



After the C-5, What Next?
Exploring the Possibility of the DoD and Commercial Industry
Jointly Developing A New Large Cargo Aircraft
C-NXT

GRADUATE RESEARCH PROJECT

Harold N. Rollins, Captain, USAF

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Degree of Masters of Air Mobility

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Preface and Acknowledgements

This research was initiated for two reasons. First, as an officer with a background in space operations, I wanted to research a subject that would help me learn more about strategic airlift. Second, it initially seemed that combining military and commercial markets for moving cargo by air would be a natural solution to our continuing airlift shortfalls. I can honestly say I achieved the first objective to an extent even greater than anticipated. Unfortunately, I learned that my idea to serve both markets with the same aircraft was not original and there are significant reasons why it has not worked previously and may not ever. The construct relationship I hypothesized is probably not strong enough to overcome these barriers. Ultimately the primary value of this effort has been in my education, with a secondary value in the recommended concept exploration.

On a more personal note, I owe a great deal to the many people who helped me complete this educational effort. My advisor, Lt Col Bill Stockman, provided crucial scooping and content guidance. He provided succinct, pertinent recommendations that made this paper more complete and greatly improved its format. The Air Mobility Warfare Center Research Librarian, Ms. Janice Missildine, was an immense help in mining data on many aspects of this paper. Her incredibly knowledge of research databases provided the jump off point for me on many occasions, and her ability to obtain hard copies of research material on short notice allowed me to make the many hours in airplanes much more productive. Ultimately, I owe my greatest thanks to my family. My kids have well weathered yet another uprooting as well as countless nights without me at home. I am very proud of them. Finally, no one has worked harder to support me this past year than my wife. I am most grateful to her for her love and patience.

Abstract

The basic research question is: *Can the U.S. Air Force team with the U.S. aerospace industry in jointly developing a new aircraft to meet Air Force strategic lift shortfalls and compete in the commercial market for cargo airlifters?* To answer this question I studied the military and commercial markets for air cargo transport. I also looked at industry efforts in the way of advanced airframe concepts. The C-17 CAMAA effort and EELV program were examined for lessons learned that could potentially be applied to the development of a dual-purpose aircraft. While studying these issues, important real physical differences emerged between commercial and military transports. Ultimately, the answer to the basic research question is; yes, it is possible, but not very probable. The barriers to producing a dual-purpose aircraft are significant. Nevertheless several recommendations are made as to how to go about launching such an effort.

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Chapter 1 - Issue and Importance

Basic Research Question: *Can the U.S. Air Force team with the U.S. aerospace industry in jointly developing a new aircraft to meet Air Force strategic airlift shortfalls and compete in the commercial market for cargo airlifters?*

Strategic airlift capability is a hotly debated topic today. The U.S. Army and U.S. Air Force disagree on some aspects of warfare and joint doctrine such as who and what should be brought to the fight first. However, they do agree on the need for more airlift capability. This awareness comes on the heels of our experiences in Desert Storm and Operation Allied Force, but the shortage of strategic airlift is certainly not new. What may be new about the situation today is a unique combination of factors that may make a different acquisition and procurement strategy appropriate. Specifically the growth in the commercial air cargo market may be sufficient when combined with military needs to stimulate a research and development cost sharing initiative between the U.S. Air Force and one or more American aerospace industry contractors. For the rest of this paper, the term “airlift” is used to represent the strategic airlift of cargo, or in the military sense moving military equipment from CONUS to distant theaters in Europe or Asia.

Airlift capability studies have shown since 1977 the Air Force has not had enough airlift¹. Specifically since early 1990s there has been a recognized inability to support two simultaneous or nearly simultaneous major theater wars without substantial increase in risk. The risk is an increased potential for lost lives and territory, along with an increase in time and money to end a conflict on terms favorable to the United States and

¹ Huneycutt, Tyler B. III, Future Strategic Airlifters -- How Can Government And Industry Share the Costs (Research study, Air Command and Staff College, Maxwell AFB, AL, May 1977) 2.

its allies². Although the Air Force has never closed the gap between required airlift and capability, recent studies have helped us fund and deploy the C-17 program. Yet the Air Force is still short of the required lift capability and unlikely to close the gap in the near future as C-141s are retired faster than C-17s are brought into the inventory. The planned purchase of 120 C-17s plus 15 for Special Operations when coupled with the existing C-5 fleet do not meet daily Million-Ton-Mile per Day (MTM/D) requirements during time of crisis. Expressing shortages with MTM/D numbers is standard practice when arguing for more aircraft, but it is not necessarily the best measure of strategic airlift capability. A better measure of our ability to project force abroad from an airlift perspective is closure time for various scenarios. There is a growing awareness of the need to focus on closure capability among Army and Air Force leadership. Even with a focus on closure dates as the measure of capability, we still can not satisfy the Army's desires to deliver a Brigade in 4 days, a Division in 5 days, much less deliver 3 Divisions in 30 days³. However MTM/D measurements will still be heavily used to argue for more C-17s and C-5 improvements as we begin the next Quadrennial Defense Review (QDR) under a new presidential administration. This may be because of a reluctance to move away from the MTM/D stand-by or perhaps because closure times are too difficult to use in sound bites.

At a cost of approximately \$5B, the C-5 Reliability Enhancement and Re-Engine Program (RERP), which is not yet funded, is projected to bring C-5 mission capable rates up to a level nearer that of the C-17 and KC-10, or approximately 73%, if fully funded.

² Owen, Robert C. "The Airlift System – A Primer" (Air Power Journal Fall 1995) 4-6.

³ Tirpak, John A. "A Clamor For Airlift" (Air Force Magazine December 2000) 24-26.

This translates to increasing our current capacity by approximately 2.2 MTM/D⁴. The C-17 is quickly becoming the Air Force's airlift workhorse, replacing the venerable C-141. As such its usage rates are projected to be very high, outpacing that of the C-5. Conservative studies have even shown the oldest C-17s will be approaching structural fatigue limits between 2035 and 2040⁵. This is about the same time the C-5 will be approaching structural fatigue limits. The Air Force is considering buying up to 60 additional C-17s beyond current funding. This could potentially address airlift shortfalls in the 2006 time frame if funding can be obtained to continue production and delivery of 15 C-17s per year through 2006. If production is reduced to eight per year through 2010 and the C-5 program is not bolstered, the Air Force will face an even greater airlift bathtub as C-141s retire faster than C-17s are delivered⁶. But even if the Air Force successfully funds and completes both the C-17 acquisition and C-5 improvements, these aircraft will not last indefinitely and there are limitations on how much the C-17 and C-5 can do. Airfields can only support so many C-17s. The Air Force also has a finite amount of aircrews, technicians, and supporting tanker aircraft.

There is no question that the U.S. Department of Defense is growing more expeditionary, a trend unlikely to reverse itself in the absence of a sizable, well organized threat of invasion to one of our allies or strategic interest. As such, there is a growing recognition of the value of airlift as the key enabler of our ability to project military

⁴ Greer, W.L. Analysis of Alternatives for Out- and Over-Size Strategic Airlift: Reliability and Cost Analysis. (Contract DASW01 98 C 0067 (IDA Paper P-3500) Alexandria, VA: Institute for Defense Analyses, March 2000) 9.

⁵ Greer, 6.

⁶ Ledden, John M. Briefing comments to ASAM-01 class during "DO Issues Brief" Directorate of Operations, Hq Air Mobility Command, Scott AFB, IL, June 2000.

power from the CONUS. There is also growing public recognition of the need to bolster our military capabilities. This increased awareness makes the timing right to not only acquire airlift capacity in the short term but also to plan for the acquisition of the next generation of cargo aircraft. Typically, the research and development of a new aircraft can be expected to take about 8-10 years based on previous military aircraft development⁷. Add to this a 10-15 year production run and it will take approximately 18-25 years to bring a new fleet of strategic airlifters into the force. Given this lengthy lead-time, it is crucial that the Air Force act soon to acquire and preserve our rapid global mobility capability for the future. It is even more important that we plan for the next generation of strategic airlifter because we can not be certain current C-5 and C-17 efforts will not falter or that the need for strategic airlift will not grow significantly beyond projections. But how can the Air Force seriously consider funding a new strategic airlifter when it hasn't even finished buying C-17s?

Certainly there are and will be competing objectives within the Air Force and DoD. The Joint Strike Fighter, the F-22, and more B-2s are all weapon systems that are or may be vying for funds. The Army's transformation to a lighter, faster, more mobile force will be very expensive. The DoD quality of life initiatives such as improved medical care and housing will also continue to draw funds away from weapons system acquisitions. Improvements in base infrastructure and spare parts management are also sorely needed yet costly endeavors. If airlift capacity is going to be acquired and

⁷ Estimates for R&D time from DoD/IG Report Number 92-046 on C-17 program and SECDEF Rumsfeld's comments in article to Defense Daily, page ii.

sustained, a new and more affordable approach will help C-NXT acquisition compete with other important DoD objectives.

The commercial market for air cargo may be in need of a new dedicated cargo aircraft. Just how big is the worldwide market for air cargo movement? Last year the top ten cargo airlines accounted for a total movement of approximately 28,581 Million-Ton-Miles (MTM)⁸. Most predictions put growth in this market at 5-8% annually⁹. Yet, cargo aircraft consist almost exclusively of converted passenger jets or brand new cargo planes built on passenger airframes¹⁰. These aircraft are optimal people movers, but not optimal for moving bulk cargo. They are very poor movers of oversized cargo. Converted airliners are largely incapable of moving outsized cargo. The commercial market for oversized and outsized cargo is also growing. Approximately 90% of this sub-market is served by a single airframe type, the Antonov An124-100¹¹. This air cargo market demand and growth may represent a potentially lucrative market for a dedicated freighter aircraft.

The commercial market may also offer a unique opportunity to help meet DoD needs for the long term. If it can be shown that the commercial market could benefit from a new affordable cargo airliner, the Air Force could pursue development of a dual-purpose aircraft with a cost sharing arrangement between the Department of Defense and leading industry contractors. By partnering with industry, the sizable research and

⁸ Orton, Charles W. "The Top Air Cargo Carriers" (World Trade 13: June 2000) 64-65.

⁹ Growth estimates combined from estimates in Scherck article, "Air cargo: Beyond the Valley Lies a Land of Milk, Honey, and Profits" and from Dahl article "Air Freight Market is Expanding" 45-47.

¹⁰ Dahl, Robert V. "Air Freight Market Is Expanding" (Aviation Week & Space Technology 146: 13 Jan 1997) 52.

¹¹ Taverna, Michael and Cochennec, Yann. "Ruslan Opening the Door for CIS Cargo Airlines" (Interavia Business & Technology 586: January 1995) 50.

development costs could be shared, and both military and commercial markets could be addressed with the same effort. In other words, improvements upon the current C-17 and BC-17x effort would reduce per airframe costs by starting the design phase with a goal of producing a joint military and civilian aircraft. To head off the impending problems of an aging tanker fleet, technological advances may make more feasible the development of a modular aircraft system to perform both tanker and transporter roles. In fact, Airbus already builds all its aircraft around a modular concept and Boeing is moving that way.

One might also logically question what a joint market aircraft might look like. Aircraft manufacturers are looking at a number of new concepts. Boeing Aerospace Corporation is considering a Blended-Wing-Body airplane to compete initially as a large airliner and perhaps ultimately as a cargo mover. Lockheed Martin Aerospace Corporation is designing a box wing aircraft to perform both as a super tanker with multiple refueling booms and as a cargo airlifter. Airbus is developing its A3XX super aircraft to serve as an airliner. Advanced Technologies Group (ATG) is designing an advanced dirigible to move up to a million pounds of cargo across the oceans at approximately 100 knots, positioning them between the slower and cheaper ship transportation and the faster but more costly airplane modes. All of these programs hold enormous potential for military application but not without active military involvement and funding. It is potentially in the best interest of the Air Force, DoD, and the taxpayers to foster the development of one or more of these initiatives to help satisfy the demand for strategic airlift in the near and distant future.

This paper does not attempt to prove there is a shortfall as this has already been the conclusion of several studies. Rather it takes as given that there is a shortage and

explores ways to add to our strategic airlift capability in the future. To flush out this idea, several ideas are evaluated and elaborated on. First, rough estimates for the current and projected shortfalls in strategic airlift are surveyed from other sources. From these shortfalls a list of baseline capabilities for a new airlifter is proposed. Next, the commercial market is explored and growth rate projections are estimated from various expert sources. To see how this demand might be met, three industry initiatives are studied. To better understand the issues associated with fielding a joint use aircraft, the C-17 civilian application program is examined. The Evolved Expandable Launch Vehicle acquisition is also looked at as an example of shared DoD and industry funding. This idea of a dual usage aircraft is not new, and this paper includes a look at why one has not been developed already. Finally, this paper looks to see what conclusions can be drawn and what acquisition recommendations can be made. So, after the C-5, is a dual market aircraft, C-NXT, possible?

Chapter 2 – Literature Review

A thorough and exhaustive literature study has been performed as part of this research project. Sources include transportation trade journals, defense technical papers, various books and periodicals, other research papers, and world-wide-web sources. Some of the findings are summarized here. Most of the ideas in this paper are not original and wherever reasonable, specific credit is given to the authors. However, some of the points made in this paper are an amalgamation of opinions and trends that have been gleaned during this literature review and through personal interviews. Throughout this paper an attempt has been made to strike a balance between giving due credit and referencing sources to the point of distraction.

2.1 What are some rough estimates for the shortage of strategic airlift?

The DoD shortage of strategic transportation is approximately 10 MTM/D. The Air Force is 29% short of its required capability to deliver forces with strategic airlift or approximately 5 MTM/D. Simple, concise and palatable, these numbers suggests the shortage can be accurately quantified by any organization willing to add up available aircraft and bounce them against war plans for fighting two nearly simultaneous major theater wars (MTWs). However, the variations in estimates that can be found suggest that quantifying a shortage is as much an art of assumptions as it is a science.

2.2 What is the market for cargo airlift and what is the expected growth?

In September 2000 Air Transport World called air cargo “the fastest-growing segment of the airline industry, and one of the most rapidly changing.” Aviation Week & Space Technology foresees an annual growth rate of 6-8% and a quadrupling of cargo traffic by 2015. The data and findings presented in this work are a mere subset of the

volumes of information describing the air cargo industry and growth expectations. These highlights support a few conclusions that can be asserted from literature review. The air cargo industry is significant and growing but vulnerable to economic downturns.

2.3 What is industry working on right now?

Reviewing numerous literature, periodical, and world-wide-web sources uncovered many vastly different development efforts in the area of future strategic airlifters. Boeing's efforts are focused on a Blended Wing Body (BWB) design. Basically it is a fuselage with an elliptical cross-section blended into a flying wing. A modular design would allow widespread part sharing between aircraft of varied size and capabilities. This concept holds definite promise as an airliner and cargo carrier with limited potential as a tanker/transport or bomber. Lockheed Martin Aeronautics (LMA) is focusing its development efforts on a box wing concept. This aircraft would have a traditional cylindrical fuselage. The top wing design is forward swept and joined at the tips to a bottom aft swept wing. This aircraft is also supposed to incorporate a modular design and promises to perform a multitude of military missions in its different configurations. Airbus is developing a 550-seat airliner or A3XX aircraft. Airbus is also trying to bring to the European transport market its Future Large Aircraft (FLA) or A400M. However, this effort is mainly aimed at competing with the C-130 and does not meet this paper's definition of strategic airlifter. Advanced Technologies Group (ATG) is building its SkyCat airship. Based on a hybrid design, it combines traditional airship technology (blimp) with a lifting-body shape. This hybrid vehicle's lift is made up of 65% lift from helium and 35% from aerodynamic lift. Therefore, this flying-wing shape is not considered a conventional airship. It holds promise as a transoceanic carrier with

capacities up to 1 million pounds and cruising speeds of 100 knots. In general, the literature review showed there are key advantages and disadvantages of these design efforts and emerging technologies.

