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INSTITUTE FOR DEFENSE ANALYSES

Study on Size and Mix of Airlift Force, Unclassified Synopsis

W.L. Greer, Project Leader
G.M. Koretsky, Deputy Project Leader
J.P. Woolsey, Deputy Project Leader

Draft Final
February 2009
IDA Paper P-4428
Log: H 09-000196/1
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10-S-1672

This work was conducted under contract DASW01-04-C-0003, Task CB-1-2869 for the United States Transportation Command (USTRANSCOM) and the Assistant Deputy Under Secretary of Defense, Transportation Policy. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

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E.A. Adelizzi	B.R. Harmon
H.S. Balaban	J.S. Hong
J. Bracken	S.K. McGee
G.A. Davis	J.A. Schwartz
W C. Devers	D.G. Shiels
B.G. Gladstone	P.B. Strickland
J.M. Gray	R.V. Uy
K.M. Guerrera	L.M. Williams

PREFACE

The National Defense Authorization Act (NDAA) for fiscal year 2008[1] requires that the Secretary of Defense—using a Federally Funded Research and Development Center (FFRDC)—conduct a study on the proper mix of fixed-wing airlift assets. The Office of the Secretary of Defense selected the Institute for Defense Analyses as the FFRDC to conduct the study. The study focuses both on organic military and on commercially available airlift under circumstances that meet the needs of the National Military Strategy. Life-cycle costs for all assets are also estimated.

The study considers a range of issues, to include intertheater and intratheater airlift under major combat conditions, peacetime use, humanitarian aid and crisis support, the Global War on Terrorism, irregular warfare, and homeland security. The study also considers tradeoffs between upgrading C-5s and acquiring new C-17s, the use of additional commercial airlift for military purposes in peacetime and wartime, stopping and resuming the C-17 line, aircraft service life, and dual use of tankers as airlifters. Tradeoffs among C-130s, C-27s, and C-17s in intratheater movement are also considered.

The study team benefited from extensive communications with a number of Government organizations and contractors. Of special assistance were the sponsors at the U.S. Transportation Command (USTRANSCOM) at Scott Air Force Base in Illinois and the Assistant Deputy Under Secretary of Defense for Transportation Policy [ADUSD(TP)]. The USTRANSCOM sponsors, through the Air Mobility Command component, provided details on aircraft characteristics, models for airlift effectiveness assessments, and other data. Most notable in this assistance were Mr. Michael K. Williams (Director, USTRANSCOM Joint Distribution Process Analysis Center), Mr. David L. Merrill (Director, AMC/A9), Mr. Randall G. Johnson, and Mr. Michael S. Barnes (both AMC/A9). The Command also arranged for access to information from the *Mobility Capabilities and Requirements Study (MCRS)*, a concurrent DoD study with

1 National Defense Authorization Act for Fiscal Year 2008, Section 1046, *Study on Size and Mix of Airlift Force*, enacted 28 January 2008.

similar objectives but wider scope. The Office of the Secretary of Defense, Program Analysis and Evaluation (PA&E) made available data from the previous DoD mobility assessment, the *Mobility Capabilities Study (MCS)*. The IDA cost team also held several meetings with the OSD Cost Analysis Improvement Group (CAIG). Finally, the IDA study benefited from several data collection meetings with representatives of the Boeing Company, Lockheed Martin Aeronautics Company, Alenia, and L-3 Communications.

The study team leadership consisted of Dr. William L. Greer (project leader), Dr. Geoffrey M. Koretsky (deputy project leader for operational effectiveness), and Mr. James P. Woolsey III (deputy project leader for cost estimates). Other team members, in alphabetical order, were Dr. Eric A. Adelizzi, Dr. Harold S. Balaban, Dr. Jerome Bracken, Mr. Gregory A. Davis, Mr. Waynard C. Devers, Mr. Brian G. Gladstone, Dr. John M. Gray, Ms. Kristen M. Guerrera, Mr. Bruce R. Harmon, Dr. John S. Hong, Mr. Shaun K. McGee, Mr. Joshua A. Schwartz, Dr. Douglas G. Shiels, Mr. Peter B. Strickland, Dr. Robert V. Uy, and Dr. Laura M. Williams.

The study team gratefully acknowledges expert assistance from the IDA Review Committee: Dr. Steve Warner (Chair and Director, System Evaluation Division), Dr. David L. McNicol (Director, Cost Analysis and Resources Division), Dr. Joseph T. Buontempo, Mr. Stanley A. Horowitz, Gen. Hansford T. Johnson, USAF (ret.), and Dr. John R. Shea.

Ms. Patricia G. Phillips provided expert and extensive editing and oversaw full document preparation. Ms. Toni J. Crow provided professional document preparation support and integration, and Ms. Patricia A. Hatter provided the final publication coordination.

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EXECUTIVE SUMMARY

A. BACKGROUND

Following the National Defense Authorization Act (NDAA) for fiscal year 2008, IDA was tasked by the Department of Defense (DoD) to assess a range of fixed-wing airlift aircraft issues. These assessments included analyzing the cost-effectiveness of a number of alternative force mixes of intertheater and intratheater airlift in the context of peacetime use, humanitarian aid and crisis support, homeland security, and major combat operations (MCOs). More specifically, we considered alternative airlift fleets that contained tradeoffs between installing C-5 upgrades and acquiring new C-17s, tradeoffs among various tactical lift forces (C-130s, C-27s, and C-17s), the use of commercial airlift for military purposes in peacetime and wartime, and dual use of tankers including the yet-to-be-selected KC-X as airlifters. Assessments included operational as well as life-cycle cost estimates for all alternative airlift forces. Finally, we assessed airlift aircraft service life and addressed the cost and time issues associated with stopping and resuming the C-17 line.

The study began with the airlift Program of Record (POR) [a force with 205 C-17s, 59 C-5As, 52 C-5Ms, 269 C-130Hs, and 120 C-130Js, plus tankers and Civil Reserve Air Fleet (CRAF) commercial airlifters available in various call-up stages]. Alternative forces were generated for cost and effectiveness analysis by changing these numbers and adding additional C-27Js for intratheater movement, in addition to the 78 C-27Js already programmed for quick-response joint operations.

B. FINDINGS

The main questions identified in the NDAA and the findings of this study are summarized here.

What are the airlift requirements?

The requirements for single or two concurrent MCO demands were based on those used in the *Mobility Capabilities Study (MCS)* from 2005. For the non-MCO demands, however, this study was able to take advantage of early versions of the more current Steady State Security Posture scenarios in order to derive demands outside the major theaters of war. Together, these constituted the requirements assumed for airlift.

Does the currently programmed fleet meet the requirements?

We found that the POR fleet is adequate in meeting the benchmark requirements identified in the MCS for moderate acceptable risk. Three different computer models used in this study produced somewhat different results for deliveries. The most pessimistic results matched MCS benchmark results, and with the other models, lower force levels than programmed also met the MCS benchmark level.

What programmatic alternatives might also be considered and how well do they meet these requirements? What are the life-cycle costs of these alternatives?

The study considered 36 alternative mixes and sizes and compared them both in cost and effectiveness with the POR. Figure ES-1 illustrates the relative capabilities of several alternative fleets that differ only in numbers or types of strategic lift aircraft (i.e., numbers and types of C-5s and C-17s). Results are shown relative to the capabilities that met the MCS moderate risk delivery demands for cargo. Similar analyses were performed for alternative fleets that differ in the numbers and types of intratheater airlift aircraft.

