in June 2002.¹ The second type of information to benefit from data link capabilities includes Flight Information Services (FIS) and Terminal Information Service – Broadcast (TIS-B). FIS will provide weather information (to include TAFs, METAR, SIGMETS, AIRMETS, and PIREPS) and NOTAMs, while TIS-B provided radar generated information, including the identity, position and estimated ground speed of aircraft that are not ADS-B equipped.² The FAA is currently developing an ADS-B based cockpit display of traffic information that will

provide the pilot with a graphical display of pertinent FIS and TIS-B information. The third type of data is perhaps the most exciting of them all: ADS-B.

ADS-B is one of the core technologies that all other changes will be based upon. It uses onboard GPS rather than ground based radar to determine aircraft position. Then, it broadcasts (over data link) the aircraft's GPS coordinates, which are more accurate than radar, and its velocity, attitude, altitude, identification, and destination to ADS-B aircraft and ground controllers within 150 miles.³ This capability will enable Free Flight's dream of aircraft flying most places point to point because ADS-B equipped aircraft will know each other's trajectory and will command the pilot, or autopilot, to make corrections as necessary to avoid potential conflicts without a controller's input. Furthermore, the accuracy of ADS-B will allow greater use of available runways. For example, at San Francisco there are two slightly offset runways. United would like to use them both simultaneously. ATC is working out procedures that would allow two ADS-B equipped aircraft to use the runways in non-VMC conditions because ADS-B tells each pilot exactly where the other aircraft is.⁴ Finally, ADS-B represents a tremendous breakthrough in surveillance capabilities. In January 2000, the FAA equipped over 150 aircraft in Alaska with ADS-B. With the appropriate ground transmitters in place, controllers were able to "see" the satellite data ADS-B aircraft transmit and provide radar vectors. Encouragingly, they found the accuracy, frequency and reliability of ADS-B to be superior to radar as a source of aircraft surveillance information.⁵ The final type of information that will benefit from data link capabilities is aircraft systems monitoring.

Currently, Boeing is working on data transmission systems that will provide a great deal of information about an aircraft in flight. Called Connexion, this plane-board

broadband data link will provide a secure pipeline for transmission and reception of information among aircraft and other users of the common information network. Connexion will allow near-real-time audio, video, and aircraft data monitoring from the ground and from a suit of sensors in the cockpit, cabin, and cargo areas to detect and notify authorities of chemical, explosive, or biological threats.⁶ Next, we will consider upgrades to the navigation system.

Although not directly a part of the OEP, the Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) will significantly improve the usefulness of GPS. WAAS is a satellite based navigation augmentation system designed to warn users when GPS signals are not functioning properly, and it also corrects the signals for ionospheric and similar disturbances, making them accurate to within 11.5 feet,⁷ giving airfields a GPS based precision approach capability. LAAS is a ground-based transmitter that will augment GPS and WAAS signals in the vicinity of the airport. With one-meter accuracy, LAAS will permit curved precision approach paths, category II and III approaches down to zero ceiling/visibility conditions, and airport controllers to track aircraft movement on the ground.⁸ WAAS service entry is expected late in 2002, while CAT II/III LAAS production is expected in 2006.⁹ Having covered communication and navigation, we will now take a look at changes to the surveillance/flight planning environment.

In addition to collaborative decision making, ADS-B, and data link, there are other tools and services under development by the FAA and Boeing that will have important repercussions on the NAS. As part of the OEP, the FAA will implement the User Request Evaluation Tool (URET), the Center-TRACON Automation System

(CTAS), and the Traffic Management Advisor (TMA). URET is a software tool that can predict an aircraft-to-aircraft conflict 20 minutes ahead in time. When pilots request changes in their routing, the tool will inform the controller of conflicts, allowing the controller to suggest other routing that will be conflict free.¹⁰ TMA enables en route controllers and traffic management specialists to develop complete arrival scheduling plans of properly separated aircraft. These plans then support early runway assignments that maximize an airport's use of its available capacity.¹¹ CTAS works in conjunction with TMA providing controllers with a timeline display of aircraft approaching the airspace and runways. Controllers can observe potential imbalances and use the data to suggest optimal solutions. While TMA aids in optimizing traffic flow in the extended airspace around an airport, the CTAS Terminal tool helps controllers optimize the flow to touchdown.¹² Boeing hopes to contribute to the effectiveness of these tools with its vision of trajectory based flight management.