2.4 What lessons learned are available from the C-17 CAMAA program?

Most of the literature available on the C-17 program is of two varieties. The majority of the available literature was self laudatory, proclaiming the virtues of the production run aircraft and the dramatic turn around from its early design and budget problems. The remaining literature, mainly in the form of Government Accounting Office (GAO) and other government reports, focuses on the early cost overruns and limited aircraft range with full payload. To fully answer this question, I depended more heavily on conversations and interviews with officers in the Air Staff XPPM office and Boeing representatives on the CAMAA team.

2.5 Can the acquisition be patterned after the EELV acquisition process?

The Program Element Office (PEO) for space provided a wealth of information about the program structure, philosophy, cost sharing, and challenges. The overarching theme from the material was a reliance on competitive market pressures and cost sharing in proportion to commercial and military market allocation. Recent projects for commercial rocket launch demand have dropped dramatically and are squeezing already tight profit margins. The effect of this market pressure on EELV success is not yet known.

2.6 Why don't we have a dual-purpose aircraft already?

This section was added based on studies that surfaced during my research. I found several papers dealing in general with combined military/commercial aircraft applications. Some of these sources focused on the differences in military and commercial market priorities. Others spelled out the specific differences in aircraft design features and associated performance impacts. This serendipitous discovery led me to view the potential for dual-purpose aircraft much more pessimistically.

Chapter 3 – Methodology

3.1 Overview

Basic Research Question: *“Can the U.S. Air Force team with the U.S. aerospace industry in jointly developing a new aircraft to meet Air Force strategic lift shortfalls and compete in the commercial market for cargo airlifters?”*

In the broadest sense, the research method is a combination of literature reviews, expert interviews, and case studies. The basic question is predicated on a theoretical relationship between these constructs: commercial demand, military demand, innovative acquisition approach, and industry R&D efforts. The theory is that by combining commercial and military demand with an innovative acquisition approach and existing industry R&D efforts, the synergistic effect can bring to production a new and mutually beneficial aircraft sooner than if a military or commercial version is developed in a vacuum. This relationship is depicted in the simple figure on page 19. This research work is organized around a subset of questions that support the overall goal of making recommendations on how the Air Force should maintain and improve upon its core competency of rapid global mobility from a strategic airlift perspective.

3.2 Guiding Research Questions

- 1) What are some estimates for military airlift needs?
- 2) What is the market for cargo airlift and what is the expected growth?
- 3) What is industry working on right now?
- 4) What lessons learned are available from the C-17 CAMAA program?
- 5) Can the acquisition be patterned after the acquisition process in use for the Evolved Expendable Launch Vehicle (EELV)?
- 6) Why hasn't a joint military and commercial cargo aircraft happened already?

3.3 Technique for answering each question

What are some estimates for military airlift needs?

The shortage of strategic airlift capability is a hot topic. To show there has been and continues to be an enduring shortage, one need not recreate the wheel with a fresh analytical effort. This work begins with the results of previously completed studies. A literature review of open source documentation subsequently collaborates this effort.

What is the market for cargo airlift and what is the expected growth?

This question has been answered by reviewing books, magazine articles, and professional transportation journals. Numerous sources from within and external to the industry have been included to insure a balanced, objective picture. The synthesis of opinions paints a picture of the commercial market and its expected growth rate.

What are the options for dedicated cargo aircraft?

Dedicated cargo aircraft come from a handful of sources, namely modified commercial airliners, original production cargo airliners built by Boeing and a handful of offerings from Airbus and Antonov Airlines.

What is industry working on right now?

The groundwork for this area was another exhaustive literature review of books, magazine articles, and professional transportation journals. However, the most valuable information came from personal visits to Lockheed Martin Corporation, Boeing Aerospace, and to the Office of the Joint Staff in the Pentagon. All sources were helpful and provided detailed insight into their proprietary efforts. An unexpected benefit was an appreciation for corporate philosophy and market targeting.

What lessons learned are available from the C-17 CAMAA program?

The C-17 program is used as a benchmark or pseudo case study to approximate the costs of developing a new aircraft. Primary data will be sought from the C-17 program offices at USTRANSCOM and/or Air Force Material Command. A literature review will also be conducted in this area and may also yield valuable information about fielding a commercial version of a military cargo aircraft.

Can the acquisition be patterned after the acquisition process of the Evolved Expendable Launch Vehicle (EELV)?

This is a case study approach to look for lessons learned that would be applicable to acquiring a new strategic airlifter. Primary data will be sought from the Program Element Offices (PEO) for space on the Air Staff. A literature review will also be conducted in this area and may also yield valuable information about launch expenses and other shared costs.

Drawing Conclusions and Making Recommendations

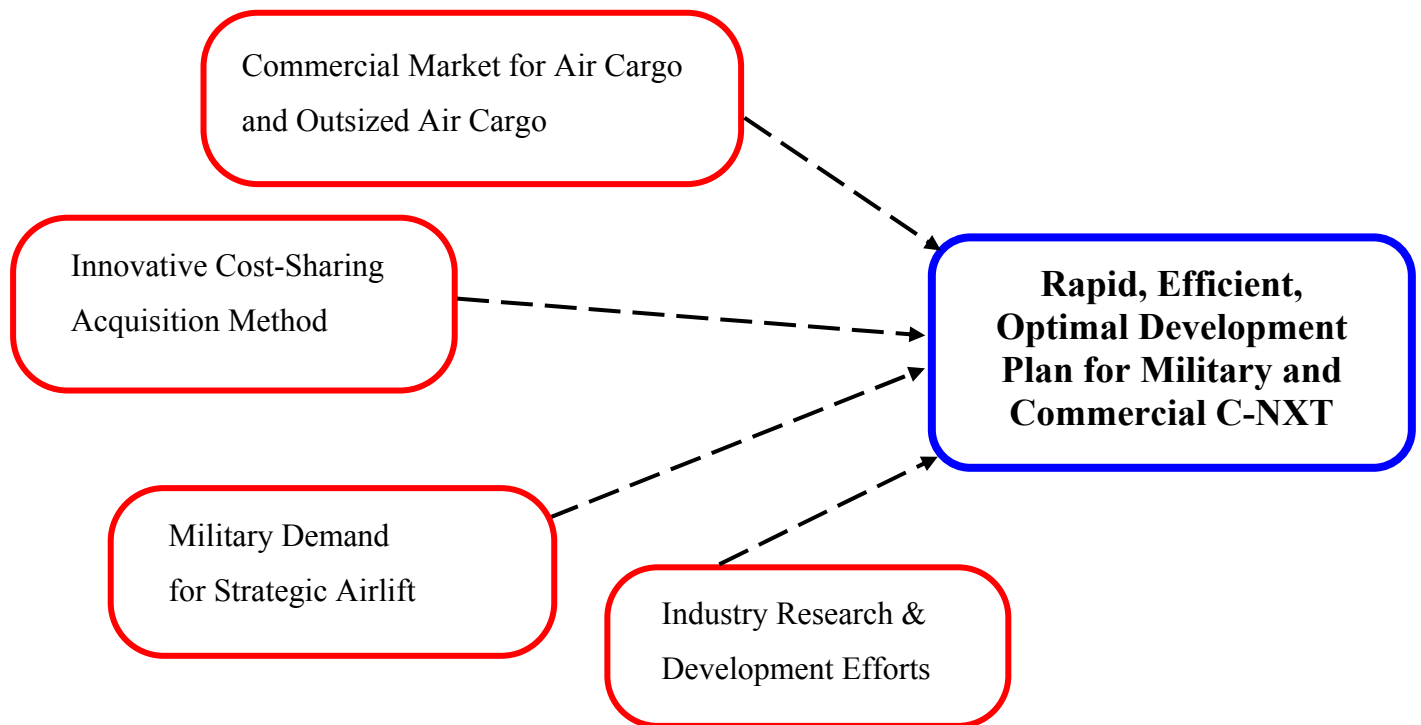
The result of answering these investigative questions should be a clear understanding of the viability of a joint commercial and military funded aircraft development. If the demand is sufficient from the combined military and commercial air cargo markets and a precedent can be found in another military program, then we should be able to propose a course of action that will lead to a sufficient and robust rapid global mobility capability.

How does this research improve upon previous research efforts?

In 1977 Lt Col Douglas G. Dumont published a research paper for Air Command and Staff College entitled “Future Strategic Airlifters—How Can Government and

Industry Share the Costs.” Since that time little has been done to foster the cost sharing idea until the recently initiated effort to sell a civilian version of the C-17. This research paper intends to further the idea by proving that we are at a unique point in time. Specifically the confluence of military need, fiscal pressures, immerging technology, and civil market demand may make it the ideal time to pursue a cost sharing development and procurement plan for the next generation of strategic airlifter.

3.4 GRP Theory Diagram:



Chapter 4 – Findings

4.1 Military Demand

Lately it seems as if everyone is talking about change in the world's political arena and the associated need to dramatically transfer the military. There is a great deal of truth to this widely held opinion and a great deal of potential for abuse. Numerous weapons systems and programs were inappropriately sustained or squelched under the auspices of total quality management. Likewise individual services and major commands will vie for funding of their parochial interest by claiming they are a crucial part of the new administration's vision for a modernized American military. In this atmosphere of change the need for airlift remains constant. In 1942 when Gen. Hap Arnold recognized the futility of an army that could not get to the fight in a timely matter. The associated need for airlift has not changed and is still recognized today¹². The only real change in this concept has been its growth in importance to national military strategy as more forces are stationed stateside¹³.

There is no need to conduct additional exercises or studies to prove that the U.S. needs more airlift. Beginning as far back as 1977 and continuing through MRS-05, the shortage of strat airlift has been well documented¹⁴. Historically and periodically, there have been successes in addressing this shortfall, most notably the C-141 and C-17. But with the C-141 retiring from the force and C-5 reliability issues continuing, the Air Force

¹² The need for airlift is so well documented it almost seems unnecessary to reference sources. As a representative example, this reference quotes several prominent military leaders. Fellows, Lt Col James A., Harner, LCDR Michael H., Pickett, Maj Jennifer L., Welch, Maj Michael F. "Airlift 2025: The First with the Most" (Presented to Air Force 2025 Symposium August 1996) 1.

¹³ Ryan, Michael E. and Peters, Whitten F., Global Vigilance Reach & Power America's Air Force Vision 2020 8.

¹⁴ Early shortage documentation found in Huneycutt's Future Strategic Airlifters -- How Can Government And Industry Share the Costs and shortage documentation appears periodically in reports through the recently released MRS-05.

again finds itself facing a shortfall. General Robertson, U.S. TRANSCOM Commander estimates the current shortfall at approximately 5 MTM/D¹⁵. The GAO collaborated this figure with its own estimated shortfall of 5.7 MTM/D¹⁶. There are two potential criticisms of this number. The first is a criticism of the validity of the MTM/D measure.

$$\text{Million Ton Miles per Day} = \text{Average Block Speed} \times \text{Ute Rate} \times \text{Productivity Factor} \times \text{Average Payload} \times \text{PMAI Allocation} / 1,000,000 \text{ [MTMs/D]}$$

This long equation contains variables that are prone to misinterpretation or inaccuracy¹⁷. Specifically UTE rate is generally but not uniformly interpreted as the objective UTE rate, average block speed is very weather (and therefore seasonally) dependent, and average payload values vary greatly over the course of a MTW deployment. Nonetheless, it is the chosen measure of capacity, and it has utility despite its potential inaccuracy. Military force planners and, perhaps more importantly, congressional appropriators need simple aggregate numbers to measure capability. Simply put, the acknowledged inaccuracies do not preclude meaningful estimates nor are they severe enough to negate the estimated shortfall.

A second and perhaps more valid criticism, would be based on the dated national military strategy of being prepared to fight two nearly simultaneous Major Theater Wars (MTWs) as the basis for calculating airlift requirements. Indeed Secretary Rumsfeld has been given a broad mandate to examine the relevance of our aged NMS in light of the

¹⁵ Two shortage quantities are frequently quoted and often confused. A shortage of 5 MTM/D is based on anticipated airlift capability versus demand in the year 2005. A shortage of 10 MTM/D is loosely interpreted as the difference between current capabilities and demand. The numbers from MRS-05 are based on an assumed 2005 force structure of 120 C-17s and non-RERPed C-5s with 65% reliability.

¹⁶ Curtin, Neal, Official correspondence to Representative Curt Weldon with attached slides from showing GAO estimates for shortages of strategic airlift (GAO letter B-286562 March 16, 2001) 11.

¹⁷ Brigantic, Maj. Robert T., Pocket Mobility Calculator (AMC Studies and Analysis Flight (AMCSAF) robert.brigantic@scott.af.mil May 15, 2001) 3.

post cold war threat environment¹⁸. It is unclear what Rumsfeld's 18 different military review panels will come up with, but the primary responsibility of America's military, to deter potential adversaries and to fight and win wars decisively, will not change¹⁹. Will future NMS and force structure be based on one MTW and two to four Small Scale Contingencies (SSC)? Will operation Northern Watch, Southern Watch, and the Balkans count as a SSC or MTW? These questions are as yet unanswered, however there is some certainty that airlift demands will not abate. The Phase III report of the Hart-Rudman commission sights a fundamental need to project U.S. power globally and the maintenance of rapidly employable expeditionary/intervention capabilities as one of only five key military competencies²⁰. Joint Vision 2020 sights only four operational concepts; dominant maneuver is one of them. AF Vision 2020 says we will provide "the mobility to rapidly position and reposition forces in any environment, anywhere in the world." It also says, "We'll rely increasingly on distributed (or reach back) operations to efficiently sustain our forces, providing time-definite delivery..."²¹. The point is clear: our Air Force, Pentagon, and civilian leadership all envision a continued need for moving our military forces rapidly over vast distances to the theater of need. Coupled with a decreased overseas presence, this unity of vision demands voluminous and robust airlift capabilities. It is extremely probable that the demand will increase and not diminish. Therefore, even in the face of an evolving NMS, it is prudent and in fact imperative to

¹⁸ Sanger, David E. "Bush Details Plan to Focus Military on New Weaponry" (The New York Times On The Web, www.nytimes.com/2001/02/14/politics/14BUSH.html February 14, 2001) n.pag.

¹⁹ Fellows, 4.

²⁰ Hart, Honorable Gary and Honorable Rudman, Warren B., Road Map for National Security: Imperative for Change, (February 15, 2001) 78.

²¹ Ryan and Peters, 6.

take steps to shore up the capabilities shortage and to modernize the airlift fleet. History has shown that we have not had excess lift and fiscal constraints are likely to promulgate this trend.

4.1.1 Need for C-5 Replacement

There are several possible basic scenarios for addressing our shortfall.