The study identified several relatively inexpensive ways of generating higher capability from existing forces, without procuring additional strategic airlifters beyond those already programmed. These include the following: use C-5s at Emergency Wartime Planning levels (adds 2-4 percent, depending on whether the extra weight carried is fuel or cargo); transport with CRAF whatever oversize cargo that CRAF can carry, in addition to bulk cargo on pallets, in order to free up organic airlifters for the larger and heavier cargo (adds 10 percent); use host nation airlifters to the maximum extent possible (4 or 5 percent); and make use of tankers not involved in tanking missions to carry cargo in theater (adds about 4 percent). Use of these capabilities could also allow for a smaller strategic fleet that still meets MCS benchmark delivery requirements. Thus, our analyses using the MCR moderate risk benchmark suggest that an upper bound on the number of required strategic airlifters is 316, indicated by the two yellow boxes in Figure ES-1.

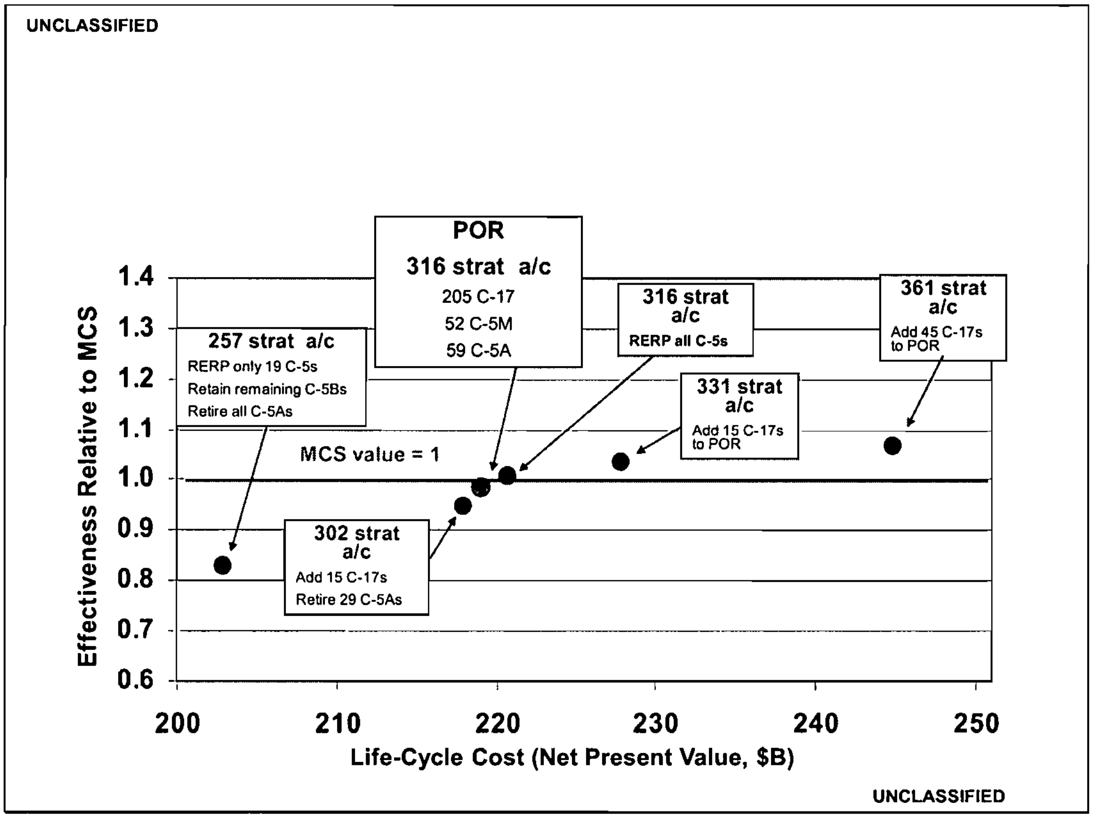

Figure ES-1. Comparison of Cost-Effectiveness for Several Airlift Force Alternatives in Two Concurrent MCOs

A small amount of additional capability could be achieved if all C-5s are converted through Reliability Enhancement and Re-engining Program (RERP) to C-5Ms. This alternative is at comparable life-cycle cost to that of the POR; near-term acquisition costs are almost repaid over time in later years by reduced operating and support (O&S) costs.

Traditionally, airlift and other force requirements are set by wartime demands (i.e., MCOs), not steady-state peacetime demands. Airlift is heavily used in both. If the appropriate acquisition planning scenarios are not MCOs but are high tempo non-MCO operations such as in Iraq and Afghanistan today, we find that some C-5As could be retired to save O&S costs with no loss in capability for those missions. This is illustrated in Figure ES-2. Moreover, a more cost-effective fleet than the POR is one that, in addition to having fewer C-5As, uses the smaller C-27Js instead of the larger

C-130Js. These observations are driven by the need for numerous, geographically separated, but small loads during non-MCO operations, as currently anticipated in DoD planning scenarios.

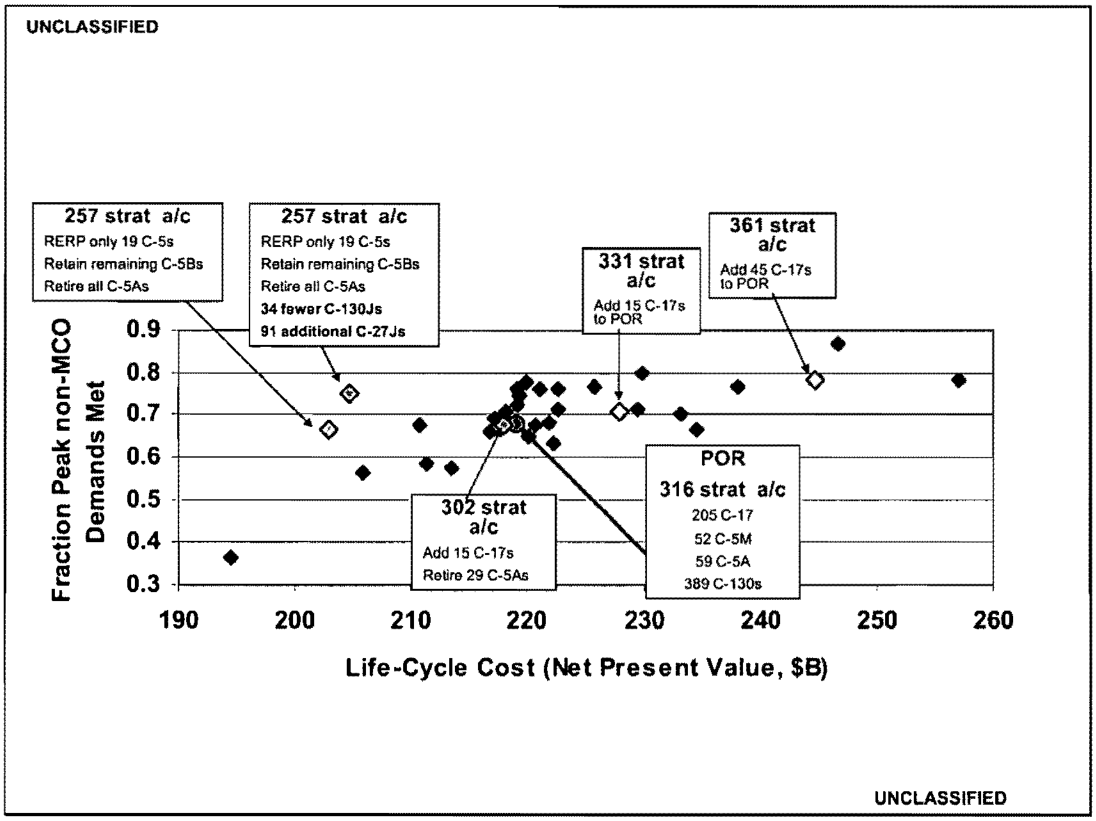

Figure ES-2. Comparison of Cost-Effectiveness for Several Airlift Force Alternatives in Airlift-Stressing non-MCO Operations

What are the cost and other implications for stopping production of the C-17 line and then restarting it later, if needed?