According to Boeing, the fusion of the technology and tools mentioned above will enable dynamic flight replanning and flexible flow control. At the heart of the system will be the National System Flow Model, hosted at the FAA Air Traffic Control System Command Center. This flow model will incorporate: aircraft trajectory (airspeed, altitude, heading, and time) for 40 minutes or more into the future; weather information (data linked from national weather service and aircraft sensors); and user requests; to anticipate flow problems across the nation.¹³ Ultimately, flight plans will be continuously monitored through the National System Flow Model, and required trajectory changes, due to congestion or weather, will be automatically sent via data link to the aircraft.¹⁴ According to Boeing, "The ability to replan flightpaths of airborne

aircraft will enable planners to sustain near-normal airspace capacity during disruptive events.”¹⁵ These enhanced capabilities provide important guidance for how airlift UAVs will operate in the NAS.

The first implications for UAV operations are technical in nature. Upgrades to the GPS system will mean that an unmanned airlifter will be able to use a single source for all of its navigational needs. If WAAS and LAAS accuracy is as good as predicted, then combined with precise digitized airfield maps, aircraft will be able to taxi themselves, takeoff, fly en route, land and taxi to parking using only GPS signals--ceiling and visibility will be irrelevant. Upgraded GPS information in conjunction with the use of ADS-B and TIS-B information will allow aircraft to maintain proper spacing from other aircraft both on the ground and in flight. Since upgrades to the NAS represent an evolutionary process, the UAV will still require a low power radar to have a “see and avoid” capability, which it would require anyway to avoid flocks of birds, ultralights, or other non-ADS-B equipped flyers. Other changes to NAS technology and procedures have conceptual implications for UAV command and control.

The widespread use of data link for general aviation will permit a new philosophy of UAV control. Currently, the US operates two types of UAVs, totally autonomous, like Global Hawk, and pilot dependant, like Predator. In the new NAS, the switch to data link for issuing controller instructions and dynamic flight planning in which the system automatically sends updated flight plan information to the cockpit are ideally suited for automated flight. Since data link information will be transmitted via satellite, it will not matter where the aircraft operator sits. In the aircraft or a ground control station, as long as the operator can receive a satellite signal, he will receive the same information.

Furthermore, the data feed will be digital, which is the ideal media for use by a computer. Finally, the fusion of traffic, weather, terrain, and flight plan information in a digital display (like the one mentioned above) will provide the single source necessary for decision making. Since the operator, the FAA Air Traffic Control System Command Center, and the controller will have access to the same information, control of UAVs in the NAS will be a collaborative effort. Controllers will issue taxi instructions and flight plans via data link, so UAV basic functions, including taxi, takeoff, en route collision avoidance, and en route altitude and course maintenance will be performed automatically. Controllers, in coordination with the national command center, will make suggested changes to flight trajectories via data link, and operators will acknowledge receipt and crosscheck their accuracy. Therefore, the operator, controller, and the aircraft play important roles in maintaining airspace system integrity.

Before concluding this chapter, there is one other point that must be made regarding the operation of UAVs in the airspace system. In order to limit the scope of this paper, most of the discussion has been centered on the US NAS. This limitation is also important because it permits the author to be consistent with dates the technologies will be available. However, as mentioned at the beginning of this chapter, the Europeans are testing data link communications. They are also in the midst of developing ADS-B and their own version of Free Flight.¹⁶ Furthermore, Jane Garvey, FAA Administrator, commented on ADS-B, “This technology has the potential of filling huge gaps in radar coverage including vast areas in South America, Africa and in remote areas of the United States.”¹⁷ Finally, Boeing envisions global coverage for CNS with its common information network satellite system, and has set up offices in Europe and Asia to garner

support and acceptance for its proposals. The significance for UAV operation is that a *global* operating environment may not be as far away as one may have thought. However, its development is far less easy to predict than the US system.

Although the discussion throughout this chapter was highly conceptual in nature, it is significant because it is based upon changes that are actually occurring to the NAS. Economic pressure to get more out of our available airspace is driving the FAA to build a foundation of tools and procedures that favor automated operations. The next chapter discusses the SATS program and other technical advances that will challenge our perception of airmanship, what it means to be a pilot, and the requirement to have a “pilot” on board the aircraft.