Specifically, the DoD and U.S. Air Force could:

1. Buy more C-17s, fund Re-Engine & Reliability Program (RERP) for C-5Bs, then fund RERP for C-5As
2. Buy more C-17s, invest nothing in C-5 and continue tolerating poor C-5 reliability
3. Fund RERP for C-5s only and stop C-17 procurement at 120 aircraft
4. Develop and build a C-5 replacement, do not buy more C-17s or RERP C-5s

Of these scenarios, 1 is most desirable but is expensive and does not represent a dramatic change in approach. While not required, this incremental approach may be criticized since it does not represent any leap in technology. Scenarios 2 and 3 are the most affordable, with 2 being the most likely as an interim effort towards a long term solution. Scenario 4 is the least likely unless the new administration emphasizes new airlift requirements such as stealth, extended unrefueled range, expanded cargo volume, or improved fuel efficiencies. It is most likely the Air Force will start with scenario 2 with the ultimate goal of funding C-5 RERP as outlined in scenario 1²². There are several reasons why. For one, extending C-17 production will drive down the per unit aircraft costs. The aircraft is enormously popular. Its restricted (unrefueled) range is its only major drawback. Additionally, an incremental game plan is probably the most palatable for congressional appropriators.

²² Butler, Amy. "TRANSCOM CINC: Operational Flexibility Hampered By Maintenance Woes" (Inside the Air Force, December 15, 2000) 8.

This discussion of scenarios is important for two reasons. Any of the four scenarios will still eventually lead to a need to replace the C-5. Also the chosen game plan will indicate the time when a C-5 replacement will be needed. The need is right now with scenario 4 and no later than 2040 with scenario 1. As mentioned, unless redirected, the Air Force will probably pursue more C-17s and then C-5 improvements. If successful, the need date for a new aircraft pushes out to the 2040 timeframe²³. The need date is obviously much sooner if only C-17s are purchased. With lengthy acquisition and procurement cycles, the time to plan for a C-5 replacement is either quickly approaching or already here.

4.1.2 C-NXT Capabilities

So if we can ignore the question of when, and accept the need to replace the C-5, it is possible to focus on what the new aircraft should be able to do. Proposed requirements were drawn from as many sources as possible including but not limited to the already sighted Hart-Rudman commission, Joint Vision 2020, and Air Force Vision 2020. Setting out requirements is not pure science. The art comes in drawing the concept of operations, missions, and assumptions for the new aircraft. In the most general of terms, C-NXT should be able to move large amounts of cargo, including outsized military equipment, from CONUS to far points in Europe or Asia unrefueled. These listed requirements represent a departure from some long held beliefs about airlifter missions. They have been tailored to help narrow the gap between military and commercial industry needs. This gap is discussed in detail in section 4.6.

²³ Greer, 6.

Baseline Capabilities

- 300,000 lbs. payload capacity
- 7000 - 7500 mile unrefueled range with fuel reserves
- Roll-on, Roll-off cargo capability with built in ramp
- Back-up capability like the C-17
- Runway length minimums the same or less than 747 or C-5
- Sustained airspeed of approximately 450 knots
- Reinforced flooring to support heavy equipment like tanks
- 463L pallet capability
- Usable footprint - Landing gear breadth, aircraft not too big for commercial airports
- Cargo bay to accommodate outsized equipment – tanks, helicopter, patriots, rockets
- Responsiveness – aircraft can be quickly generated and launched
- Reliability – contracted minimums with penalties for failure to perform
- All weather capable
- Commercial engines
- Low operating and maintenance costs
- Either no required MHE or use existing MHE – tonners etc.
- Meet FAA noise and pollution standards

Second Tier Capabilities

(Desirable but not as imperative as above requirements)

- Passenger accommodations
- Supports aeromedical evacuations
- Stealthy
- Intermodal with respect to containerization
- ~~• Point of use delivery and execution~~
- ~~• Airdrop~~
- ~~• Short/austere landing field capable~~
- ~~• Defensive systems~~
- ~~• Air refuelable~~

Some of these capabilities are shown but struck through because they are some of the traditionally held beliefs but are probably not required in a new airlifter for various reasons. For example, the old construct of dropping in army brigades into insecure territory is probably passe. What is the scenario that would require such a mission? Many are challenging the notion that we would put hundreds of soldiers and dozens of

aircraft at risk²⁴. We have not fought a war or contingency without air superiority since WWII. It is far more likely that we will continue to deploy army soldiers by air as far forward as we have control of the skies and the ground, and we will land our aircraft to unload them and their equipment. Assumed air supremacy also calls into question the need for defensive systems. As long as C-17s and C-130s are in the inventory, a new strategic airlifter probably does not need the capability to fight its way into short/austere fields with questionable security. There are runways dispersed all over the world that can support 747s and C-5s. C-NXT should be able to support nearly anywhere using these fields in conjunction with C-17s and C-130s in hub-and-spoke scenarios. Modern airliners combine efficient engines and low swept wings to fly unrefueled from Chicago to Seoul, and C-NXT should be able to do so as well. The main point is that C-NXT does not have to be and in fact should not be a “jack-of-all-trades” aircraft. The C-5 replacement should be able to move massive quantities of large military equipment long distances from CONUS to a secure location in the theater of need. If we can accept a pure strategic airlifter role for C-NXT, the Air Force can successfully challenge many of the assumed requirements, repel the attempts to pile on sideline requirements and capabilities, and acquire an efficient, affordable aircraft.

²⁴ This was initially an intuitive opinion based on public reaction to casualties, or the risk of casualties, over the past ten years. Throughout the year I have queried numerous military leaders on the subject and found near universal support for this opinion. The only exception was the need to preserve the ability to airdrop Special Forces into any environment. Additionally, senior officers in the Royal Air Force (RAF) believe the attitudes in England also preclude sending a massive airdrop of troops into hostile territory.

4.2 Commercial Demand

There are approximately 112 cargo airlines operating in the world. Their fleets range in size from British Airway World, operating only one aircraft to UPS and FedEx, operating over 200 and 300 aircraft respectively²⁵. Fleet size is not the only distinction. FedEx carries almost exclusively small packages with the bulk of their cargo being letters and business forms. UPS specializes in moving small to medium size packages, generally up to 80 lbs. Volga-Dnepr carries primarily outsized cargo. A connecting thread to all but the few outsized cargo airlines is their choice of airframes. Most of the leading cargo airliners fly a mixed fleet of aircraft consisting of some of these popular airframes: Boeing 747s, 727s, Airbus A310s, A300s, McDonald Douglas MD-11s, DC-8s, and Lockheed L-1011s. There is a sprinkling of other airframes among the carriers, but more importantly, the choice of new cargo aircraft is primarily limited to the 747s and A300s. Modified passenger aircraft retired from the passenger airline account for nearly 70% of the cargo aircraft entering the market²⁶.

New cargo aircraft are being acquired at a steady rate for a couple reasons. Obviously, some older and/or noisier aircraft are being retired and must be replaced. The main force behind the acquisitions is industry growth. The air cargo industry is predicted to enjoy continued growth at a sharply increasing rate. This prediction is almost universal from industry participants and outside observers. While there are a considerable breadth of opinions, a popular conservative prediction is 6% growth through at least 2005 with continued accelerating growth rates through 2015 and beyond.

²⁵ Wright, Alan J. Cargo Airlines (Shepperton, UK: Ian Publishing Ltd., 2000) 32, 55, 102.

²⁶ Krause, Kristin S. "Big Dreams" (Traffic World, 254: May 25, 1998) 28-29.

The industry is growing because of the increased recognition of the time value of air cargo delivery. As the world economy grows and seams between national economies blur, air cargo is playing an ever more important role. The increased acceptance and implementation of supply chain management is also fueling this growth. The Colography Group, a transportation and logistics consulting firm, has estimated that for every \$1 invested in premium priced air cargo transportation the typical firm can expect to realize between \$1.20 - \$1.50 in savings from reductions in warehousing and distribution costs²⁷. This return does not even address the very recognizable, but somewhat intangible returns from improved customer service.

Given that the air cargo industry composes a substantial fleet and that the market for air cargo is growing, there may be justification for the development of a brand new cargo aircraft. Increased efficiencies in loading and unloading abilities could be obtained from designing an aircraft for this express purpose rather than continuing to use modified passenger aircraft designs. For international market segments, there may be justification for the development of a super cargo aircraft with 2-3 times the capacity of a 747 if the cost of each airframe was less than 2-3 times the cost of a new 747. New 747 aircraft cost between \$120 – \$160M depending on quantity and other factors²⁸. Certainly there are alternatives to a new dedicated aircraft such as the BC-17x and hybrid vehicles such as the blimp-like Cargo Lifter that merit consideration and evaluation. But first things first, the focus of this section is describing the demand for cargo airlift and surveying growth predictions.

²⁷ Scherck, Theodore R. "Air Cargo: Beyond The Valley Lies a Land of Milk, Honey, and Profits" (Transportation & Distribution, 39: July 1998) 45-47.

²⁸ Brull, Steven V. "A Tidy Bundle in Air Cargo" (Business Week, 3625: August 1991) 128.

4.2.1 Quantifying the Demand for Air Cargo Movement

Just how big is the worldwide market for air cargo movement? Last year the top ten cargo airlines accounted for a total movement of approximately 28,581 Million-Ton-Miles (MTM). The actual mass shipped by the top ten carriers by tonnage was approximately 8.08 million tons. A look at the top 25 carriers shows they accounted for 43,838 MTM or 12.6 tons²⁹. Even though there are over 100 cargo carriers operating worldwide, the amount each carrier contributes drops off rapidly after the 50th ranked company. It is tempting to use the MTM and tonnage numbers to estimate an average distance flown, but the airline rankings in each list are not the same. Analysis to look at average distance flown could be done in subsequent research by studying individual airlines. In this manner one could empirically derive the approximate required range of a new commercial aircraft. However, for this paper it is assumed that the longest range required would be from Midwestern United States to Asian markets in Korea or China. As such a range of 6,500 – 7,500 miles would be sufficient.

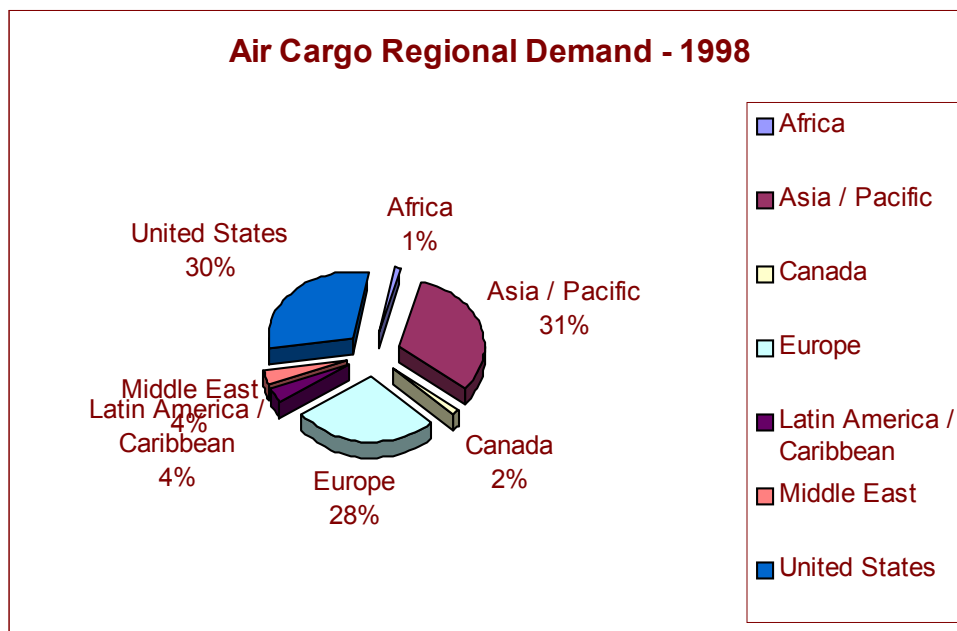
Another interesting aspect of this market is its impact on international passenger airlines. Huge Doyle, director of the freight program at Unisys, estimates that the economic viability of 95% of all international passenger air routes is dependent on contribution from airfreight. Other estimates put cargo contribution to airline profitability as high as 30% for some companies³⁰. These belly loads of cargo on passenger flights represent a significant portion of the market that is not transported by dedicated cargo aircraft. It also contributes to stressing the infrastructure at the busiest airports. Although

²⁹ Orton, Charles W. "The Top Air Cargo Carriers" (World Trade, 13: June 2000) 64-65.

³⁰ Schwartz, Beth "Change in the Air for Cargo" (Transportation & Distribution, 41: March 2000) 53-55.

it may not be possible or even desirable to separate the passenger and cargo markets completely, there is a limit to how much the passenger airplanes and terminals can handle. The amount of cargo transported by dedicated cargo aircraft should also be examined in future research.

To better understand the air cargo market, the following chart is provided as a summary of data taken from Air Cargo World's first annual report. It shows the amount of air cargo originating in each region for 1998³¹. The implication is that the vast majority of international air cargo is moving between the U.S., Asia, and Europe, and that aircraft should be able to service these routes efficiently.



4.2.2 Market structure for Outsized Cargo

A subset of the overall air cargo market is the movement of oversized cargo such as tanks, aircraft fuselages, satellites, construction vehicles, and oil drilling equipment. Volga-Dnepr operates ten Antonov AN-124-100 heavy freighters and holds over 60% of

³¹ Schwartz, Beth "1999 World Air Cargo Report" (Transportation & Distribution, 40: August 1999) 22-29.

this market. Until recently Volga-Dnepr operated its aircraft through a partnership with the U.K. based firm Heavy-Lift. Heavy-Lift marketed and brokered the An-124s. It is unknown at this time why Volga-Dnepr and Heavy-Lift just severed ended their partnership. Antonov Airlines and Volga-Dnepr are now engaged in alliance talks. Together they are funding the restoration and completion of three An-225s, each capable of carrying up to 250 short tons. The first An-225 just returned to flight in May of 2001.

This relatively small number of firms and aircraft account for approximately 93% of the market³². Commercial competition in this market comes primarily from the four Airbus A300-600STs or Beluga transports which may generate as much as \$15M annually³³. The U.S. Air Force C-5 and C-17 aircraft also carry outsized aircraft, however the C-5 isn't available for commercial air cargo and the civilian version of the C-17, has yet to enter the market place. Volga-Dnepr estimates the heavy and outsized air cargo market value as \$200M annually³⁴. Lockheed also quotes this minimum market value in their marketing for a potential new global transporter. Boeing's marketing department estimates the market to be worth \$300-\$400M annually. American Shipper categorizes the market for outsized air cargo as in its infancy and "one of the fastest expanding segments in the international air cargo business"³⁵. Given that all of these sources are at least somewhat prone to parochial optimism, the current annual demand for moving outsized air cargo, measured in terms of before cost revenues, is probably at best \$200-\$400M.

³² Krause, 30-31.

³³ "Airbus Industrie creates freight airline for Belugas" (Flight International, 150: 16 October 1996) 9-11.

³⁴ Velovich, Alexander "Volga-Dnepr in Alliance Talks" (Air Transport 12 September 2000) n.pag.

³⁵ "Big profit in heavy air freight. Volga-Dnepr" (American Shipper, 39: June 1997) 72-74.

4.2.3 Survey of Growth Predictions

Expedited service, just-in-time delivery, and logistics management are shifting the way the world does business. While the bottom line remains important, service outweighs price in importance to cargo airline customers³⁶. Service means primarily two things in this context: shipment tracing/tracking and information technology. The huge investments required in improving information technology (IT) systems might represent a considerable challenge for the industry. The challenge may be more aptly met through alliances of major carriers or by individual carriers dominating niche markets.