Our assessment of the C-17 line shutdown and restart is that continued production, even at low rates, is expensive relative to restart costs. Moreover, under the scenarios and other assumptions considered in this study, additional C-17s were not needed to meet the MCS moderate-acceptable-risk delivery rates used as a benchmark by the analyses conducted here. We also found that retiring C-5As to release funds to buy and operate more C-17s is not cost-effective.

How do the alternatives differ in service life?

We projected aircraft service lifetimes based on planned flying hour and flying severity conditions. Excursions to the planned operating conditions were also examined. Our findings are that all airlifters except the C-130E have structural lifetimes that are beyond 2030. Virtually all the C-5s and C-17s have lifetimes beyond 2040. The C-130E is near its structural life limit and extensions to that life are not cost-effective by our analyses.

How well do CRAF aircraft contribute to wartime deliveries? At what specific organic fleet inventory would it impede the ability of CRAF participants to remain a viable augmentation option?

We included CRAF in the simulated airlift deliveries and find them to be useful for passenger and cargo delivery, especially in MCOs if CRAF aircraft are allowed to carry some oversize cargo. Nonetheless, fewer than half of the CRAF aircraft available for Stage III (during two MCOs) are actually used, so current incentives provide more than enough CRAF for wartime demands. We also note that restructuring airline fleets should not significantly influence CRAF availability but may reduce numbers of charter passenger aircraft. A larger organic military fleet of airlift aircraft does not challenge passenger CRAF viability but could influence cargo CRAF because the organic fleet would be expected to shoulder a larger amount of the cargo movement required in peacetime. However, the cargo CRAF participates in a strong economic sector, does not strongly depend on CRAF in contrast to other commercial revenues, and is not likely to be significantly hurt by likely changes in DoD force levels.

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INTRODUCTION AND SUMMARY

INTRODUCTION & SUMMARY

A. DIRECTIVE

The National Defense Authorization Act (NDAA) for fiscal year (FY) 2008 required that a study be conducted by the Secretary of Defense on alternatives for the future force mix of fixed-wing airlift aircraft.

The NDAA tasked the Department of Defense (DoD) to use a Federally Funded Research and Development Center (FFRDC) to carry out this study and the Office of the Secretary of Defense (OSD) selected the Institute for Defense Analyses (IDA). Subsequent funding and sponsorship for the task was assumed by the U.S. Transportation Command (USTRANSCOM), with co-sponsorship from the Assistant Deputy Under Secretary of Defense for Transportation Policy [ADUSD(TP)] in the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)].

IDA was asked to consider a range of issues, to include intertheater airlift, intratheater airlift, peacetime use, humanitarian aid and crisis support, homeland security, and major combat operations (MCOs). IDA was also tasked to consider tradeoffs between various programmed or proposed C-5 upgrades and acquiring new C-17s, tradeoffs among various tactical lift forces, the use of commercial airlift for military purposes in peacetime and wartime, stopping and resuming the C-17 line, aircraft service life, and dual use of tankers as airlifters. The study examined time periods out to 2024, under circumstances that meet the needs of the National Military Strategy. Life-cycle costs (LCC) for all systems considered were also estimated, in accord with NDAA tasking.

B. STUDY OBJECTIVE AND MOTIVATION

1. Objective

The purpose of this study was to address the airlift issues of cost and effectiveness that were identified in the FY 2008 NDAA, summarized in the following section. The full text of the relevant NDAA directive is located in Appendix A.

2. Motivation

This study was motivated by concerns about aligning airlift capabilities and requirements in the war on terrorism and in potential future major conflicts. Airlift capabilities and requirements have changed from those envisioned by earlier recent assessments.

For one thing, 25 additional C-17s have been programmed beyond the 180 aircraft addressed in the DoD-directed *Mobility Capabilities Study (MCS)* that was published in 2005. In addition, peacetime use of airlift has changed from the number used in the MCS with growing support for ongoing global operations.

At the time of the MCS in 2004-2005, it was envisioned that all C-5s would be upgraded and re-engined to C-5Ms. This process upgrades C-5s via the Avionics Modernization Program (AMP) and the Reliability Enhancement and Re-engining Program (RERP). After the Nunn-McCurdy cost breach in 2007, the C-5M program was restructured to provide AMP and RERP for C-5B/Cs only, while the older C-5As, now more than 40 years old, are to be upgraded with AMP but not RERP. The NDAA asked whether this new programmed approach is cost-effective, whether all C-5s should be upgraded through RERP, or whether additional C-17s should be acquired with the possible concurrent retirement of older C-5s. As a part of this consideration, the NDAA also directed that the service life remaining in current airlifters be determined.

One continuing issue is the effect of closing and re-opening the C-17 production line. Differences exist between closing cost estimates made by the C-17 manufacturer and the Air Force. The NDAA asked that this issue be addressed as well.

The new KC-X aerial refueler (yet to be selected in competition to replace KC-135s) may also be useable in airlift roles, an activity that could conceivably meet some airlift demands now envisioned for DoD-owned military and commercial airlift.

Moreover, can commercial aircraft in the Civil Reserve Air Fleet (CRAF) contribute more than currently planned? And would a larger military aircraft fleet interfere with the peacetime incentives for CRAF participation? The NDAA directed that those issues be addressed.

Finally, the issues of intratheater and intertheater lift have become more complex and intertwined with the advent of the Joint Cargo Aircraft (JCA), a dedicated intratheater airlifter, and the increasing use of C-17s for both intertheater and intratheater movement to and within Afghanistan and Iraq. The JCA has become the C-27J and will be referred to by that name henceforth. Twenty-four C-27Js are programmed for the Air Force and 54 for the Army. Also, the Air Force is planning to buy more C-130Js and retire C-130Es. The NDAA asked that this balance among C-130s, C-27Js, and C-17s be addressed from a cost-effectiveness perspective.

C. STUDY ISSUES

To summarize, the main questions specified in the NDAA were:

- What are the airlift requirements that meet the National Military Strategy in the time period from 2012 to 2024? These requirements involve the full range of military activities from peacetime through major combat, to include movement within the continental United States (CONUS), between theaters, and within foreign theaters of war.
- How well does the currently programmed fleet meet the above requirements?
- What programmatic restructurings (alternatives) might be considered and how well do they meet these requirements? These alternatives could involve different mixes of programmed forces or different mixes of DoD-owned and contracted CRAF forces.
- Based on these considerations, what is the appropriate mix of C-17s, C-5s, C-130s, and C-27Js?
- What are the life-cycle costs of these alternatives?
- What role might the future KC-X tanker play in meeting airlift requirements?
- How well do CRAF aircraft contribute to meeting delivery requirements across the spectrum of conflict? At what fleet inventory levels for each type of DoD aircraft, to include air-refueling aircraft used in the airlift role, would the size of the DoD force—and the resulting peacetime operating tempo needed to maintain readiness—reduce day-to-day DoD demands for CRAF

aircraft, thus potentially undermining the financial viability of CRAF/potentially participants and thereby reducing CRAF augmentation capabilities in wartime?