Notes

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Chapter 4

Changing the Perception of UAV Operator Requirements

In his study, “Piloting the USAF’s UAV Fleet: Pilots, Non-Rated Officers, Enlisted or Contractors?”, Major Keith Tobin identified three categories of UAVs: high altitude, tactical, and “all others, which include those UAVs designed to operate within and in combination with manned aircraft and their airspace.”¹ He focused on the final category because the type of operator required to fly UAVs in the NAS would address the majority of Air Force requirements.² In his conclusion, Major Tobin argued that the most appropriate operators would be pilots because the airmanship a pilot develops by operating in the NAS and through mission accomplishment will be required for UAV operations in the foreseeable future.³ This paper challenges this conclusion, not because the argument is faulty, but because NASA’s SATS program, in conjunction with the technical changes discussed previously, will fundamentally change what is required to be a pilot, and what is required to have airmanship.

The SATS program has three key objectives that are pertinent to this study. First, enable higher volume operation at non-towered/non-radar airports. SATS technology and procedures will allow simultaneous, all-weather operations by multiple aircraft in non-radar airspace. To accomplish this, aircraft will use vehicle-to-vehicle collaborative sequencing and automated flightpath management systems. Second, SATS will allow

lower landing minimums at minimally equipped landing facilities. Small aircraft will receive precision approach and landing guidance, through the use of graphical flightpath guidance and artificial vision, to any touchdown zone at any landing facility while avoiding land acquisition and approach lighting costs, as well as ground-based precision guidance systems such as ILS. Finally, SATS intends to increase single-pilot crew safety and mission reliability. Through the use of human-centered automation, intuitive and easy to follow flightpath guidance superimposed on a depiction of the outside world, software enable flight controls, and an onboard flight planning/management system, SATS expects that one SATS pilot will be able to equal two ATP pilots in safety and reliability.⁴ At the very heart of the system is a concept that marries “synthetic vision” with “highway in the sky (HITS).”

To ensure safe single-pilot operations, NASA intends to employ synthetic vision and HITS technology. Synthetic vision is a 3-D projection of the surrounding terrain and obstacles, allowing a pilot to “see” his surroundings even in IMC conditions. Additionally, the HITS display will project a pre-planned course “highway” for the pilot to follow, instead of gauges and dials for the pilot to interpret and synthesize into a mental picture of the airplane situation. The graphical display system includes a two-panel display of GPS position and attitude, course, weather, and aircraft track performance. The integrated flight display system provides the pilot with an intuitive pictorial for situational awareness, and with a system that is affordable for use in general aviation aircraft.⁵ Both synthetic vision and HITS technologies were developed under NASA’s Advanced General Aviation Transportation Experiment (AGATE) program. Now NASA hopes to fuse them with other advancements to help lead a revolution in air

transportation. Another key development for safety and pilot reduction is the Cyber Tutor program.

Cyber Tutor will redefine how pilots are trained. In conjunction with the Southeast SATS Lab Consortium, Embry-Riddle University is developing the technology and procedures necessary to significantly reduce the amount of training required to become a pilot. According to Bob Peak, Technical Director, Southeast SATS Lab Consortium, Embry-Riddle has already developed and received approval from the FAA to conduct a course for pilots to gain their pilots license and an instrument rating *simultaneously*.⁶ Building upon this progress, the Cyber Tutor program will rely upon performance, rather than time based training. After the appropriate amount of ground and in-flight instruction, the student will be able to go to a SATS aircraft, program the aircraft for a specific flight profile, and the aircraft will direct the student to practice the required flight skills. At the end of the mission, the student will download his flight to disk (or tape) and review his performance with an instructor. The instructor will grade his efforts, and outline his next profile.⁷ Using this performance-based methodology, Mr. Peak believes that the amount of training required to produce an instrument rated pilot will be cut in half.⁸ This type of training should begin within the next two years, when the first SATS aircraft are available. Another enabler of single-pilot operations is the dynamic approach calculation capability.