Some of the biggest winners in the niche markets like Volga-Dnepr, the previously discussed outsized cargo carrier, and Atlas, an airplane outsourcer based in Golden, Colorado. Atlas buys cargo aircraft, primarily new and used 747s, and then leases them with non-union flight crews to whoever needs them. Atlas customers include China Airways and British Airways. These customers enjoy increased capacity without the capital investment. Atlas enjoys stability with three to five year lease contracts and greater flexibility in employment options for its aircraft resources. Since launching in 1992, Atlas has grown to be the third largest carrier in the world in terms of freight carrier behind FedEx and UPS³⁷. Similarly, Gemini Air Cargo is the world's second-largest dedicated wet-lease cargo airline providing aircraft, crews, maintenance, and insurance³⁸. Beyond the traditional cargo carrier airliners, and the outsized carriers, these wet-lease carriers may represent significant demand for a new airliner.

³⁶ Nelms, Douglas W. "Perceptive Reality" (Air Transport World, 37.9: September 2000) 97-98.

³⁷ Brull, 128.

³⁸ Nelms, Douglas W. "Rising Star" (Air Transport World, 37.9: September 2000) 99-100.

According to John Kasarda, director of the Kenan Institute of Private Enterprise at the University of North Carolina at Chapel Hill, the most significant trend in the industry is the teaming of air carriers with third-party providers and freight forwarders to provide sophisticated door-to-door delivery. Indeed there appears to be great potential for improvement. The industry average for door-to-door international shipment by air is still six days, only a slight improvement over the six and a half-day average of 30 years ago³⁹. As a response we are seeing more partnerships between expedited carriers and the more conventional air cargo carriers.

Walter Johnson Jr., chairman of the education committee of the International Air Cargo Association recently said, "No one measures the price of air transport vs. the price of surface transport. What people measure is the cost of air transport vs. the cost of inventory."⁴⁰ As the lifecycle of consumer products such as fashion, electronics, or international produce shortens, it becomes ever more important that these goods spend less time in transit. Even though the cost of airfreight can be as much as ten times the expense of surface freight, the additional cost is often more than compensated by the benefits of reduced inventory, increased speed, and decreased losses in transit⁴¹. David Pierce, marketing director for Boeing sees the air freight market growing at twice the rate of GDP. Even after the downturns and subsequent recover in Asia, he predicts 6.5% growth annually⁴². Boeing anticipates the world wide freighter fleet will double by 2017.

³⁹ White, Michael D. "Air Cargo Takes Wing" (World Trade, 12: June 1999) 60-62.

⁴⁰ Petterson, Edvard "Air Cargo Demand Rising Sharply, Could Strain LAX" (Orange County Business Journal, 23: March 13, 2000) 18.

⁴¹ Petterson, 18.

⁴² Schwartz, Beth "1999 World Air Cargo Report" 27-29.

While 70% of the fleet may come from modified passenger aircraft, Boeing is still producing 50% of its new 747s as freighters.

Evidence of industry growth can be found in the booming success of several smaller ventures. Pilot Air Freight in Jacksonville, FL, sees 1300 to 1500 shipments per month through Jacksonville International Airport. They had \$180,000 in sales in 1998, \$2.3M in 1999, and a projected \$4.0M for 2000⁴³. Another example is the Huntsville International Airport (HSV), which has turned into a major cargo hub. The reasons why Emery Worldwide and Panalpina are flocking to this North Alabama cotton patch are better service, lower costs, and less crowding. The growth in both the passenger and cargo airlines is leading to increased crowding at traditional major hubs. HSV also offers integrated air rail service through its on site intermodal center. Panalpina, an international freight forwarder, started using HSV with just one 747 wet-leased from Cargolux in 1990. Their U.S.-direct-to-Europe operation from HSV has now grown to ten flights per week and includes aircraft from Cargolux, Kitty Hawk, and Atlas. Their operations now include service to Asia-via-Alaska from HSV⁴⁴.

Given that air cargo carriers and aircraft manufacturers may be optimistically biased when predicting growth for their own market, it is important to include external perspectives on growth potential for the market. In September 2000 Air Transport World called air cargo “the fastest-growing segment of the airline industry, and one of the most rapidly changing.”⁴⁵ Aviation Week & Space Technology foresees an annual growth rate

⁴³ Schoolcraft, Lisa R. "Pilot Air's Revenue Soars to New Heights" (Business Journal: Serving Jacksonville & Northeast Florida, 15: April 21, 2000) 26-28.

⁴⁴ Nelms, Douglas W. "Alabama Triad" (Air Transport World, 37.4: April 2000) 78-81.

⁴⁵ Nelms, Douglas W. "Perceptive Reality" 98.

of 6-8% and a quadrupling of cargo traffic by 2015. David Hoppin, a principal with a freight transportation and logistics consulting firm, notes that world trade has traditionally grown at a rate twice the growth in world economy, and he predicts air cargo to grow twice as fast as international trade or four times the rate of the world economy. Already growing as fast as 18% annually, Hoppin further predicts Malaysia, China, Indonesia, and Thailand will be fast growing markets for international air cargo⁴⁶. The Colography group forecast a global growth rate of at least 3.9% to as high as 9.98% per year with potentially higher growth in Asia and Western Europe⁴⁷. Perhaps even more impressive is the change in perceptions of air cargo. For decades air cargo was associated with rush or emergency shipments. Now many companies are realizing savings from streamlined distributions and reduced warehousing and handling costs. Many shippers are shifting to buying time specific deliveries and away from mode specific transportation. John Kasarda predicts air cargo services to grow by as much as 6% annually for two to three years and at a double digit rate starting no later than 2005⁴⁸. He also warns this will require air carriers to “constantly monitor the needs of their customers and respond quickly and flexibly.”

The data and findings presented in this work are the highlights of the volumes of information describing the air cargo industry and growth expectations. Hopefully this provides an accurate overall representation. A few conclusions can be comfortably asserted from the work. The air cargo industry is large and growing. The industry,

⁴⁶ Petterson, 19.

⁴⁷ Schwartz, Beth "Taking Command of Cargo Demand" (Transportation & Distribution, 39: March 1998) 60-61.

⁴⁸ White, 60-62.

while regionally and temporarily vulnerable to economic downturns, is predicted worldwide to enjoy steady or increasing growth in excess of 6%, quadrupling in size between 2015 and 2017. The market for transporting outsized air cargo is estimated at \$200 - \$400M annually. Providers of Antonov An-124 aircraft dominate this market. The impact of the BC-17x has not been felt, as it is not yet available. This sub-market of the overall air cargo market is also expected to enjoy continued strong growth. But what does this mean for new aircraft design? As yet, no one is clamoring to bring a dedicated cargo aircraft to market. Airlines are not asking for one. It appears that the current market size and consistent growth predictions are too modest to motivate demand for a dedicated cargo airframe and that the price and capabilities of present aircraft offerings are sufficient.

Further research is needed to explore the potential for a new large cargo airlifter. First, market analysis should be performed to gauge potential for consolidating multiple flights on certain routes and thereby reducing costs. This could prove doubly beneficial in serving some markets such as China, where the number of foreign flag carrier flights into the country is limited. Second, estimates for research and development and purchase price of a new commercial airlifter are needed to perform a cost benefit analysis. Third, major air carriers should be interviewed to gauge their interest in seeing a new aircraft come to market.

4.3 Industry Efforts

One way to solve the shortfall in strategic airlift may be with a truly “global range” transport. The idea is to eliminate the need for aerial refueling of a super sized strategic airlifter. If the Air Force could acquire the capability to quickly move an aircraft with 300,000 – 1,000,000 pounds of cargo nearly half way around the world without refueling, it would reduce the tanker dependency. The New World Vistas study suggests a range near 12,000 nautical miles is achievable by the year 2025 if unspecified technological advances are achieved⁴⁹. Without these unspecified technological advances, a range of 6,500 – 7,500 miles should be achievable based on current technology found in commercial airliners.

To head off the impending problems of an aging stratlifter and tanker fleet, technological advances may make a number of new aircraft concepts a reality. The development of a modular aircraft system capable of performing both tanker and transporter roles would allow the Air Force to tackle two capability shortfalls using less research and development resources than for two separate aircraft. Additional benefits would be achieved from crew, parts, and infrastructure interoperability. At least two of the concepts being explored, the blended wing body and box wing aircraft, offer the additional advantage of providing two refueling boom attachment points.

Technological advances may also make an old concept of lighter than air transportation viable again. Instead of steel-framed hydrogen filled cylinders, the Air Force and commercial industry are using the latest in airfoil design, power plant efficiencies, and control systems technology to design a new type of a hybrid aircraft.

⁴⁹ Scientific Advisory Board. "Global Range Transport" (New World Vistas, Mobility Volume: 1995) 36.

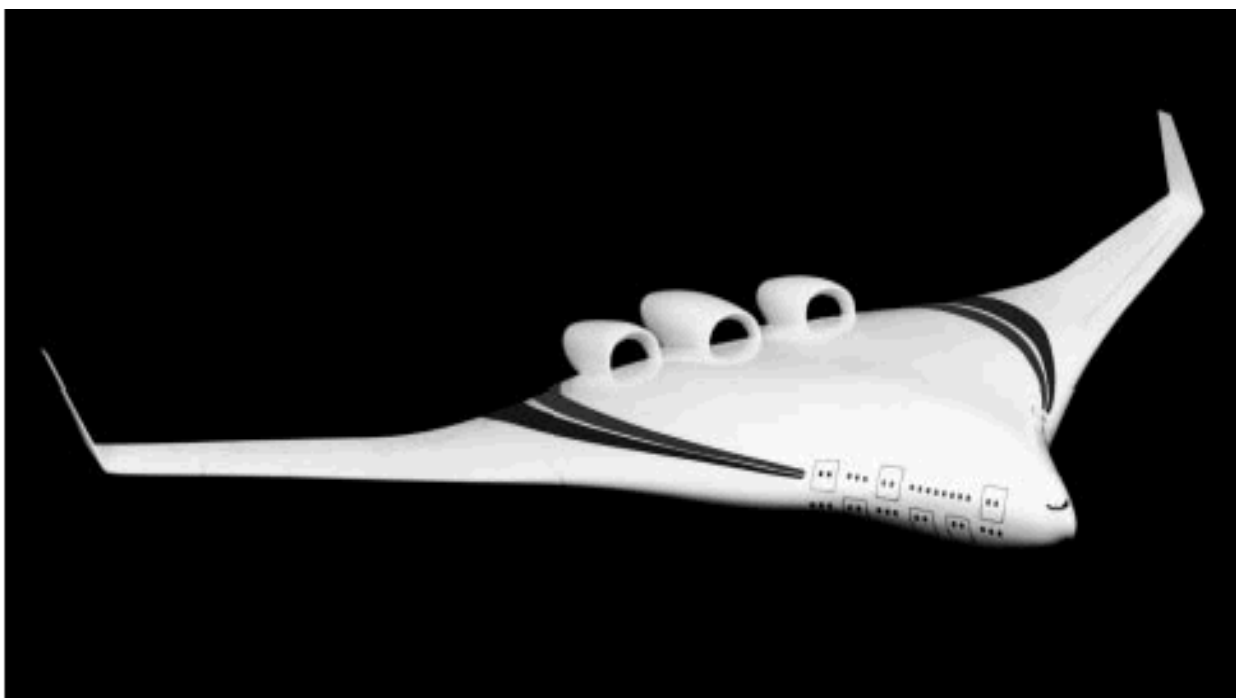
This new dirigible, or wing shaped airship, could potentially cross the ocean with a million pounds of cargo.

This section examines three different aircraft design efforts that have the potential to eliminate or at least alleviate U.S. military shortcomings in strategic airlift. Overviews include the blended wing body, box wing aircraft, and hybrid lighter-than-air programs, as well as their potential capabilities, advantages, limitations, and developmental challenges. Each section is concluded with a snapshot of each program's research and development status. The blended wing body and box wing fuselage aircraft may also provide a low cost replacement to the Air Force's aging tanker fleet of over 500 aircraft.

4.3.1 BLENDED WING BODY

What is it?

The Blended Wing Body (BWB) concept combines the wing and fuselage in a tailless aircraft with potential applications as a commercial airliner, air refueling tanker, bomber, and/or cargo transport. The BWB will have a thick airfoil-shaped fuselage section. The idea is to maximize efficiency and capability by integrating the engines, wings, and body into a single lifting surface. The concept has potential benefits of long range, large payload, and reduced acquisition costs. Operational costs may also be lower because of the reduced parts and assemblies associated with eliminating the empennage. The concept is not completely new but rather an extension of the ideas and technologies used to develop the YB-49, B-2, and other flying wing aircraft. If developed, the BWB will actually be a series of aircraft with common major components such as the cockpit, power plants, and wing tips.



Blended Wing Body⁵⁰

Capabilities and Advantages

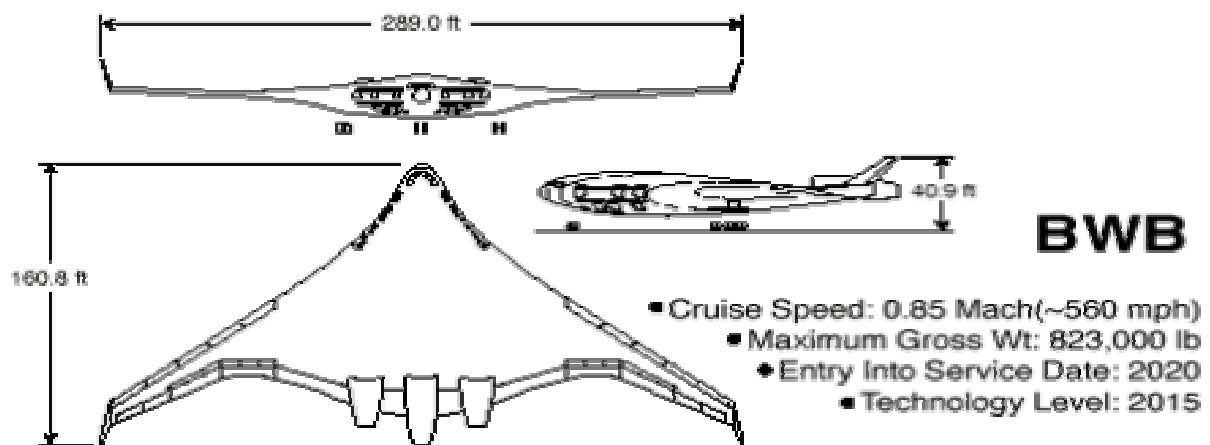
There are two planned versions of the BWB, a 3-bay and a 7-bay model. The configuration of the 7-bay could potentially support a 360,000-pound payload or approximately 150% of the working capacity of a C-5 and slightly more than the 150 short ton capacity of the An-124 Antonov. The 7-bay would also have a gross take-off weight of approximately 1.1 million pounds and a range in excess of 4500 nautical miles when fully loaded. Global range, roughly defined as 8,000 nautical miles, is achieved by reducing the payload to approximately 240,000 pounds. The 3-bay BWB would support 23 military 463L pallet positions⁵¹.