- How do the aircraft differ in service life, availability, and other important airlift metrics?
- What are the costs and other implications for stopping production of the C-17 line and then restarting it later?

D. APPROACH

The analytical approach entailed a parallel assessment of the operational effectiveness of alternative airlifters and airlift fleets and their costs. It also involved a consideration of service life projections, the effect of C-17 aircraft production line stops and restarts, the effect of tankers being used for airlift, and the effect of CRAF. Some parts of these assessments were, by necessity, linked. Others were treated by separate assessments.

1. Alternatives

Alternatives were selected to span the decision space indicated by the NDAA questions. These are divided into two parts: those alternative force structures that trade off C-17s and C-5s for long-distance transport and those alternative structures that trade off C-130s, C-27Js, and C-17s for tactical range transport. Additional alternatives combine elements of both.

All alternatives were excursions from the Program of Record (POR). This fleet consists of 205 C-17s, 59 C-5Ms, 52 C-5As, 389 combat-delivery C-130H/Js, and 78 C-27Js (24 USAF and 54 Army). This POR fleet can be augmented by various stages of CRAF call-up.

Alternatives that trade off C-17s and C-5s for strategic airlift missions included:

- Maintaining (POR) RERP
  - Add C-17s to POR
  - Retire some or all C-5As, add C-17s
  - Retire some or all C-5As, no additional C-17s
- Increasing RERP

  - RERP all C-5A/B/Cs
  - RERP all C-5A/B/Cs, add C-17s
- Decreasing RERP: RERP only 19 C-5Bs to C-5Ms.
  - Retain remaining C-5A/B/Cs
  - Retain remaining C-5A/B/Cs, add C-17s
  - Retain remaining C-5B/Cs, retire remaining C-5As
  - Retire remaining C-5A/B/Cs, add C-17s

Alternatives that trade off C-130s, C-27Js, and C-17s in tactical airlift missions included:

- Retiring C-130H1s (47) and replacing with
  - C-130Js
  - C-17s for intratheater
  - No replacement
- Retiring C-130H1s (47) and additional C-130H2s (50) and replacing with
  - C-130Js
  - C-17s for intratheater
  - No replacement
- Procuring 34 fewer C-130Js than planned and replacing with
  - C-27Js
  - C-17s for intratheater
  - Service Life Extension Program (SLEP) for C-130Es
  - No replacement.

A number of alternatives combined features of both strategic and tactical restructurings. These involve changes in force structure of all fixed-wing airlift aircraft at the same time.

A graphical depiction of the range of values assumed for increases or decreases in airlifters relative to the POR is in Figure 1.

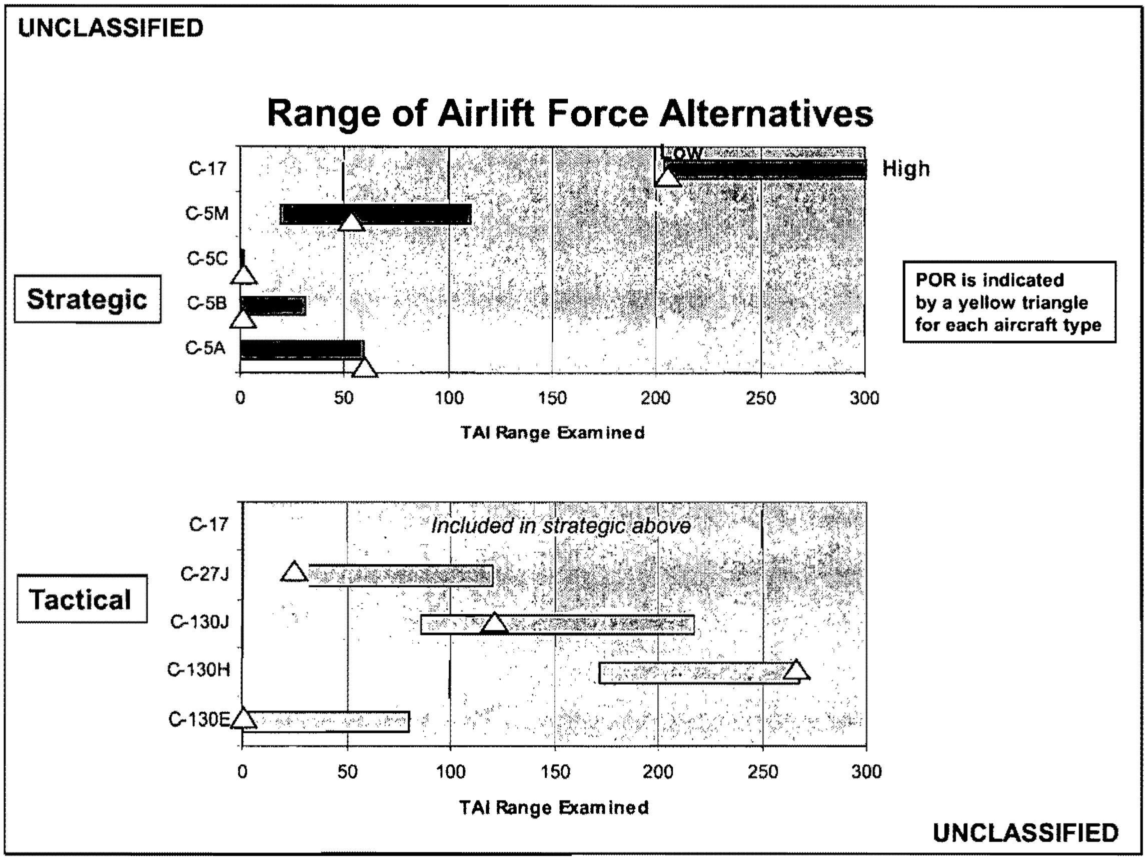

Figure 1. Range of Values Used in Alternatives for Airlift Mix Comparisons

2. Operational Effectiveness

IDA used three computational models to determine how rapidly airlift forces can deliver military units and personnel to theaters and move them to tactical positions within the theaters. The primary measure of operational effectiveness is throughput (tons delivered to required destinations at designated times).

Each model requires the input of aircraft and payload characteristics; the type, amounts, and delivery dates required for cargo and passengers in specific scenarios [i.e., the Time-Phased Force and Deployment Data (TPFDD); routes to be flown; airbases to be used; and crew and fuel constraints, among others]. IDA selected AMOS,[1] the model

1 Air Mobility Operations Simulation; see Appendix C for more detail on this model.

used by the Air Mobility Command (AMC) as the primary model, but also used NRMO,[2] an in-house optimization model to provide parallel checks and balances and to determine some of the assumptions used in AMOS, such as the best allotment of C-17s between intertheater and intratheater movement and the best routes to use. In addition, IDA developed a new model, called DASM,[3] for further validation and to provide a means for examining issues that the other two models were not well-equipped to do—i.e., the effect of en-route failure rates on deliveries.

The models provide insight into the rates of delivery of all types of cargo and passengers. The delivery of outsize and oversize cargo turned out to be the discriminator among all the alternatives. All alternatives met MCS benchmark delivery goals for bulk cargo and passengers, but differed in how fast they delivered out- and oversize cargo.