It is the dynamic approach calculation functions that will allow SATS aircraft to operate safely in and around non-towered, non-radar airfields in IMC conditions. SATS will develop vehicle-to-vehicle collaborative sequencing and separation systems that provide time-based flightpath guidance. This flightpath guidance will dynamically

account for traffic, terrain/obstacles, NOTAMS, and airspace restrictions while providing efficient flightpath management from takeoff to touchdown.⁹ In other words, the aircraft will be able to take into account the factors mentioned above, and in real time calculate the most appropriate approach course to the landing runway, all the while establishing sequencing and maintaining required separation from other traffic. Before discussing SATS implications for unmanned airlift, there are two other technologies that must be discussed.

Boeing's Pilot Associate and NASA's Intelligent Vehicle Research initiative both may contribute to the development of safer UAVs. The Pilot Associate program is based upon a dynamic human/computer function allocation process for a rotorcraft. The Associate's Cockpit Information Manager (CIM) assesses the rotorcraft pilot's external environment and situation. It also assesses pilot intent based on control inputs, and monitors workload. The CIM manages information presented to the pilot, and to the extent allowed, will perform certain tasks automatically if the pilot becomes overloaded.¹⁰ The CIM software has been thoroughly ground-tested in simulators, and is now in flight test. Boeing is modifying the CIM for application to the UCAV mission.¹¹ The Intelligent Vehicle Research program will begin with advancements in flight control technology. The first task will be to establish a Research Flight Control System (REFLCS) to demonstrate the potentially live-saving technology of Intelligent Flight Controls that can keep damaged aircraft controllable.¹² Boeing intends to install the system on a C-17 in 2002, and NASA will commence testing at its Dryden Flight Research Center in 2003. This technology, as well as the others mentioned above may have a tremendous impact on our ability to make progress toward unmanned airlift.

The SATS program, especially the emphasis on single pilot operations and significantly reduced pilot training, opens the door for several possibilities. The first is flying airlift/tanker aircraft with only one pilot. SATS will prove that one pilot can operate a small aircraft safely in the NAS. Can one pilot operate a larger aircraft just as safely? Only a human analysis study based upon demonstrated SATS technology will tell. The most important determination would be how well one pilot performs over a long crew duty day. If one pilot can operate the aircraft safely, then it will permit a “walk then run” process for progress. Single pilot operations will allow time for testing fully automated procedures with a pilot in the seat, and it will also allow time for building aircraft monitoring and control centers wherever necessary. With the innovation in pilot training, the Air Force may also be able to redefine what it takes to be an airlift pilot. As mentioned earlier in this paper, unmanned airlift does not mean that no people will be on board, only that there will be no dedicated pilots. The Air Force currently has flying crew chiefs that fly with the aircraft to perform maintenance when required. If SATS technology makes pilot training truly intuitive, flying crew chiefs may become “pilots” as part of their technical training, with the intent of having them perform emergency landings if ever called upon to do so.

Another important outcome of SATS is that it will allow time for our culture to change its thinking about what is required to fly an aircraft. If SATS is successful, more people will be exposed to the advanced technology, the ease of single-pilot operations, and it will hopefully engender a mindset that aircraft can just about fly themselves. SATS may also help more people become interested in becoming pilots, making more aware of the advancements being made and how safe automation in aviation will be.

Furthermore, smart controls such as the Pilot Associate and the Intelligent Vehicle Initiative may add to the sense that aircraft are ready for fully automated operations. Obviously, no one will know how aviation will progress until SATS completes its demonstration in 2005 and the OEP is implemented in 2010. However, economic forces are driving aviation toward automation, and because of SATS and the other innovations discussed, what it takes to be a pilot and how one defines airmanship will change significantly over the next 8 years.

Notes

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Chapter 5

The Path to the Future

Prediction is a risky thing, especially when it's about the future.