⁵⁰ "Blended-Wing-Body" (NASA Facts On Line. <http://oea.larc.nasa.gov/PAIS/BWB.html>. July 1997) n. pag.

⁵¹ Brown, Derrell L. "Blended-Wing-Body Military Applications" (Briefing to various HQ USAF offices provided via e-mail, Long Beach CA. September 2000) 6.

As a tanker or bomber, the 3-bay BWB would carry approximately 110,000 pounds. A unique advantage over today's tankers would be a twin boom configuration. This would be very advantageous when performing fighter drags across the Atlantic or Pacific oceans. It also would help with acquisition costs because the Air Force could buy the same refueling capability with fewer airplanes. The 7-bay BWB could offload up to 503,000 pounds of fuel⁵².

As an airliner, the 7-bay BWB would carry 800+ passengers, or roughly twice the passenger count of a 747-400. It would be quieter for passengers with the engines aft of the cabin areas. There would be ample room adjacent to the cabin for baggage and cargo.



Blended Wing Body⁵³

Limitations and Challenges

Advanced composite materials will be required to minimize the amount of structure needed to withstand the cabin pressurization loads and deflections in the skins. Here-to-fore, pressurized passenger cabins have generally had a circular cross section,

⁵² Brown, 3.

⁵³ "Aircraft Evolution" (Excerpts from unpublished article http://www.bayinsider.com/new/fox2000_060499.html 4 June 1999) n. pag.

which makes structural design and pressure distribution fairly straightforward. The BWB cabin will have an elliptical cross section, and cabin pressurization will be a significant leap in technology according to Boeing officials. However, the An-124 fully pressurizes only the top slice of its fuselage. Therefore, this may not represent quite so significant a challenge. At 289 feet wide (approximately 88 meters), it is 67 feet wider than the 747⁵⁴. Some existing runways and taxiways will not be able to accommodate the BWB. Parking and infrastructure concerns will further limit which airports the BWB can use. A footprint of 80 meters square is considered the maximum that many major airports and existing infrastructure can efficiently handle, a size smaller than the An-124 requires⁵⁵. The thickness of the airfoil will present new challenges in laminar flow design to overcome substantial aerodynamic drag as compared to current aircraft and their relatively thin cross sections. To meet stability, control, and ride quality requirements, the BWB will require advanced flight control systems such as the type typically found in a dynamically unstable aircraft like the F-16. Advances in engine technology will also be required to imbed them in the body and allow them to efficiently breathe laminar air as opposed to current airliner engines that breathe free-stream air⁵⁶. Again, there is potential to learn from other aircraft designs both good and bad, such as the F-117, B-2, and B-1. Because the BWB represents such a radical design change from current mass production carrier and cargo aircraft, the development cost and risks are estimated to be much higher than for other aircraft such as the B-2 or Concorde.

⁵⁴ "Blended-Wing-Body" (NASA Facts On Line. <http://oea.larc.nasa.gov/PAIS/BWB.html>. July 1997) n. pag.

⁵⁵ Mizrahi, Joe. "Flight to the Future" (*Wings*, 29; April 1999) 8-19.

⁵⁶ Potsdam, Mark A. "Design of a Blended Wing/Body Aircraft" (excerpt from on-line research paper <http://www.nas.nasa.gov/Pubs/TechSums/9495/final6178.html>. 9 October 2000) n. pag.

Accordingly, very large returns will be required to motivate development beyond the current, small, proof of concept effort⁵⁷.

Status

Boeing, Stanford University, and NASA are leading a joint research and development effort to investigate the technologies that will be required to make the BWB possible. Other supporting team members include The University of Southern California, Clark Atlanta University, and the University of Florida⁵⁸. Although research has been ongoing in many forums since 1991, the current research contract is for \$2.3M over a three-year period⁵⁹. This team has built and flown a prototype with a 17-foot span as a proof of concept developer. They have also done transonic wind tunnel testing to prove theoretical lift and drag characteristics. Additional test flights are planned to fully explore flight control characteristics⁶⁰. To explore the low-speed stability, control, and handling behavior NASA and Boeing are now building a 14% model of the BWB⁶¹. If the remaining, sizable, technological hurdles can be cleared, funding for full-scale prototype development must still be obtained.

4.3.2 BOX WING AIRCRAFT

What is it?

The box wing aircraft is Lockheed Martin's variant of joined wing technology. Previously, joined wing aircraft designs have been a co-planer union of the wing tips

⁵⁷ "Blended Wing Body Airliner - the next generation of civil transport aircraft" (Excerpts from Preliminary Design Study BW-98 <http://www.cranfield.ac.uk/coa/tech-avt/avt-4.htm> 9 October 2000) n. pag.

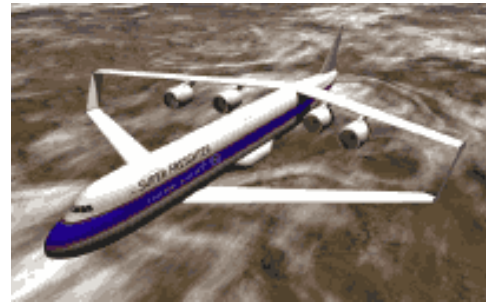
⁵⁸ "Aircraft Evolution." (Excerpts from unpublished article http://www.bayinsider.com/new/fox2000_060499.html 4 June 1999) n. pag.

⁵⁹ McKinley, Robert E. Jr. Blended-Wing-Body: Design Challenges for the 21st Century (NASA Brochure, March 1997) n.pag.

⁶⁰ McKinley, n.pag.

⁶¹ Sweetman, Bill. "Flights of Fancy Take Shape" (International Defense Review, 33.7 1 July 2000) 8.

from a forward fuselage mounted swept-back wing with the wing tips from a forward-swept aft fuselage mounted wing. In other words, the wings look like a normal single wing from the nose of the aircraft and a diamond from the “God’s eye” view. Lockheed has proposed a variant in which the wings do not fly in the same plane. One wing is mounted near the top of the fuselage with the other mounted near the bottom. Endplates or vertical wings connect the wing tips. This concept also looks like a diamond from a “God’s eye” view but looks like a boxed fuselage when viewed from the nose of the aircraft. This closed rectangle, or box design, has been predicted to have the lowest possible induced drag for a given wing span and area⁶². Lockheed is proposing the use of this concept in the development of a family of aircraft to serve as air refueling tankers, cargo aircraft, and global range transporters.



Box Wing Aircraft⁶³

Capabilities and Advantages

Like other concepts for future large aircraft, this concept is for the development of a modular aircraft to serve in a multitude of roles. Lockheed envisions the box wing

⁶² Carroll, T.M. A Vortex Lattice Program for Prediction of Box Wing Aerodynamic Performance. (MS thesis (A-A023 540/8/XAB), Air Force Institute of Technology, Wright-Patterson AFB, OH, December 1974).

⁶³ "Advanced Mobility Aircraft" (Lockheed Martin website <http://www.lmasc.com/ama/index.htm> 12 September 2000) n. pag.

flying as a passenger airline carrier, strategic airlifter, multi-point in-flight refueling aircraft, and super-freighter⁶⁴. Each version would make the maximum use of interchangeable parts and modules.

As a tanker, the box wing also has the advantage of offering multi-point or multi-boom configurations. Therefore it offers a similar advantage to the BWB in its ability to lower the overall number of required tankers as compared to the USAF's inventory today. The tanker would also serve in a dual cargo lifter capacity like the KC-10 but with the added advantage of roll-on and roll-off capabilities of vehicles, equipment and ISO containers. It will be able to perform this airlift mission over a 4,600-mile range and still offload more fuel than a KC-135 aircraft⁶⁵.

As a passenger airliner, the box wing aircraft would carry over 600 passengers and still operate at existing airports within their infrastructure for two primary reasons. First, the aircraft would have conventional narrow track landing gear attached directly to the fuselage, which would make it more compatible with existing infrastructure than the BWB⁶⁶. Second, the box wing aircraft would have no bigger footprint than current aircraft and as much as 20% less than some of today's large passenger liners.

A 350,000 pound maximum payload capacity and global range of almost 7000 miles with a 200,000-pound payload would make this a very attractive super freighter. These capabilities would easily surpass those of the 747 and the C-5B aircraft⁶⁷.

⁶⁴ "Market Report - Strategic Airlifters" (Jane's Defense Weekly, 33.7: 16 February 2000) 2 pages.

⁶⁵ "Market Report - Strategic Airlifters" 2 pages.

⁶⁶ Sweetman, 6.

⁶⁷ "Advanced Mobility Aircraft" n. pag.

Limitations and Challenges

A review of available literature indicates there are no significant technological hurdles to overcome with this concept. Probably the most significant obstacles are Lockheed's history with large aircraft and current attitude towards their manufacturing. The L1011 and C-5A aircraft nearly bankrupt the company⁶⁸. Their only successful large aircraft manufacture in the latter half of the 20th century has been the C-130, and it may have not proved profitable except for the many variants and long production run made possible by congressional authorizations far in excess of military request. Privately, Lockheed officials have admitted a corporate philosophy of steering clear of the commercial airline business, instead preferring purely military aircraft production with full DoD funding. Lockheed officials have also shown no interest in preparing expensive aircraft production proposals if they think their efforts will only be used as a "stocking horse" for Boeing. Without a serious and substantial government commitment, Lockheed may well get completely out of the big aircraft manufacturing business when C-130 orders are complete⁶⁹. This would leave the U.S. with only Boeing as a large airframe manufacturer.

Status

Beginning in 1997, Lockheed has flown 18 test flights of the pictured scale model of the box wing tanker/transport concept. In their words, the model has "exhibited excellent flight characteristics, and the tests met and exceeded all objectives." They are

⁶⁸ Boyne, Walter J. Beyond The Horizons (St. Martin's Press, 1998).

⁶⁹ Comments from Lockheed officials in this paragraph were recorded during interviews and a factory tour in Marietta, Georgia on 6 November 2000. Comments primarily came from Larry Donaldson and Andy Bennet, two managers employed there. Their comments on corporate philosophy should be protected as private information. Donaldson contact information provided in bibliography.

currently planning to build a larger proof of concept vehicle⁷⁰. Wing section testing to date has shown the box wing can achieve design strength requirements with a 25 percent weight savings compared to a metal wing baseline⁷¹. Lockheed was contracted by NASA to compare an advanced conventional wing and a box wing concept. Their test showed an estimated 23-26% reduction in operating costs and a 21-23% reduction in acquisition costs for the box wing design. As for expected or anticipated sales, Lockheed claims an expected market for 500 aircraft in the C-141 class⁷². Market expectations for the tanker and super freighter are unknown.



Prototype Box Wing Test Model⁷³

4.3.3 THE AIRSHIP

Background

Old airships (blimps) of the early century were not effective in carrying cargo, mainly due to the high structural weight of the blimp itself. These ships also had poor maneuverability and at times tended to catch on fire (Hindenberg). Hence, airship development has lagged dramatically, compared to aircraft development over the same

⁷⁰ "Advanced Mobility Aircraft" n. pag.

⁷¹ Giffin, C.F. and Harvill, W.E. Composite Transport Wing Technology Development: Design Development Tests and Advanced Structural Concepts (Provided under Contract NAS1-17699 Burbank, CA: Lockheed Aeronautical Systems Co., September 1988).

⁷² Cook, Nick. "Looming Large" (Jane's Defense Weekly, 29.16: April 22, 1998) 24.

⁷³ "Advanced Mobility Aircraft." n. pag.

time span. If we apply today's technology to the early century blimp, we can easily foresee the development of airships that are effective, safe, structurally light, and aerodynamic. The technologies of today concentrate on airship construction materials (high strength-to-weight fabrics) and the airship structure (composite framing). Also, engine technology has increased the speed, range, and controllability of the airship, while significantly decreasing the workload need for operation⁷⁴.

What we don't have today is an open mindset to the fact that this new technology on an old system may just be the answer to our global transportation needs. The fact is that heavy lift cargo airships will open many new markets by providing rapid global delivery of cargo (time-sensitive or oversized) directly from source to market. Considering the benefits to supply-chain-management and to our Department of Defense, this new airship technology may be very important in the near future.

These new airships carry ten times the cargo of current aircraft at a speed four times faster than sealift⁷⁵. Airships offer some of the best qualities of airlift and sealift. We can best look at the overall airship "product" if we consider its "door-to-door" delivery capability and timeframe. Conventional airfreight cost about \$1.50 per pound to ship and takes 4 to 5 days to go door-to-door. Sealift (including rail legs) cost about \$.30 per pound and takes 10 to 25 days. The airship will cost about \$.70 per pound and, like airfreight, takes 4 to 5 days⁷⁶. A key assumption is that the airship can match airplane delivery times by picking up and delivering from source to need. This would eliminate

⁷⁴ Fellows, 27.

⁷⁵ Airship-Advanced Technology Group (ATG) SkyCat website (<http://www.airship.com.html> 11 October 11, 2000). n. pag.

⁷⁶ Moughon, Col. James C. III "JCS Brief on Ultra Large Airlifters" (The Joint Staff, Logistics Directorate, J4 Pentagon 20 September 2000).

the time aircraft freight loses getting to and from the aircraft. In all, the airship offers low-cost, expedient, ultra-heavy lift, directly from the point of origin (stateside base) to the customer (battlefield).

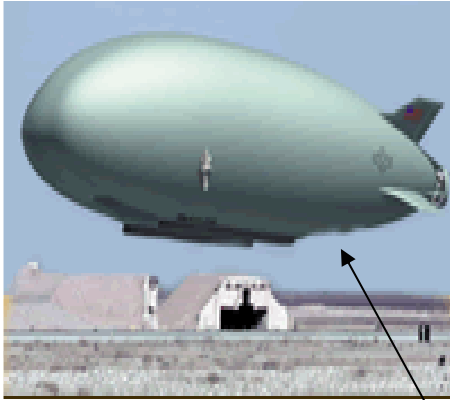
Many companies are looking at the development of airships, including CargoLifter, Laslink, and Advanced Technologies Group (ATG). This section looks at the ATG SkyCat 15, 200, and 1000 because this series of airships hold the most promise for military use. This section will specifically look at airship, design, commercial and military capabilities, advantages, limitations and challenges. Finally we look at its current development status.

What Is It?

The ATG SkyCat airship series is based on a hybrid design, combining traditional airship technology (blimp) with a lifting-body shape. This hybrid vehicle's lift is made up of 65% lift from helium and 35% from aerodynamic lift. Therefore, this flying-wing shape is not considered a conventional airship. The design of the SkyCat incorporates the benefits and capabilities of cargo aircraft (C-17 type cargo bay), blimps (helium lift and frame design), hovercrafts (landing mechanism), and catamarans (aerodynamic lift)⁷⁷. Some of the more important design features of the SkyCat are its hovercraft landing gear, which allows it to land on nearly any flat surface, and its very strong composite fabric hull, which carries the load and allows for very little metal structure. Additionally the SkyCat has patented bow-thrusters, similar to marine supertankers, which allow it to direct its nose with accuracy and do away with the traditional thirty-man ground crew.

⁷⁷ Moughon.

Finally, the SkyCat uses “fly-by-light” technology. Its flight control system uses fiber-optics which are immune to EMI and lightning strikes⁷⁸.