3. Costs

IDA estimated life-cycle costs for all alternative aircraft and force mixes. Procurement cost estimates addressed all elements of production and initial support and relied on existing and proven methods, tailored to each of the subject aircraft. Operating and support (O&S) costs were estimated according to the work breakdown structure defined by the OSD Cost Analysis Improvement Group (CAIG) and were developed using historical data and IDA methods previously developed for estimating O&S cost. For many of the subject aircraft, IDA used recent work as a foundation for the cost analysis. Where required, IDA obtained contractor proprietary information.

Many of the aircraft in question are fairly mature with a stable cost history. These include the C-17, the C-130J, and the C-5 AMP programs. Other programs have been the subject of recent detailed cost estimating efforts by IDA or others. The C-5A, C-5B, C-130E, and C-130H programs fall into this category, with stable O&S cost histories. Our analysis took full advantage of existing cost estimates and historical data.

The program with the greatest uncertainty from a cost estimating standpoint was the C-27J. This is a new procurement program, and no actual production cost data are available on which an estimate might be based. While the first lots are under a firm

2 Naval Postgraduate School/RAND Mobility Optimizer; see Appendix D for more detail on this model.

3 Discrete Airlift Simulation Model; see Appendix E for more detail on this model.

fixed-price contract, the force sizes examined in this study go well beyond the lot sizes covered by this contract and its options. O&S cost estimates for the C-27J are affected by uncertainties in the reliability of the system, maintenance concept, basing plans, and flying hours per year. Some of these factors might also affect the C-130J estimate. Although cost data exist on which to base prices for the C-130J, estimates of its future costs could be affected by changes to expected sales for foreign customers and to other changes to the business base in Lockheed Martin facilities where it is manufactured.

Given the large number of alternatives considered and the time available to complete the study, it was not feasible to develop detailed budget quality cost estimates for each aircraft type. Instead, the goal was to characterize important tradeoffs, to identify significant differences between costs of various aircraft types, and to identify assumptions that had important influence on overall costs. The resulting cost analyses contain more uncertainty than detailed estimates would, particularly for aircraft that are not yet in production or in service. This should be taken into account when interpreting the results, particularly when the cost differences between alternatives are relatively small.

4. Service Life, Production Lines

The FY 2008 NDAA directed that an assessment be made of how current, ongoing, high-tempo operations affect aircraft service life. It specifically calls for such an assessment for the C-5A/B/C/M and C-17 aircraft and for C-130E/H/J and JCA intratheater airlift aircraft. This assessment was performed for individual aircraft.

The C-17 production line may have to be stopped or paused if no further funding is provided. An analysis was performed on consequences (cost, delays) of aircraft production line stop and restart, such as was experienced for the C-5 line. The approach taken is to estimate costs associated with four different decisions and two different end states. The four decisions are (1) stop the C-17 line and, if needed, restart; (2) retain a warm line that maintains a capability to restart, if needed; (3) continue a low rate of production of five C-17s per year; and (4) maintain full C-17 production of 15 per year. The two end states assessed are (1) no additional C-17s, or (2) 90 additional C-17s.

5. CRAF

The CRAF program is a voluntary program in which civil air carriers contract with the Government for peacetime defense business in exchange for making available a specified number of aircraft to augment DoD airlift during a crisis or war. The CRAF aircraft carry both passengers and cargo. This study examined the use of CRAF to meet requirements, including an assessment of the effect of organic military airlift growth on the viability of the CRAF program. Use is made of prior IDA studies in this area for USTRANSCOM.

6. Integration

The life-cycle cost and effectiveness assessments are synthesized in two-dimensional displays of effectiveness versus cost to show how alternatives compare in both regards. Passenger delivery was measured as numbers of passengers (PAX) delivered over time to each destination. Cargo delivery was also measured and represented in terms of tonnage delivered. This cargo was further characterized as bulk, oversize (trucks, typically), and outsize (largest or heaviest vehicles, typically). The out- and oversize cargo delivery during two concurrent MCOs turned out to be the most sensitive measure of key effectiveness among the force alternatives identified.

A comparison of cost and effectiveness requires a different key measure of effectiveness during non-MCO operations, such as those conducted currently in Iraq and Afghanistan. In that case, with no concurrent MCO demands, the key measure used is the number of peak demand non-MCO operations that can be fulfilled simultaneously.

7. Use of Other Studies

IDA made significant use of recent studies and analyses for DoD. The primary study used was the MCS whose cargo and PAX delivery demands expressed in the TPFDD and other considerations helped orient this study. The study also made use of the Steady-State Security Posture (SSSP) scenarios and early analyses available from the *Mobility Capabilities and Requirements Study 2016 (MCRS-16)*. An early version of the *Joint Future Theater Airlift Capabilities Analysis* was also used, as was the RAND *USAF Intratheater Airlift Fleet Mix Analysis*. Information taken from other studies include several IDA studies: the *Independent Analysis of the C-5 Modernization Study*, the *Analysis of Alternatives for Out- and Oversize Strategic Airlift*, the *C-130 AMP AoA*, the

Intratheater Airlift Analysis, and, most recently, assessments of alternatives for the C-130 AMP and C-5 RERP Nunn-McCurdy breach certification processes and the *Civil Reserve Air Fleet: Economics and Strategy Study.*

E. FINDINGS

The main questions addressed in the NDAA and the findings of this study are summarized throughout this section.

> *What are the airlift requirements that meet the National Military Strategy in the time period from 2012 to 2024? These requirements involve the full range of military activities from peacetime through major combat, to include movement within CONUS, between theaters, and within foreign theaters of war.*

Requirements were based on MCOs identified in the MCS of 2005 as well as non-MCO scenarios from more recent studies. Since the ongoing MCRS-16 study was still developing its scenarios and TPFDDs when this study was nearing completion, the requirements for MCOs are based on the TPFDDs of the MCS from 2005. For the non-MCO demands, however, this study was able to take advantage of the early versions of the more current SSSP scenarios in order to derive demands outside the major theaters of war. Together, these constituted the requirements assumed for airlift.

> *How well does the currently programmed fleet meet the above requirements?*

Since we are looking at future scenarios, we interpret the question to refer to the Program of Record. We find the POR fleet adequate to meet the requirements identified in the MCS for moderate acceptable risk. The three different computer models used in this study produced somewhat different results for deliveries, though even the most pessimistic model results (AMOS) matched MCS benchmark results. With the other models (NRMO and DASM), lower force levels than programmed also met the MCS benchmark requirements.

> *What programmatic restructurings (alternatives) might also be considered and how well do they meet these requirements? These alternatives could involve different mixes of programmed forces or different mixes of organic and CRAF forces. What are the life-cycle costs of these alternatives?*

A total of 36 alternative mixes and sizes of airlift fleets were compared in cost and effectiveness with the POR. Some key findings follow.

When comparing delivery for MCOs, the more strategic lift the better, although the POR seems to provide enough, if the MCS moderate-acceptable-risk delivery rates are used as a benchmark. Results of cost and effectiveness are illustrated for six of the alternatives in Figure 2. Results are shown relative to accepted MCS deliveries at selected critical wartime dates.