--Yogi Berra

Having conducted a survey of emerging technologies, we now turn to the steps that must be taken to make unmanned airlift a reality. Most importantly, the U.S. Air Force must define mission requirements, based off of QDR predictions, and adopt unmanned airlift as part of its operational vision. Even if the Air Force does not spend any money or conduct any studies in the near term, public acknowledgement of the vision could pay big dividends. For example, it is disappointing to think NASA has funded a research project on this subject, but the researcher could not find anyone who was interested. This is a lost opportunity. Furthermore, public acknowledgement would allow agencies such as the Radio Technician Commission for Aeronautics (RTCA) to begin serious dialogue on the subject. Currently, RTCA includes over 270 government, industry, and academic organizations from around the world, and provides a working forum to guide the operational use of aviation systems and technology in response to airspace user needs.¹ Discussion among RTCA members would help establish the baseline necessary to formulate the common operating procedures of the future. Having publicly

acknowledged a plan to operate unmanned mobility aircraft, the next steps follow the development of specific technologies.

As the technologies discussed in this paper mature and are realized, they will cue further developments that will help unmanned airlift progress. Between 2005 and 2010, SATS will have demonstrated important enabling technologies, and most of the pieces of the OEP will come into general use. It will be during this time that DARPA and the Air Force Research Laboratory should begin work on the “system-of-systems” that will help control unmanned airlifters in the new NAS. Also, if SATS is able to reach its goal of having one SATS pilot equal two ATP pilots, then it would also be the time to begin serious study on the human factors issues involved with operating a large aircraft with only one pilot and the Pilot Associate technologies that would be necessary to make it a success. Furthermore, it would be time to review the Air Force’s pilot training requirements in general, to see how much they might benefit from SATS developments such as the Cyber Tutor. Finally, if the OEP evolves as planned, and the Air Force has success in its human factors study/Pilot Associate development, 2010 would be an appropriate time to petition the FAA for an exemption to applicable FARs so that the Air Force could operate its next airlifter with a single pilot, and transition to pilotless operations when ready.

Of course, there are other capabilities that need to be developed as well. With LAAS stations coming on line after 2006, the possibility exists to develop an automatic aircraft taxi capability. This would be beneficial to manned operations as well, allowing aircraft to move when weather prohibits visual separation procedures. Another very important development would be the procedures necessary to keep aircraft separated during

partial/total systems failures. Ultimately, this is why control of unmanned airlifters would have to be a collaborative effort, and aerial technicians may need to be on board to provide an emergency landing capability. However, the system would be more resilient than one might expect. With aircraft communicating to each other via data link, and to controllers through satellite and ground stations, it would take an extremely capable adversary and a well coordinated attack to disrupt a meaningful portion of the NAS.² Ultimately, working out these technical details will take years of coordinated effort, and must begin with an acknowledgment of an operational vision.

Areas for Further Study

The first area for further study would be one of a highly technical nature—what are the ramifications of the entire airline industry relying on satellite data links, especially with so many other applications in the communications industry turning to that mode of data transfer. Will there be enough bandwidth and will we have the global common operating procedures necessary to operate UCAVs, UAVs, airlifters, and every other type of aircraft?

The next area for further study is the evolution of the aerial logistics system. In addition to the transformational concepts outlined in the QDR, the Air Force is currently developing concepts to support the Global Strike Task Force and the Army its Objective Force. What type of unmanned aircraft will best serve these new constructs? Furthermore, the Army is currently studying airlift large and small. Recently the Army received a briefing on the utility of airships that could carry up to 2.2 million pounds of cargo,³ and they are also seeking funding to begin work on a Modular Unmanned Logistics Express (MULE) helicopter that would provide “just-in-time” logistics delivery

to combat troops. How would unmanned airlift in general, and using it in conjunction with the airship and the MULE change the airlift logistics equation?

Finally, this paper suggests that we need a new vocabulary for “unmanned” aircraft. UAV and UCAV do not cover the types of missions that will be accomplished by pilotless aircraft, nor do they accurately describe the type of control required to run the aircraft, as it may be autonomous, collaborative, or directly operated.

Conclusion

This paper began with a very interesting observation. Despite the recommendations of two USAF studies, *Air Force 2025* and the Scientific Advisory Board’s *UAV Technologies and Combat Operations*, the Air Force has not defined requirements for air mobility UAVs. Furthermore, the USAF does not include unmanned airlift as part of its operational vision for the future. This lack of vision and identified requirements has already led to a setback. In November 2001, NASA contracted with Pennsylvania State University to do research on automated (pilotless) cargo-carrying aircraft. Those tasked to do the research could not find any organization, military or commercial, willing to admit to a desire to operate unmanned airlifters. This observation leads to our first conclusion: the USAF must define military requirements and an operational vision for unmanned airlift. Agencies such as NASA, the Defense Advanced Research Projects Agency (DARPA), and the Air Force Research Laboratory are ready, willing, and able to conduct research along these lines, they just have not been tasked to do so. This leads to the very important question, “what defines the need for unmanned airlift?”