Military and Civilian Versions of SkyCat⁷⁹

The SkyCat series of airships will transport heavy loads over long distances, faster than sealift and cheaper than airplanes, considering the fact that it can move freight from the point of origin directly to the market, or point of delivery. This nearly eliminates intermodal requirements, if not entirely. As stated before, the SkyCat will be able to land on nearly any flat surface to include swamp, desert, snow, or water. Using its patented hover suction landing system, the SkyCat is also able to land without docking infrastructure or ground crew. Because of the SkyCat’s unique design and capabilities, it has the potential for many commercial and military uses as described in the next section.

⁷⁸ ATG SkyCat website. n. pag.

⁷⁹ ATG SkyCat website. n. pag.

Capabilities and Advantages

The SkyCat will come in three models, the 15, with a 15 tonnes (16.5 tons/33,000 lbs) payload, the 200, with a 200 tonnes (220 ton/440,000 lbs) payload, and the 1000, with 1000 tonnes (1,100 tonnes/2,200,000 lbs) payload (Airship, 2000). Table 1 shows the characteristics of each Skycat model.

SkyCat Numbers

	SkyCat 15	SkyCat 200	SkyCat 1000
Envelope Volume	864,550 cu.ft	16.1 million cu. ft	70.6 million cu. ft
Dimensions			
Length	269.4 ft	807 ft	1,007 ft
Width	110.5 ft	253 ft	446 ft
Height	67.6 ft	154 ft	253 ft
Payload Bay Space			
Length	80.8 ft	162 ft	265 ft
Width	10.3 ft	24.5 ft	40 ft
Height	6.25 ft	16.5 ft	26 ft
Payload	16.5 tons	220 tons	1,100 tons
Range (max load)	2000 nms	3,225 nms	4,000 nms
Altitude	9000 ft/18,000 ft	9000 ft	9000 ft
Cruise Speed	74 KTAS	75 KTAS	100 KTAS
Maximum Speed	87 KTAS	90 KTAS	110 KTAS

The SkyCat 15 is the first of the airship series to be put into production. The 200 is the mid-range model and will be the first to be fitted with cargo ramps on both ends of the payload bay, allowing roll-on-roll-off operations. The 200 will be fitted with a floor built to military specifications. Finally, and most important to the military, is the SkyCat

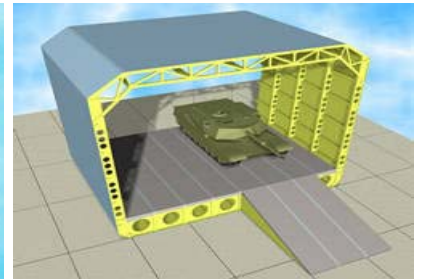
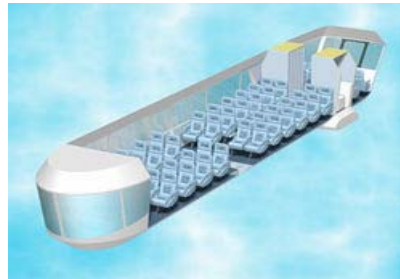
1000. The rest of this section will mainly look at the 1000 because of its military airlift capabilities⁸⁰.

The SkyCat 1000 will be the largest aircraft ever to fly. It is basically designed to meet the needs of the military for large troop and equipment moves to Major Theaters of War. One main problem the SkyCat 1000 solves is fighting unit re-constitution. In a Congressional testimony on the Gulf War, re-constitution was classified as “a nightmare.” Many times units arrived in different places and weeks apart from their equipment. The 1000 can transport a unit in its entirety along with their equipment and supplies. Additionally, the unit is offloaded combat ready and near the fight. This delivery of the units near the operational start-line is important. Over 3,000 trucks were used in the Gulf War just to take personnel from the coast and airports to the main buildup areas. Militarily, the capability of near direct deliver is quite important.

The SkyCat 1000 will be able to carry 16 main battle tanks (compared to one for a C-5B) with supplies, enabling them to go immediately into battle. The flight deck will be above the main forward ramp, providing side-by-side pilot seating along with 900 sq.ft. of accommodation for off-duty crew members. The main load bay will provide clear space for cargo on a military rated floor structure. Also, there will be mezzanine (2,100 sq.ft.) decking providing a multiple lower load area as needed for crew/passenger space. Finally, the 1000’s bay has forward and rear ramps providing total access to cargo for easy onloading and offloading⁸¹.

⁸⁰ ATG SkyCat website. n. pag. used for all the data in this paragraph.

⁸¹ ATG SkyCat website. n. pag.



Example SkyCat 1000 Military Uses⁸²

Other than cargo, military uses of the SkyCat 15 and 200 models include Patrolling and Surveillance, Airborne Early Warning, Minesweeping and Counter Measures, Landmine countermeasures, Anti-Submarine Operations, Peacekeeping, Humanitarian Operations, Telecommunications, and Arsenal Ships.

A specific cargo capability of the SkyCat is its virtually flat payload/range curve for military airlift applications. This means that very large cargo loads can be hauled with low fuel consumption and long range. The cargo bay and heavy lift ability of the 1000 allows the transport of the largest and heaviest military loads, including tanks, armored vehicles, helicopters, and artillery.

⁸² ATG SkyCat website. n. pag.

These capabilities are important to look at when assessing military applications. Airlift 2025, a study of air mobility requirements in 2025, expressed the need for increased airship capabilities to make them a viable mode of military transportation in the future. The specific capabilities pointed out in the study are 500-ton (1,000,000 lbs) useful lift capability, maximum airspeed of 250 knots, maximum range at gross weight of 12,500 miles, and a defensive/stealth capability. These characteristics would make the airship three times as effective as the C-5B when considering load capacity, range, and speed. The airship, compared to the C-5B, also eliminates transshipment time (direct pickup and delivery) and reduces infrastructure requirements and cost⁸³. The SkyCat does not exactly meet this study's requirement, but it does provide a significant amount of the requirements needed. The SkyCat can deliver 1,700,000 lbs over 10,000 miles, which is nearly twice the load capacity over virtually the same distance⁸⁴. The SkyCat can even carry 2,200,000 lbs over 4000 miles. One characteristic not met is the airspeed. Although these requirements are a template of what the future airship should be like, they may not be what is technologically feasible. The bottom line is that we are realizing many of the 2025 capabilities today and in some cases even exceeding them.

The civilian application of the SkyCat is also very promising. The SkyCat will have the ability to transport 1,500,000 lbs over 6000 miles in 2.5 days. With this capability, the Skycat 1000 can haul fresh produce from South America to Europe, and then fly more than 880 automobiles between Europe and the United States. This transportation capability has not been realized to date. The SkyCat has the ability to

⁸³ Fellows, 22.

⁸⁴ Moughon, James C. III, Colonel. "JCS Brief on Ultra Large Airlifters." The Joint Staff, Logistics Directorate, J4. Pentagon. 20 September 2000 n.pag.

combine segments of the sealift and airlift markets. As stated before, the SkyCat's freight rates would be substantially less than airfreight and only slightly more than sea freight⁸⁵. Additionally important is the fact that the SkyCat has the ability to fly directly from the producer to the customer, which lowers the trans-shipment time and cost, and eventually lowers the overall cost of the whole supply chain. In all, the possibilities of airship use in the commercial market are numerous. Along with freight transport and heavy lift, commercial applications of the SkyCat 15, 200, and 1000 include tourism, advertising, law enforcement, and humanitarian aid. The lower overall cost of airship transportation, along with its direct delivery capability may in fact change the way we look at airship operations and especially the way we deliver goods, both commercially and militarily.

Limitations and Challenges

The biggest thing to look at as a limitation is vulnerability, particularly considering the military role of the Skycat. The size of this aircraft's payload and its slow speed makes it quite an inviting target. One very glaring threat revolves around the fact that it would not be hard to get under the airship for a direct missile shot or gun shot to the gondola.

The SkyCat typically can operate above the range of gunfire at 9,000 ft. but not out of the range of a surface-to-air missile. Other protections from gunfire would include armor coating the gondola with kevlar. The Skycat has no potential for explosion since it is not under pressure and filled with helium, an inert gas⁸⁶.

⁸⁵ ATG SkyCat website. n. pag.

⁸⁶ ATG SkyCat website. n. pag.

Although not totally protected from danger, the SkyCat does invoke some protective measures. As stated before, the control system for the Skycat is fiber-optic and therefore immune to EMI. Also, test have proven that the SkyCat can take 100 bullets holes (200 total with exit holes) and still fly for four hours before having to land. This same test showed that a typical shape charge (like a SA-16) exploding next to the airship only made the hull deform from the explosion but not break⁸⁷. Other protection measures include the use of stealth fabric for the hull, which also surrounds the gondola, and the use of night operations to limit sight acquisition from shooters.

Status

Advanced Technologies Group (ATG) will launch its series of SkyCats beginning in 2001. The SkyCat 15 is already under construction and is due to fly at the end of 2001. The projected cost is \$50M. The construction of the payload module of the SkyCat 200 is also currently underway, with the airship's projected fly date being 2003⁸⁸. Its projected cost is \$100M. Finally, the SkyCat 1000 is projected to fly around 2007 at a cost of \$200M.

ATG has already successfully completed its first and second series of flight test of its 40-ft scale model called the "Sky Kitten." The test looked at all design, handling, take-off, and landing functions, including its hover-cushion landing system⁸⁹. Also, ATG

⁸⁷ Moughon, n.pag.

⁸⁸ "Advanced Technologies Group Successful Maiden Flight of SkyCat Prototype" (Excerpt from ATG press release website. <http://www.airship.com/news/release> 9 October 2000) n. pag.

⁸⁹ "Advanced Technologies Group Successful Maiden Flight of SkyCat Prototype" n. pag.

has signed on IAR S.A. Brasov, a Romanian manufacturing company, as a partner in the production of the 200⁹⁰.

If that were not enough to prove the SkyCat is well on its way, then look at the fact that numerous European companies are investing in the development of ATG's airships. Significant contributors include shippers and even the U.S. DoD. The Skycat will be a significant cargo lifter for the cargo industry. For the commercial transportation business, the SkyCat bypasses heavily clogged airports and deepwater ocean ports, and provides the transport of cargo around the world at one quarter the cost of operational aircraft and four times the speed of ships⁹¹. For the DoD, the SkyCat can transport unusually large and extremely heavy components of a MTW deployment over long distances, and do it point-to-point⁹². In all, the SkyCat may just be the answer to the transportation needs of the future, both for our commercial supply chain and our Department of Defense.

Conclusions from Industry Efforts

This paper covered three possible strategic airlifters of the future. The fact that these aircraft are breakaways from traditional mindsets should not go unnoticed. Our military and commercial air transportation system may be reaching its peak performance, and only through a paradigm change will we see substantial gains in cost effectiveness and "throughput." This section covered the blended wing, box wing, and airship concepts. Although each of these aircraft offer unique, performance enhancing

⁹⁰ "Advanced Technologies Group names IAR S.A. Brasov as the first SkyCat 200 partner" (Excerpt from ATG press release website <http://www.airship.com/news/release> 9 October 2000) n. pag.

⁹¹ "Revolutionary SkyCat aiming to prove it's a purr-fect transporter" (Excerpt from ATG press release website <http://www.airship.com/news/release> 9 October 2000) n. pag.

⁹² Done, Kevin "SkyCat transport carrier to compete for Airbus contract" (Airticle from ATG press release website <http://www.airship.com/news/release> 9 October 2000) n. pag.

capabilities for the military and commercial market, they also each pose limitations. This section does not advocate one of these aircraft as “the” aircraft of the future. The main take away is that industry has performed initial study and design steps in the case of the BWB and the box wing aircraft. The airship is already well underway as a purely commercial endeavor. If the military is take advantage of one of these concepts, it will have to provide the funding to promote and protect its interest in a military variant. As the Scientific Advisory Board and the Airlift 2025 study suggest, the DoD should look at all concepts for future airlift possibilities. In addition to these three possibilities, ideas include supersonic transport, wing in ground effect transport, unmanned transport, rocket transport, stealth transport, twin fuselage transport, sea-based transport and should not be precluded from seed-corn support, no matter how “out of the box” there designs seem⁹³. The answer to our future strategic mobility needs may not be more C-17s. In fact, it might be one of the aircraft described in this paper or one listed above, or perhaps some system not even thought of yet.

4.3.4 Compatibility with DoD Requirements Analysis

The potential requirements identified in section 4.1.2 are repeated and numbered here for reference. The numbers do not represent a prioritization of requirements.

- 1) 300,000 lbs. payload capacity
- 2) 7,000 – 7,500 unrefueled range with fuel reserves
- 3) Roll-on, Roll-off cargo capability with built in ramp
- 4) Back-up capability like the C-17
- 5) Runway length minimums the same or less than 747 or C-5
- 6) Sustained airspeed of approximately 450 knots
- 7) Reinforced flooring to support heavy equipment like tanks
- 8) 463L pallet capability
- 9) Usable footprint - Landing gear breadth, aircraft not too big for commercial airports

⁹³ Scientific Advisory Board, 42.

- 10) Cargo bay accommodates outsized equipment – tanks, helicopter, patriots, rockets
- 11) Responsiveness – aircraft can be quickly generated and launched
- 12) Reliability – contracted minimums with penalties for failure to perform
- 13) All weather usable
- 14) Commercial engines
- 15) Low operating and maintenance costs
- 16) Either no required MHE or use existing MHE – tonners etc.
- 17) Meet FAA noise and pollution standards
- 18) Supports In Transit Visibility (ITV)
- 19) Passenger accommodations
- 20) Supports aeromedical evacuations
- 21) Stealthy
- 22) Intermodal with respect to containerization

To complete the look at what industry is currently working on, these different platforms are compared in table form in a qualitative look at their potential to meet these numbered requirements. Each platform is assigned a value of High, Medium, or Low potential to satisfy a particular requirement.

<u>Requirement</u>	<u>Blended Wing Body</u>	<u>Box Wing Aircraft</u>	<u>Airship</u>
1) Payload	H	H	H
2) Range	H	H	H
3) RORO	H	H	H
4) Back-Up	M	M	H
5) Runway	H	H	H
6) Airspeed	H	H	L
7) Flooring	M	M	L
8) 463L	M	M	M
9) Footprint	M	H	n/a
10) Outsized	M	M	H
11) Responsive	H	H	L
12) Reliability	H	H	M
13) Weather	H	H	L
14) Engines	H	H	M
15) O&M Costs	H	H	?
16) Low MHE	M	M	M
17) FAA	H	H	H

18) ITV	H	H	H
19) Passengers	H	H	L
20) Aeromedical	H	H	L
21) Stealthy	M	L	L
22) Intermodal	M	M	H

4.4 C-17 as a Benchmark

4.4.1 CAMAA Overview

The C-17 Civilian Application of Military Airlift Aircraft CAMAA idea emerged from the need to increase airlift capacity in the face of fiscal constraints. The Air Force has said it needs 50 more C-17s beyond the planned buy of 120⁹⁴. There is also a realization that maintaining a full fleet in peacetime is very costly. It is felt that subsidizing the purchase price of C-17s down to \$124-128M may motivate commercial enterprises to purchase BC-17 aircraft and develop the market for out and oversized air cargo transport⁹⁵.

The potential growth in this market is uncertain, as previously discussed in section two of this chapter. The C-17 CAMAA program will be telling in that it should show if the Antonov is leaving a portion of the market untapped. The plan is to sell ten aircraft to the commercial market with an approximate subsidy of \$60M per aircraft and guarantee of government business. This business guarantee should give a company the

⁹⁴ Lockhart, Greg. "Bullet Background Paper on Commercial Application of Military Airlift Aircraft (CAMAA)" (Information paper for HQ USAF, Washington DC, 19 March 2001) 1 page.