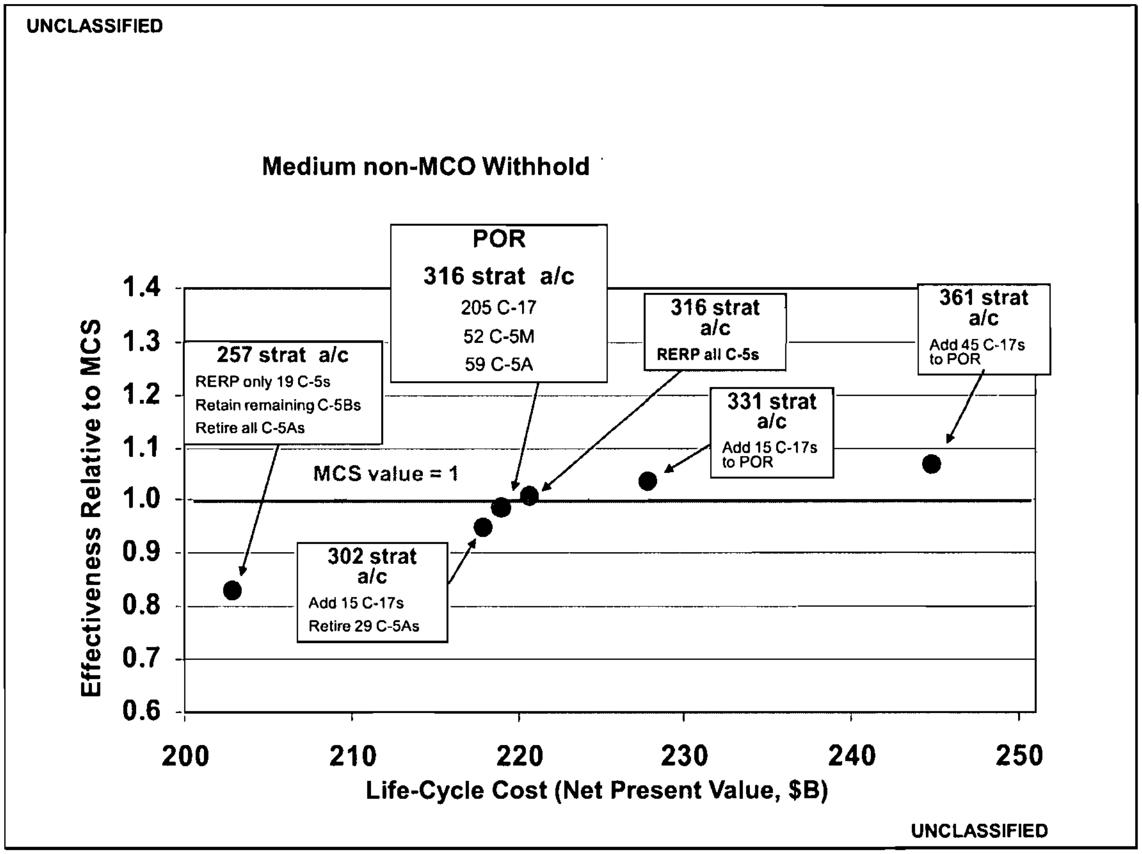

Figure 2. Comparison of Cost-Effectiveness for Several Airlift Force Alternatives in Two Concurrent MCOs

The study identified several relatively inexpensive ways of generating higher capability from existing forces, without adding any additional strategic airlifters beyond those already programmed. In fact, if used, forces with fewer strategic airlifters and lower costs than the 316 in the POR could provide effectiveness equal to that obtained in the MCS. These include the following and are illustrated in Figure 3.

1. Use C-5s at Emergency Wartime Planning levels, using AMC-approved wartime levels higher than used in analyses for MCOs. The results shown in Figure 3 assume the extra weight carried is fuel; if extra cargo can be carried instead, the percent improvement increases even more.
2. Transport with CRAF whatever oversize cargo that CRAF can carry, in addition to bulk cargo on pallets, in order to free up military airlifters for the larger and heavier cargo.
3. Make use of host nation airlifters to the maximum extent possible.
4. Make use of tankers not involved in tanking missions to carry cargo in theater.

UNCLASSIFIED

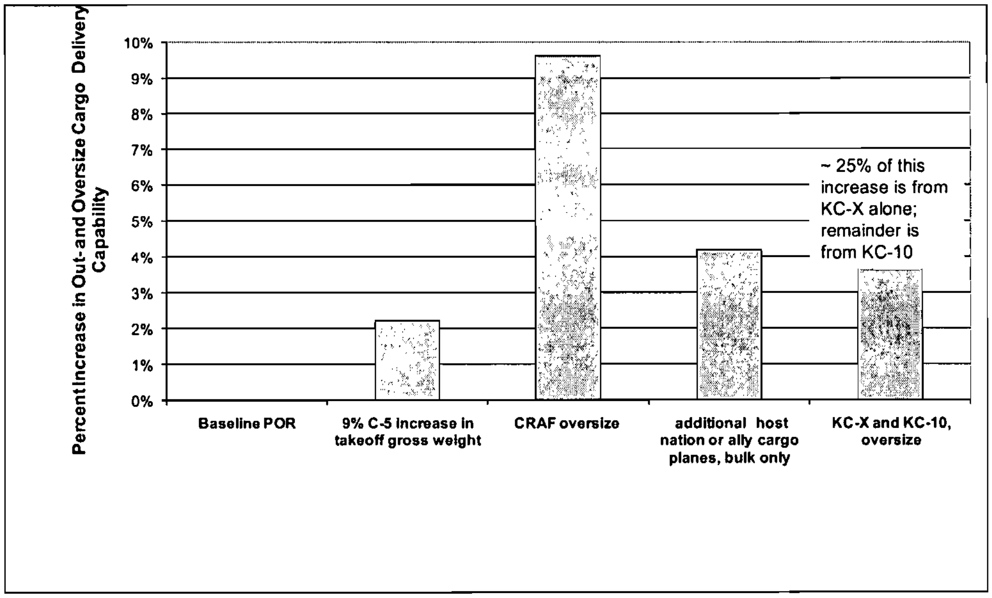

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Figure 3. Excursion Analyses

A small amount of additional capability is available if all C-5s are converted through RERP to C-5Ms. This alternative is at comparable life-cycle cost to that of the POR; near-term acquisition costs are almost repaid in later years by reduced O&S costs.

If the MCRS-16 shows that additional out- and oversize cargo airlift is needed beyond that attained by the POR, in addition to the above measures, more C-17s might be required if MCRS-16 delivery analyses are similar to those produced in this study with the AMOS model.

Traditionally, airlift and other force requirements are set by wartime demands (i.e., MCOs), not steady-state peacetime demands. Airlift is heavily used in both situations. If the appropriate acquisition planning scenarios are not MCOs but are high-tempo non-MCO operations such as in Iraq and Afghanistan today, we find that some C-5As could be retired to save O&S costs with no loss in capability for those missions. Moreover, a more cost-effective fleet than the POR is one that, in addition to having fewer C-5As, uses the smaller C-27Js instead of the larger C-130Js. These observations are driven by the need for numerous, geographically separated, but small loads during non-MCO operations, as currently anticipated by DoD planning scenarios. These findings are illustrated in Figure 4. All alternatives are shown, with the selected ones already noted explicitly identified. Note that the most cost-effective forces for non-MCOs are forces with fewer than 316 strategic aircraft that apply RERP to only 19 C-5s, retain the remaining C-5Bs without RERP, retire some C-5As, and reduce the C-130J buy by 34 aircraft while buying 91 additional C-27Js.