The most recent Quadrennial Defense Review, released in September 2001, identifies three requirements that unmanned mobility aircraft could help fulfill. The first

was an existing shortfall in strategic transport aircraft. The second was the growing need to project power from the continental United States. The third was the ability to project this power in the face of weapons of mass destruction or other means to deny access to US forces. Unmanned mobility aircraft could help meet these requirements in two ways. First, without aircrew duty day constraints, they could support surge operations without putting a tremendous strain on limited numbers of aircrew. Second, they could operate in the face of greater danger without the risk of losing the crew. These observations underscore the second conclusion for this paper: QDR requirements provide sufficient guidance to define the need for unmanned airlift. However, having defined the need, there are still major obstacles with operating UAVs in the airspace system.

The third major conclusion of this paper is although the Air Force has not defined a need for unmanned airlift, there are revolutionary concepts being applied to the airspace system that will help make UAV operations more likely. In order to reduce delays and squeeze more aircraft into limited airspace, the FAA is implementing its Operational Evolution Plan. The integrated communication, navigation, and surveillance systems and the common information network technologies that will help make the OEP a success will also produce a more UAV friendly operating environment in the US and (in time) overseas. Furthermore, in an effort to eliminate the possibility of terrorists taking control of aircraft, the FAA is investigating the ability to take control of aircraft that are operating outside of safe parameters. This automated control from the ground mirrors the requirement for unmanned airlift operations.

Another key development for unmanned airlift operations is NASA's Small Aircraft Transportation System. In an effort to help ease the pressures of a crowded airspace

system, NASA hopes to develop the technologies necessary to make small aircraft “smart” enough to fly into uncontrolled airfields in almost any weather conditions, with only one pilot. In addition to the automation technologies SATS might add, it will provide the possibility of shifting our cultural perceptions of how many pilots are required to fly commercial aircraft. If SATS is successful, it may provide the impetus for commercial and military aircraft to switch to single pilot operations and it time, no-pilot operations.

The final conclusion of this paper is that based upon the programs and concepts mentioned above, one can sketch a path to the future for unmanned airlift operations. QDR requirements define the need, the evolution of the airspace system defined the common operating environment, and SATS will help redefine our cultural perceptions of the need for pilots. This is not to say that there are not many other issues to be addressed. Key technologies like the system of systems that will monitor and control unmanned aircraft in flight and automatic taxi systems must still be developed. However, based upon the concepts discussed herein, unmanned airlift could become a frequent and desirable part of our military operations and our everyday life.

Notes

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Glossary

ADS-B	Automatic dependent Surveillance--broadcast
AFRL	Air Force Research Laboratory
AMC	Air Mobility Command
ATA	Air Transport Association
ATC	Air Traffic Control
ATM	Air Traffic Management
ATP	Airline Transport Pilot
CDM	Collaborative Decision Making
CIM	Cockpit Information Manager
CIN	Common Information Network
CPDLC	Controller/Pilot Data Link Communications
CSN	Communication, Navigation, and Surveillance
CTAS	Center TRACON Automation System
DOT	Department of Transportation
FAA	Federal Aviation Administration
GPS	Global Positioning Satellite
HITS	Highway in the Sky
ICAO	International Civil Aviation Organization
LAAS	Local Area Augmentation System
MULE	Modular Unmanned Logistics Express
NAS	National Airspace System
OEP	Operational Evolution Program
QDR	Quadrennial Defense Review
ROA	Remotely Operated Aircraft
REFLCS	Research Flight Control System
RPV	Remotely Piloted Vehicle
RTCA	Radio Technician Commission for Aeronautics
SAB	Scientific Advisory Board
SATS	Small Aircraft Transportation System
TIS-B	Terminal Information Service-Broadcast
TMA	Traffic Management Advisor
TRACON	Terminal Radar Control
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
UPS	Untied Parcel Service
URET	User Request Evaluation Tool
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System

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