⁹⁵ Comments by Maj. Geno Carter during overview and discussions of the CAMAA program. Maj. Carter works in HQ USAF/XPPM and is the lead XP officer for the C-17 program. I discussed the CAMAA program at length with Maj. Carter, visited with him, and attended CAMAA working group meetings during the period March 12-30, 2001.

security to throw capital at market expansion efforts. In return for the purchase price subsidy, C-17 operators will be required to enter a CRAF agreement with the USAF⁹⁶.

The taxpayer and the Air Force stand to save over \$6B in ownership costs over the 30 year aircraft life⁹⁷. But will it work when a 747-cargo plane can be purchased for roughly the same amount and be operated for less? CAMAA advocates point to C-17 short field capability and loading/unloading ease as attributes that will carve out a bigger niche in the air cargo market than what the An-124 occupies. CAMAA success or failure will greatly influence the likelihood of jointly developing a new airlifter.

4.4.2 Lessons Learned

Given this background and the detailed literature behind it, what can we take away from CAMAA and apply to a C-NXT development and acquisition effort? To begin, it is important to appreciate that the Air Force has not pushed for a civilian C-17 until fiscally compelled to. If full funding for the 50 additional needed planes is obtained, the whole CAMAA effort will likely wither on the vine⁹⁸. The program is not an altruistic effort to grow a civilian market, but rather a means to secure surge airlift capacity at a lower cost than full time asset ownership and maintenance. We can also approximate new aircraft development costs using the C-17 as our most recent benchmark. The R&D costs for C-17 totaled approximately \$6.6-7.3B depending on which accounting study is referenced⁹⁹. This tells us that we should assume at least this

⁹⁶ Pollock, Robert D. "Overall BC-17x Concept of Operations" (Information paper for HQ USAF, Washington DC, 23 March 2001) 1 page.

⁹⁷ Bosker, SSgt A.J. "AF, Boeing team up with commercial carriers to meet airlift requirements" (Air Force Print News from www.af.mil/news/n20010213_0209.shtml 13 February 2001) 2 pages.

⁹⁸ Carter, CAMAA overview, March 2001.

⁹⁹ Inspector General Department of Defense, Audit of Contractor Accounting Practice Changes for C-17 Engineering Costs (Report Number 92-046, Arlington, VA, 13 February 1992) ii.

much R&D cost for a new aircraft. Adjusting for inflation, this cost could easily be as high as \$12-16B in 2001 dollars¹⁰⁰.

The outsized air cargo market and growth rates are not sufficiently defined to entice market entrants. No airliner has approached Boeing about purchasing a C-17 derivative at the same price the Air Force pays¹⁰¹. The high fuel consumption and high purchase price relative to commercial alternative make the C-17 unattractive to industry to purchase outright. These inefficiencies are a function of several aircraft features. Specifically the airdrop capability, T-tail, defensive systems, high wing, and shallow wing sweep add weight, decrease cruising speed, and increase fuel consumption. These feature tradeoffs are discussed in detail in the final section of this chapter.

The significant hurdles for CAMAA go beyond design inefficiencies, questionable market conditions, and costs. Obtaining State Department and congressional approval is proving challenging¹⁰². It will also take significant effort and money to get the BC-17x FAA approved for commercial operations. The fact that BC-17x will remain on the United States Munitions List USML brings restrictions on overseas applications and cumbersome approval from State Department. Another lesson learned is the importance of setting up and funding in advance a multiyear plan so primary contractors can secure and pass on the benefits from volume purchase discounts and best value subcontracts. Purchase price has to be competitive with commercial alternatives. This is not to say it has to be the same or less than a B-747 or DC-11, but if

¹⁰⁰ This range of values was computed based on 1981 as C-17 R&D start date and 3-4% inflation since 1981.

¹⁰¹ Carter, CAMAA overview, March 2001.

¹⁰² Carter, Consensus of comments at CAMAA working group meeting, 21 March 2001.

an aircraft cost more to purchase or operate it must show quantifiable superior value. This extra value could be in the form of increased market penetration or savings from faster, easier cargo handling. The extra value could also come from opening previously unserviceable markets. This is the argument of BC-17x proponents. It remains to be seen if the commercial sector will be willing to buy the aircraft at the subsidized purchase price of \$124-128M. The C-17 program has also show that contracting for high reliability rates and maintenance support is possible. Over the long run, C-17 will show if this approach is indeed cost effective.

The CAMAA program plans to send out 30 Request For Proposals (RFPs) this summer to try to sell 10 BC-17x aircraft¹⁰³. Industry response to the RFPs will tell if the proponents are correct. Some rough calculations show that 10 BC-17X aircraft could be fully tasked if the BC-17X could capture 32-34% of the market currently served by the An-124. This required market share was calculated by comparing payload volume capacities of C-17 and An-124. Assuming the 16 An-124s are kept fully employed at their maximum volume of 40,965 cu. ft. each, it would take 31.4 C-17s at 20,900 cu. ft. apiece to serve the same market. As a percentage of market, 10 C-17 equivalents would provide 209,000 cu. ft. of capacity or 32% of the 655,440 cu. ft. capacity provided by the 16 An-124s. Although, like most cargo aircraft, the An-124 typically cubes out before it hits maximum payload weights, the above process was repeated using An-124 and C-17 payload mass capacities as a sanity check. The result was a required 34% market share

¹⁰³ Carter, CAMAA overview, March 2001

for 10 C-17 / BC-17x aircraft¹⁰⁴. This of course assumes no further competition from the nearly 30 additionally An-124s that are not currently serving commercially¹⁰⁵. In general industry or commercial carrier concerns are market size, cost of market penetration, aircraft cost, and reliability. Secondary concerns include the ability to resale aircraft. We may learn that CRAF requirements and government hoops, like the State Department, preclude industry participation even in the face of an “affordable” price.

4.5 Evolved Expendable Launch Vehicle (EELV) as a Benchmark

The Air Force may be able to lead the development of both a military and commercial version of the C-NXT by drawing on its Evolved Expendable Launch Vehicle (EELV) experiences. Similar to outsized cargo strategic airlift, a supply and demand imbalance has existed in the U.S market for rockets to boost hardware to space. The U.S. Air Force and aerospace defense industries are tackling this imbalance with an innovative design and acquisition approach in which they are sharing the R&D costs while developing the EELV to perform both commercial and U.S. military missions.

4.5.1 EELV Effort Overview

The mission of the EELV program is to enhance the national launch capability by replacing legacy boosters and simultaneously reduce the cost of launching military payloads to space by at least 25 percent¹⁰⁶. In 1994 Gen. Thomas S. Moorman, then Air Force Vice Chief of Staff, chaired the development of a Space Launch Modernization Plan. The plan identified several alternatives for modernizing how the military places

¹⁰⁴ Payload mass and volume capacities for both aircraft from – Jackson, Paul Jane’s All The World’s Aircraft 1999-2000 (Jane’s Information Group Inc, Alexandria VA, printed by Butler and Tanner Limited, Longon, England 1999) 507, 582.

¹⁰⁵ Taverna and Cochenec, 52.

¹⁰⁶ Gansler, Jacques S. Evolved Expendable Launch Vehicle Acquisition Strategy (Under Secretary of Defense for Acquisition, Technology, and Logistics August 26, 2000) ii.

satellites on orbit. In the National Space Transportation Policy, also released in 1994, the DoD reviewed the alternatives and decided to evolve current, expendable launch systems¹⁰⁷. These new rockets would be based on experience with existing boosters and would incorporate modernizing and simplifying technology.

Several characteristics of the space launch business were identified as key to shaping the acquisition strategy for these new rockets. Probably the most important aspect of the business environment was recognition of the growing commercial demand for rocket rides to low, medium, and high orbits around the earth. At the time it was estimated that the commercial sector would soon grow to represent two-thirds of the total demand for launch services¹⁰⁸. Also key was the virtually identical nature of the demand for launch services. Specifically, commercially satellites are generally the same size and shape as their military counterparts. The destinations and the routes are also the same. Both customers must choose from the same limited number of launch sites and service providers. Both types of customers require high reliability of product delivery, minimum vibration loading, specific temperature and humidity control during ascent to orbit, and precise placement at a specific location in space¹⁰⁹. The required environmental and power interfaces with the rocket are nearly identical. These factors lead the Air Force to employ a unique acquisition strategy for the design, development, production, and use of these rockets.

¹⁰⁷ McKinney, Col. Richard. "EELV Overview Briefing" (HQ USAF SAF/AQS, March 2000) 2.

¹⁰⁸ McKinney, Col. Richard. "EELV Affordability Through Innovation" (HQ USAF SAF/AQS Briefing to National Space Symposium, Catching a Ride to Orbit Session, 1998) 2.

¹⁰⁹ McKinney, Col. Richard. "EELV Overview Briefing" 7.

Development contracts were issued to two primary contractors, Boeing Corporation and Lockheed Martin Astronautics (LMA). Each was awarded \$500M for booster development, launch site construction, and associated testing. Each contractor was expected to contribute approximately \$1B of internal funds towards these efforts¹¹⁰. This split reflected the anticipated apportionment of military and commercial demand. Subsequent launch service contracts cover the actual costs of building, testing, and launching individual rocket missions. The first launches of these new rockets are scheduled for 2001 and 2002. Boeing has been initially awarded \$1.39B for 19 missions, and LMA was awarded \$506M for 7 missions¹¹¹. These are firm fixed price contracts and represent the profit potential for the contractors from government business. Performance and competition are important elements of the launch service contracting process. Incremental, advance payments are to be made on the basis of demonstrated successful and timely performance. Subsequent contracts beyond these 26 missions will be apportioned between the contractors based on quality of performance in providing initial launch services. The EELV program administrators emphasize this continued competitiveness as key to keeping cost down and the risk of failure minimized¹¹². Mitigating the risk of failure is particularly important in the space launch business because expendable rockets by their very nature are sunk cost, single use items and the cost of insuring military payloads is prohibitively high.

¹¹⁰ MacDonald, Maj. John. "Background Paper on Evolved Expendable Launch Vehicle" (HQ USAF SAF/AQSL, February 16, 2001) 1 page.

¹¹¹ MacDonald, 1.

¹¹² Shoemaker, L. Stodghill. "The Evolved Expendable Launch Vehicle: An Evolution of Launch Vehicles – a Revolution in Acquisition," (Presentation to 1999 Acquisition Research Symposium 20-24 June 1999).

Since inception, commercial market expectations have softened. The market for worldwide phone service based on satellite constellations has not matured as rapidly as predicted. Communication service providers have run into financial difficulties and have cancelled some launches and failed to schedule others. Economic downturns in both the United States and Asia have restricted the amount of venture capital available to fund commercial communication satellites. Demand from foreign launch service providers continues to etch away at Boeing's and LMA's market share. In the face of this softening demand, the Air Force has curtailed the EELV program to the extent that Boeing will be the only EELV launch service provider operating from the West Coast¹¹³. LMA will not even build an EELV launch pad at Vandenberg AFB, CA. Competitive pressures will obviously be diminished somewhat.

A final important characteristic of the EELV program has been the high level of support and oversight it has enjoyed. The EELV program is one of three top priorities for the Secretary of the Air Force¹¹⁴. The other two top-level programs are F-22 and C-17 production. The EELV program represents a new paradigm in government and industry cost sharing and it has only been made possible by this attention. If the EELV program succeeds in its mission of lowering costs and improving performance by capitalizing on combined commercial and military market demand, it may serve as a precedent for future acquisition efforts.

¹¹³ Saker, Col Robert K. "EELV Program Status Briefing" (29 June 2000) slide 40.

¹¹⁴ Shoemaker, n.pag.

4.5.2 Lessons Learned from EELV

Since the first EELV rocket has not launched yet and the market is anything but mature this program has not yet proven itself. Three principal questions remain unanswered. Will the launch services be as reliable as with current systems or better? Will these launch services yield the government the anticipated 25-31% cost savings over current costs? Will this be a profitable venture for the two prime contractors? For now all parties are moving ahead in anticipation of positive answers to these questions. Assuming for the time being that EELV will prove successful, what comparisons and contrast can be drawn between it and the development of C-NXT?

At first blush, there appear to be strong parallels. There is a growing demand in the air cargo market and a growing awareness that the military is not the only one willing to pay to move outsized cargo by air. Both the military and commercial demands are probably insufficient independently to entice an aircraft manufacturer to develop a new aircraft. Neither market is likely to independently require a 200-300 aircraft production run. Such numbers are typically used as a rules-of-thumb for estimating the break-even point in new aircraft manufacturing¹¹⁵. The role of cargo aircraft, rapidly moving large volumes of cargo over fast distances, is essentially the same for both military and civilian customers. Both programs have the potential to improve the U.S. industrial base by fostering technology development and manufacturing capacity that otherwise might not occur. Both programs would benefit from improved standardization, reliability, and cost effectiveness. But these are broad and perhaps too simplistic of comparisons. To sort through and compare the descriptive characteristics of the two programs, the following

¹¹⁵ Donaldson, comments during factory visit, November 2000.

table has been developed. The content has been gleaned from all EELV and cargo aircraft sources. The intent is to make this an objective itemized comparison and then draw generalized conclusions.

Descriptor	EELV Applicability	C-NXT Applicability
Cost Savings as Primary Driver	25-31% for EELV	Potentially, but capacity and effectiveness have been traditional military priorities.
New/Improved Technology	New engines and launch pads for EELVs	BWB and Box-Wing options.
R&D Cost Sharing	\$500M from DoD to each prime \$1B plus from each prime ROI dependent on both military & comm. launches	Potentially, however both LMA and Boeing have very limited interest in using internal funds. Will require DoD initiative.
Emphasis on cost competition throughout program	yes	DoD probably not willing to support two different airframes and contractors.
Reliability Objective	EELV is >98%	Close parallel - through C-5 & C-17 experiences, the Air Force has realized the desirability and benefits of contracted reliability.
Improved Maintainability Objective	yes	yes
Standard Customer Interfaces	yes	No, C-NXT would have to suit greatly varied commercial customer requirements.
Exact same hardware for military and civilian customers	yes	Probably not unless C-NXT eliminates airdrop capability, air refueling, and other unique characteristics that civilian version couldn't use.
Contractor leased facilities	yes	Not applicable, C-NXT must be able to operate out of a variety of military and commercial airports.

Descriptor	EELV Applicability	C-NXT Applicability
Contractor owned infrastructure	yes	Air Force would need to own/lease the C-NXT Material Handling Equipment (MHE) but may contract out or include depot level work.
Single use	Yes, by definition.	No, C-NXT should be designed to serve in the inventory for 30-50 years.
Multiple mission applications for each vehicle type	Yes, but varied mission objectives are met by configuring the EELV hardware in the small, medium, or heavy package.	No, there would probably be one basic aircraft type to serve the cargo missions.
Same government and customer service requirements	Yes, military and commercial customers want almost exact same service/product.	No, there will be great variety in C-NXT customers both internal to military and commercial markets and between the two.
Timeliness criteria	Yes, contractor penalized for late launches.	Yes, potential contractor penalties for late deliveries.
Mixed Market Demand	Yes, 50-67% of launch demands from commercial base.	Yes, but quantity of commercial demand is extremely uncertain.
Sufficient solo government or commercial demand	No	Maybe, DoD may eventually choose to fund a purely military aircraft to replace the C-5.
Secretary of Defense attention and direction	Yes, because of national importance and number of customers.	Yes, because of national importance and number of customers.
Foreign sales barriers	Yes, easier to overcome with EELV since primary use takes place in U.S.	Yes, tough to allow/control foreign use of C-NXT.
Enhance U.S. industrial base	yes	yes
Firm government and industry by in	yes	Would be required to motive aircraft manufacturers to serve military needs.