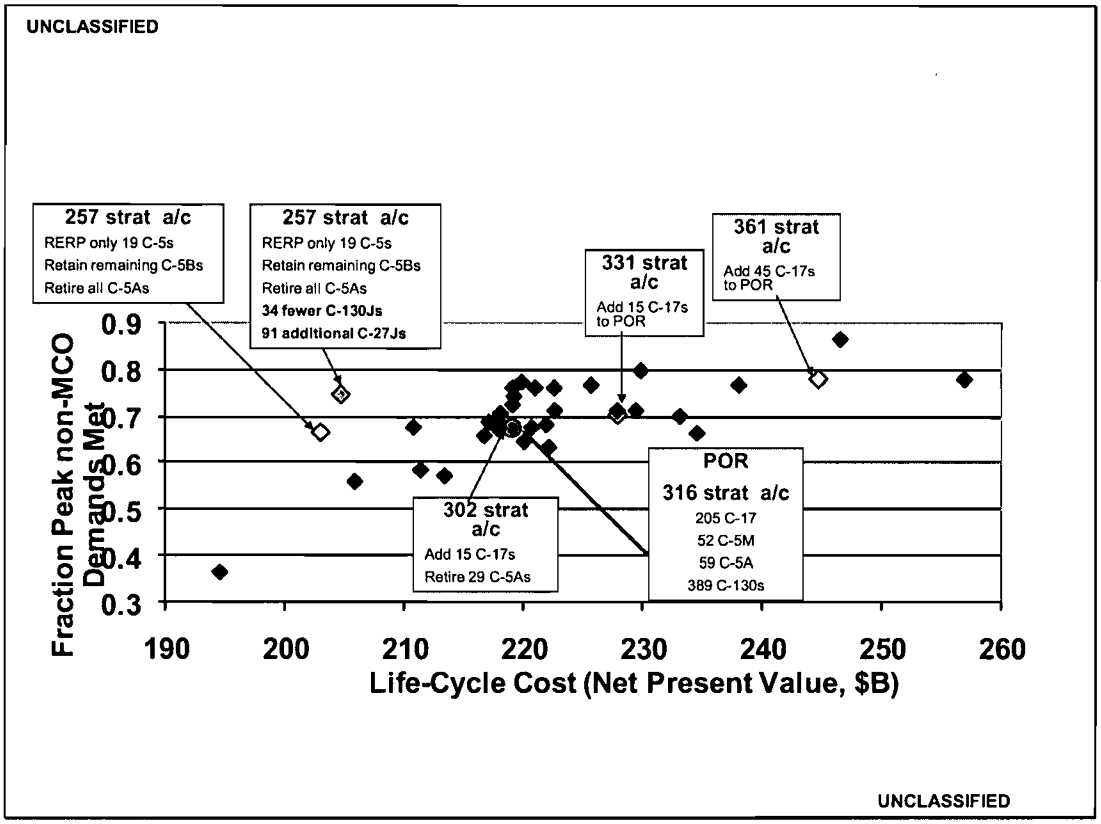

Figure 4. Comparison of Cost-Effectiveness for Several Airlift Force Alternatives in Airlift-Stressing non-MCO Operations

For MCOs, from a cost-effectiveness perspective, little difference exists among the tactical lift alternatives: C-130Js, C-17s, and C-27Js. However, for non-MCO activities, the demand for larger numbers of smaller payloads favors fleets composed of more C-27Js and fewer C-130Js. Once again, this finding is driven by the specific cargo and PAX movements called for in DoD planning scenarios for MCO and non-MCO activities.

What are the cost and other implications for stopping production of the C-17 line and then restarting it later, if needed?

Our assessment of C-17 line shutdown and restart is that continued production, even at low rates, is expensive relative to restart costs. Moreover, under the scenarios and other assumptions considered in this study, additional C-17s were not needed to meet the MCS moderate-acceptable-risk delivery rates used as a benchmark.

We also found that retiring C-5As to free funds to buy and operate more C-17s would result in a less capable force at comparable overall cost and so would not be cost-effective.

How do the alternatives differ in service life, availability, and other important airlift metrics?

We projected aircraft lifetimes based on flying hour and flying severity assumptions that included programmed, actual, and fleet-managed flying conditions (to spread the burden over all aircraft equitably). Our findings are that

1. C-5s and C-17s all have structural lives at or beyond 2040 (exceptions are the two C-5Cs that have a structural life expectancy of 2025-2030 at current use rates).
2. For one C-17, the structural life could be reached as soon as 2035 if this aircraft with the largest number of hours continues to fly at that high rate and high severity into the future.
3. Most C-130Es are near structural life limits already (although life could be extended), C-130Hs could last until nearly 2030, and C-130Js would last until nearly 2050.

How well do CRAF aircraft contribute to wartime deliveries? At what specific fleet inventory for each organic aircraft, to include air-refueling aircraft used in the airlift role, would it impede the ability of CRAF participants to remain a viable augmentation option?

We included CRAF in the simulated airlift deliveries and find the following:

1. Airlift models only use less than half of CRAF available in Stage III, so current programs are more than adequate.
2. Previous IDA studies[4] on this issue have found that

- Restructuring of airline fleets should not significantly influence CRAF availability but may reduce numbers of charter passenger aircraft.
- A larger organic military fleet does not challenge passenger CRAF viability but could influence cargo CRAF because the organic fleet could shoulder a larger amount of the cargo movement required in peacetime. However, the cargo CRAF participates in a strong economic sector, does not strongly

4 *Civil Reserve Air Fleet: Economics and Strategy*, IDA Paper P-4373, August 2008.

depend on CRAF vice commercial revenues, and is not likely to be significantly hurt by this.

F. EXCURSIONS

The study identified a number of additional analytic excursions for possible consideration in the MCRS-16 study. These are detailed in the Main Report but fall into the following general categories:

1. Anti-access scenarios in which theater airbases are at risk and ones that are more distant are used for transloading cargo and passengers.
2. Excursions in Maximum on Ground (MOG) constraints to airfields in theater or en route there.
3. Impact of future fuel cost uncertainty on life-cycle costs of alternative fleets.
4. Impact of changes to TPFDD details.

G. ORGANIZATION OF THIS REPORT

This report is organized in the following fashion.

The main report in Volume I[5] develops the main issues, approaches, and findings in greater detail than summarized here. The appendixes in Volume II[5] provide even greater detail on specific topics:

Appendix A: National Defense Authorization Act for Fiscal Year 2008

Appendix B: Major Combat Operations (MCOs) Overview

Appendix C: The Air Mobility Operations Simulation (AMOS)

Appendix D: Naval Postgraduate School/RAND Mobility Optimizer (NRMO)

Appendix E: The Discrete Airlift Simulation Model (DASM)

Appendix F: Airlifter Service Life Assessment

Appendix G: Non-MCO Analysis

Appendix H: Examination of Tankers in the Airlift Role

5 *Study on Size and Mix of Airlift Force:* Vols I (Main Report) and II (Appendixes), IDA Paper P-4425, February 2009, SECRET//NOFORN.

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APPENDIX A
NATIONAL DEFENSE AUTHORIZATION ACT
FOR FISCAL YEAR

Appendix A
NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2008

SEC. 1046. STUDY ON SIZE AND MIX OF AIRLIFT FORCE.

(a) Study Required- The Secretary of Defense shall conduct a requirements-based study on alternatives for the proper size and mix of fixed-wing intratheater and intertheater airlift assets to meet the National Military Strategy for each of the following timeframes: fiscal year 2012, 2018, and 2024. The study shall--

(1) focus on organic and commercially programmed airlift capabilities;

(2) analyze the full-spectrum lifecycle costs of the various alternatives for organic models of each of the following aircraft: C-5A/B/C/M, C-17A, KC-X, KC-10, KC-135R, C-130E/H/J, Joint Cargo Aircraft; and

(3) incorporate the augmentation capability, viability, and feasibility of the Civil Reserve Air Fleet during activation stages I, II, and III.