The EELV program provides some important lessons learned and potential applications to a C-NXT program. The biggest reasons why EELV may not serve as leader for C-NXT are the differences in missions and customers. The EELV military and commercial customers are virtually identical. The military customer for C-NXT will be highly varied, requiring cargo across the spectrum of size, weight, and complexity. The list includes items as varied as drinking water, fuel bladders, Patriot missile launchers, Apache helicopters, jet engines, and even rocket components. Within weight classes, there will be little variation in the demands from EELV customers. The result is C-NXT will have to be more generalized and less specifically tailored to individual customer needs. Taken a step further, the commercial customers for C-NXT will demand different services. The niche commercial market for outsized cargo has similar movement needs but places greater emphasis on cost effectiveness than the military outsized customer traditionally has. The commercial customer has even higher expectations for cost efficiency and speed with respect to bulk cargo. Admittedly the primary purpose of C-NXT will be to move outsized cargo, but like all other military airlifters it will undoubtedly move bulk cargo as well and must do so efficiently to attract commercial business.

The Air Force has historically called on its airlifters to perform a variety of missions such as airdrop, strategic lift, and intra-theater support to austere airfields. The Air Force has relied on its boosters to do one of two missions; either propel warheads at enemy nations or place payloads in earth orbit. There is considerable less variation in booster missions than cargo aircraft. Boosters have therefore been optimized over time to perform their mission very efficiently with respect to the physics involved if not with

respect to the fiscal costs. Military cargo aircraft have been designed around effectiveness and not efficiency. This point is the unique distinction between EELV and C-NXT. It represents both why EELV may and may not serve as a C-NXT president.

If EELV is successful and if the Air Force wants to repeat as much of its formula as possible with C-NXT, the implication is for the Air Force to tailor requirements around commercial market demands. If the USAF is willing to forgo some of its long held requirement for airlifters, it can narrow or eliminate the gap between customer demands. This idea, begun in section 4.1.2, will be flushed out more thoroughly in the last section of this chapter. Another idea to take away from EELV is the importance of top level support and scrutiny. A new paradigm in cargo aircraft development will require support from the Secretary of the Air Force and the other service chiefs as the principal military customers. Finally, the contract vehicles that are put into place must be mixed. The R&D effort will probably have to be more heavily funded by the Air Force than prime contractors because of the tremendous uncertainty in commercial market demand. Recent downward trends in commercial space launch markets are cause for concern to EELV and have reinforced to contractors the inherent risk in committing internal funds to R&D without firm commitments for long term production runs. Currently, appropriation cycles preclude providing the contractor that assurance. The production run contracts will have to be adjustable from the onset, so that the more the Air Force and commercial customers buy the better the price gets. This has typically been the case but more of an afterthought than a planned, contractually stipulate, volume-price relationship. Spelling out cost as a function of volume purchases should help convince congressional appropriators to commit funds efficiently. The production run

contracts should specify in advance how the Air Force would benefit from commercial market development. This is only fair since the Air Force will in effect be subsidizing this market development, in much the same way the DoD has subsidized the commercial space launch market development from the beginning. Ultimately, there remain numerous significant differences between EELV and C-NXT. However, if EELV is successful and C-NXT can merge civilian and customer requirements, then EELV can serve as a precedent.

4.6 Why a dual market aircraft has not already happened

If the DoD and the commercial sector have been moving cargo all over the world with airplanes for 50 years, why hasn't a common use aircraft already been developed? It would seem that a sense of practicality and normal market forces would have made this happen a long time ago. Actually, the idea of a joint use aircraft is not new at all. Initial transports were the same for the military and civilian communities. Over time, commercial airliners evolved into fuel-efficient people movers, not constrained by the need to land in austere locations. In the absence of affordable alternatives, civilian cargo aircraft have followed the trend as variations of airliner airframes. The C-141, C-5, and C-17 have all had civilian market aspirations. However, Lockheed was unable to sell the civilian versions of the C-141 and C-5 and in fact none were ever built¹¹⁶. So far the C-17 price has precluded commercial purchase and it remains to be seen if the subsidized price will attract buyers¹¹⁷. The Air Force has also been unwilling to buy commercial

¹¹⁶ Zidalis, Maj. Timothy M. "Expanding the National Airlift Fleet: The Quest for a Civil-Military Transport" (MS thesis, School of Advanced Airpower Studies, Air University (AU), Maxwell AFB, AL, May 1997) 24.

¹¹⁷ Carter, CAMAA overview, March 2001.

cargo aircraft such as the 747 cargo variant. In the simplest of terms, the barrier has been a difference in priorities and emphasis.

4.6.1. Comparison of Military and Commercial Cargo Aircraft Roles

The Air Force and DoD want maximum effectiveness from their airlifters. The reason the DoD buys and maintains its own aircraft is to have the ability to move outsized cargo anywhere. Warfighting CINCs face a tremendous variety of potential threats. Countering these threats may require forces in locations all over the world and many times we will not know where with much lead time. Not knowing exactly where our military forces will have to be deployed means the aircraft that delivers them needs greater versatility. The aircraft needs to be able to land and take off from as many different airfields as possible, and it needs to depend on a minimum amount of handling equipment once it gets there. Conversely, commercial air cargo carriers operate along established routes between fixed operating locations. Yes, routes are eliminated and added, but in a much less dynamic sense than military deployments. As a result, commercial operations are much more fixed and this translates to different needs. When the routes and locations are well established, it is much more reasonable to leave supporting equipment in place at the airfields. This allows commercial air cargo to be loaded quickly and efficiently from modified airliners. This is important because the profit-oriented enterprises are as interested in efficiency and cost minimizing as the military is in effectiveness. The commercial industry demands speed, minimized fuel consumption, and efficient package handling. The military is concerned about these

things only after assuring its ability to move big, heavy equipment anywhere. The market is simply not very easy to combine¹¹⁸.

4.6.2. Contrast in Design Features

These differences in need translate to physical differences in aircraft design. The military need to operate out of short airfields translates to shallow sweep in the wings and longer chord lengths. These wing features allow heavy aircraft to take off and land at the slower speeds required with shorter runways¹¹⁹. The ability to load to and from flatbed trucks directly means a low fuselage is necessary which in turn leads to mounting the wings high on the fuselage to keep aircraft engines and control surfaces away from potential runway debris. This feature helps the aircraft be able to land in austere locations where debris represents a very real danger. The ability to offload cargo with a minimum of support equipment has typically meant a ramp built into the aircraft and in most cases this meant a T shaped empennage. Most military airlifters have also been outfitted with defensive systems such as chaff or flares. These features come at a cost. High wings mean the fuselage needs reinforcement at the attachment points. This material is redundant to landing gear reinforcements as compared to a low wing aircraft where landing gear attachments and pods are typically built into the wings themselves¹²⁰. The T-tail also represents a weight penalty, as do the defensive systems. Taken together these differences account for a 15-20% fuel penalty as compared to a similar size aircraft with low wings, a conventional tail, no ramp, and no defensive systems¹²¹. The same

¹¹⁸ Bence, 11.

¹¹⁹ Zadalis, 20.

¹²⁰ Zadalis, 20.

¹²¹ Bence, 43.

wing shape that gives an aircraft short runway capability leads to slower cruising speed and increased fuel consumption. The thinner commercial aircraft wings with their increased sweep angle have less induced drag and are more efficient in flight but require longer runways to take-off and land. Adding airdrop capability usually means an additional door for paratroopers, translating to increased weight as well. Being air refuelable brings versatility and longer range but again adds weight and cost.

Because military aircraft have been designed with features to meet their unique requirements, their purchase price, weight, and associated operating costs have made them unattractive to profit minded businesses. Look at the C-17 for example. Using a working figure of \$175M as an unsubsidized purchase price shows a dramatic contrast with the approximate \$120M required for a 747 cargo aircraft. Obviously no commercial carrier is going to spend this much extra to move packages. If you look at the smaller market segment of moving outsized equipment that does not fit in a 747, the return on investment (ROI) picture does not entice market entrants. The An-124 serves this commercial market almost exclusively, and it is estimated at a maximum of \$400M annually. It services this aircraft with approximately 13-18 aircraft. We can see ROI will take quite some time even if we make two fairly ambitious assumptions. One that the C-17 could capture all or the majority of this market and secondarily that it could service it with fewer aircraft because of its greater reliability as compared to that of the An-124. Even at a subsidized price of \$124-128M it remains to be seen if commercial cargo carriers will be interested.

Chapter 5 – Conclusions and Recommendations:

This research effort began with a basic question. *Can the U.S. Air Force team with the U.S. aerospace industry in jointly developing a new aircraft to meet Air Force strategic lift shortfalls and compete in the commercial market for cargo airlifters?* The answer to this question is a qualified “Yes”. Qualified in that it is very unlikely that a dual-purpose aircraft will be designed and developed; the barriers are simply too great. The construct relationship I theorized is probably too weak to overcome these barriers. The commercial market for air cargo is too small, and growth forecasts are too uncertain to entice commercial airliners into contributing funds for aircraft development and market entrance and expansion. Military and commercial demands for air cargo are not the same. These two aggregate customers place different emphasis on effectiveness and efficiency in air cargo movement. They are not asking for the same product and therefore a common airframe will not please them. History is against this idea of dual usage aircraft. Attempts to market military aircraft commercial have failed, and current efforts are encountering significant hurdles and will probably fail for a variety of reasons. Finally, building a new strategic airlifter is not an Air Force priority. Faced with fiscal constraints, it appears the Air Force is content for now to acquire more C-17s and seek funding for C-5 improvements.

However, the answer is still “Yes”. It is possible, and the dramatic steps necessary are at least slightly more probabilistic with Secretary Rumsfeld’s emphasis on taking significant technological leaps with regard to weapon systems as opposed to making incremental adjustments to force structure. There are several “big picture” steps that could be taken to create an atmosphere conducive to C-NXT development. The Air

Force should probable buy the additional C-17s it is seeking to shore up strategic airlift shortfalls in the quickest, most cost effective manner. The Air Force would have to stop throwing good money after bad in funding C-5 improvements. While mission reliability rates will continue to suffer, the C-5, “as is” will still provide a second airframe type. In fact, C-5 reliability rates have typically improved during periods of heavy, continuous usage in supporting contingencies. From a risk versus return perspective, the current state of the C-5 fleet is the least expensive way to maintain a second airframe to support contingencies and even a major theater war. The money that would have been spent on C-5 RERP could be redirected at acquiring a new strategic airlifter, one with an innovative design that takes advantage of one of several future concepts in airframe design. Finally, to truly merge the commercial and military demand, the Air Force would have to change what it has traditionally asked its airlifters to do. While there will probably always be some differences in desired product, the Air Force could do much to narrow the gap. Supporting these “big picture” steps has not been the focus of the paper. Rather, they are personnel opinions arrived at serendipitously during the research. My belief is they are somewhat more tenable in the current atmosphere of change in U.S. National Military Strategy and opinions on military force structure. If these opinions prove correct and a conducive atmosphere is fostered, then I propose the following initiatives.

The Air Force should issue RFPs for dual usage aircraft concept development.

The leading contractor’s efforts need government interest and funding to evolve into a military product. The RFPs should call for both aircraft concept exploration and a business case analysis. The business case should include a civilian market analysis and

how the new aircraft would service it. The contracts to flush out aircraft and business case feasibility would be a low cost first step. More importantly the RFPs and ensuing contracts should give potential manufacturers maximum flexibility to meet broad requirements.

To provide this flexibility, Air Force requirement for strategic airlift should be as generalized as possible, specifying little more than payload, speed, range, and offload capability minimums. It is imperative that contractors be given the maximum flexibility to satisfy potential military and commercial customers. The emphasis should be on having the commercial aerospace industry tell the Air Force the best way to service both markets. It may be a common airframe is possible, or a modular design built around common parts and avionics may be the best answer. In a sense, the baseline capabilities in section 4.1.2 represent this recommended course of action. The need is for the Air Force to let go of as many traditionally held aircraft requirements to narrow the gap between commercial and military airlift needs.

RFPs should be issued to as many different potential manufacturers as possible. Although unconventional designs such as the airship appear less likely to meet Air Force needs, it is important to keep all options open during a concept exploration phase.

It is important that potential aircraft manufacturers recognize the business case is dependent on the combined market and that neither segment is likely to support design and development independently. In return, the Air Force should plan for delivery rates that stem from a mixed production schedule. If the commercial market is going to be serviced, it can not wait for all the Air Force planes to built first. This means the Air Force should begin the design and acquisition effort sooner to allow for a longer

production run and slower delivery schedule. It is possible the design effort could proceed more rapidly than in previous efforts because of improvements in computer design and by a manufacturer's eagerness to launch a commercial variant ahead of competition from Airbus and the like. However a mixed production schedule could easily double the time it takes to fill Air Force orders.

The RFPs should also include a cost-sharing agreement with potential manufacturers. The EELV program demonstrated the risk to manufacturers of relying too heavily on market demand forecast. Therefore the Air Force should be willing to front most of the R&D costs initially. The cost sharing should follow based on the proportion of sales going to commercial airlifters. An arrangement could be made where the military purchase price is initially established based on a planned lot size and subsequently reduced based on R&D refunds that are tied to commercial sales. The military purchase price should also be adjusted down based on increases in the total volume of sales, commercial and military. This concept is not new, contracting for it in advance is. The EELV program has shown both the feasibility and risk of cost sharing R&D. The C-17 program has shown the need to plan for combined sales and volume based price reductions in advance. These guidelines should be included in the RFPs but allow flexibility to submit different cost sharing structures for R&D and production contracts. In general, this arrangement should promote a manufacturer to go after new markets and encourage high volume sales because the Air Force assumes the risk up front, while protecting the tax payer interest by contracting in advance for equitable price adjustments. The up front arrangement will also protect the contractors ability to design an aircraft that is well suited and priced for the commercial market. The C-17 program

has also provided this lesson. Obviously, all the contracted adjustments that drive down government costs will still have to allow for reasonable contractor profits so high volume sales will still be sought after.

When the Air Force evaluates the proposals, it must compare the anticipated cost to that of simply contracting for a purely military aircraft from the beginning. The benefits should include eventually lowered overall R&D cost than the anticipated \$12-16B it would cost for a purely military C-5 replacement. The unit purchase price must also show cost savings. The unit price should approach those of commercial airliners, typically much closer to \$100M than \$200M or approximately two-thirds C-17 unit cost. The R&D cost saving will be the more difficult to negotiate for because unit price should be driven down by commercial market competitive pressures. Finally, lower operating cost should also flow naturally from commercial market pressures. The EELV program is depending on these commercial pressures to ensure high reliability rates. It should show if these pressures are sufficient.

So in the end, C-NXT is possible but not without significant paradigm changes. If the Air Force will narrow the requirements gap and assume the up front financial risk to develop the commercial markets, it can overcome the historical barriers and reap long-term financial benefits while modernizing its airlift fleet.

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