(b) Use of FFRDC- The Secretary shall select, to carry out the study required by subsection (a), a federally funded research and development center that has experience and expertise in conducting similar studies.

(c) Study Plan- The study required by subsection (a) shall be carried out under a study plan. The study plan shall be developed as follows:

(1) The center selected under subsection (b) shall develop the study plan and shall, not later than 60 days after the date of enactment of this Act, submit the study plan to the congressional defense committees, the Secretary, and the Comptroller General of the United States.

(2) The Comptroller General shall review the study plan to determine whether it is complete and objective, and whether it has any flaws or weaknesses in scope or methodology, and shall, not later than 30 days after receiving the study plan, submit to the Secretary and the center a report that contains the results of that review and provides any recommendations that the Comptroller General considers appropriate for improvements to the study plan.

(3) The center shall modify the study plan to incorporate the recommendations under paragraph (2) and shall, not later than 45 days after receiving that report, submit to the Secretary and the congressional defense committees a report on those modifications. The report shall describe each modification and, if the

modifications do not incorporate one or more of the recommendations, shall explain the reasons for not doing so.

(d) Elements of Study Plan- The study plan required by subsection (c) shall address, at minimum, the following:

(1) A description of lift requirements and operating profiles for airlift aircraft required to meet the National Military Strategy, including assumptions regarding the following:

(A) Current and future military combat and support missions.

(B) The planned force structure growth of the military services.

(C) Potential changes in lift requirements, including the deployment of the Future Combat Systems by the Army.

(D) New capability in airlift to be provided by the KC(X) aircraft and the expected utilization of such capability, including its use in intratheater lift.

(E) The utilization of intertheater lift aircraft in intratheater combat mission support roles.

(F) The availability and application of Civil Reserve Air Fleet assets in future military scenarios.

(G) Air mobility requirements associated with the Global Rebasing Initiative of the Department of Defense.

(H) Air mobility requirements in support of worldwide peacekeeping and humanitarian missions.

(I) Air mobility requirements in support of homeland defense and national emergencies.

(J) The viability and capability of the Civil Reserve Air Fleet to augment organic forces in both friendly and hostile environments.

(K) An assessment of the Civil Reserve Air Fleet to adequately augment the organic fleet as it relates to commercial inventory management restructuring in response to future commercial markets, streamlining of operations, efficiency measures, or downsizing of the participant.

(2) An evaluation of the state of the current airlift fleet of the Air Force, including assessments of the following:

(A) The extent to which the increased use of airlift aircraft in on-going operations is affecting the programmed service life of the aircraft of that fleet.

(B) The adequacy of the current airlift force, including whether or not a minimum of 299 strategic airlift aircraft for the Air Force is sufficient to support future expeditionary combat and non-combat missions, as well as domestic and training mission demands consistent with the requirements of meeting the National Military Strategy.

(C) The optimal mix of C-5 and C-17 aircraft for the strategic airlift fleet of the Air Force, to include the following:

(i) The cost-effectiveness of modernizing various iterations of the C-5A and C-5B/C aircraft fleet versus procuring additional C-17 aircraft.

(ii) The military capability, operational availability, usefulness, and service life of the C-5A/B/C/M aircraft and the C-17 aircraft. Such an assessment shall examine appropriate metrics, such as aircraft availability rates, departure rates, and mission capable rates, in each of the following cases:

(I) Completion of the Avionics Modernization Program and the Reliability Enhancement and Re-engining Program.

(II) Partial completion of the Avionics Modernization Program and the Reliability Enhancement and Re-engining Program, with partial completion of either such program being considered the point at which the continued execution of each program is no longer supported by the cost-effectiveness analysis.

(iii) At what specific fleet inventory for each organic aircraft, to include air refueling aircraft used in the airlift role, would it impede the ability of Civil Reserve Air Fleet participants to remain a viable augmentation option.

(D) An analysis and assessment of the lessons that may be learned from the experience of the Air Force in restarting the production line for the C-5 aircraft after having closed the line for several years, and recommendations for the actions that the Department of Defense should take to ensure that the production line for the C-17 aircraft could be restarted if necessary, including--

(i) an analysis of the methods that were used and costs that were incurred in closing and re-opening the production line for the C-5 aircraft;

(ii) an assessment of the methods and actions that should be employed and the expected costs and risks of closing and re-opening the production line for the C-17 aircraft in view of that experience.

Such analysis and assessment should deal with issues such as production work force, production facilities, tooling, industrial base suppliers, contractor logistics support versus organic maintenance, and diminished manufacturing sources.

(E) Assessing the military capability, operational availability, usefulness, service life and optimal mix of intra-theater airlift aircraft, to include--

(i) the cost-effectiveness of procuring the Joint Cargo Aircraft versus procuring additional C-130J or refurbishing C-130E/H platforms to meet intra-theater airlift requirements of the combatant commander and component commands; and

(ii) the cost-effectiveness of procuring additional C-17 aircraft versus procuring additional C-130J platforms or refurbishing C-130E/H platforms to meet intra-theater airlift requirements of the combatant commander and component commands.

(3) Each analysis required by paragraph (2) shall include--

(A) a description of the assumptions and sensitivity analysis utilized in the study regarding aircraft performances and cargo loading factors; and

(B) a comprehensive statement of the data and assumptions utilized in making the program life cycle cost estimates and a comparison of cost and risk associated with the optimally mixed fleet of airlift aircraft versus the program of record airlift aircraft fleet.

(e) Utilization of Other Studies- The study required by subsection (a) shall build upon the results of the 2005 Mobility Capabilities Studies, the on-going Intra-theater Airlift Fleet Mix Analysis, the Intra-theater Lift Capabilities Study, the Joint Future Theater Airlift Capabilities Analysis, and other appropriate studies and analyses, such as Fleet Viability Board Reports or special aircraft assessments. The study shall also include any testing data collected on modernization, recapitalization, and upgrade efforts of current organic aircraft.

(f) Collaboration With United States Transportation Command- In conducting the study required by subsection (a) and preparing the report required by subsection (c)(3), the center shall collaborate with the commander of the United States Transportation Command.

(g) Collaboration With Cost Analysis Improvement Group- In conducting the study required by subsection (a) and constructing the analysis required by subsection (a)(2), the center shall collaborate with the Cost Analysis Improvement Group of the Department of Defense.

(h) Report- Not later than January 10, 2009, the center selected under subsection (b) shall submit to the Secretary and the congressional defense committees a report on the study required by subsection (a). The report shall be submitted in unclassified form, but shall include a classified annex.

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APPENDIX B
GLOSSARY

Appendix B
GLOSSARY

ACAT	acquisition category
ACCA	Advanced Composite Cargo Aircraft
ADUSD(TP)	Assistant Deputy Under Secretary of Defense for Transportation Policy
AE	aeromedical evacuation
AFI	Air Force Instruction
AFPAM	Air Force Pamphlet
AFR	Air Force Regulation
AFRC	Air Force Reserve Command
AFSAA	Air Force Studies and Analysis
AFTOC	Air Force Total Ownership Cost
AFTTP	Air Force Tactics, Techniques, and Procedures
AJACS	Advanced Joint Air Combat System
ALD	Available to Load Data
AMC	Air Mobility Command
AMMP	Air Mobility Master Plan
AMOS	Air Mobility Operations Simulation
AMP	Avionics Modernization Program
ANG	Air National Guard
APOD	Air Port of Debarkation
APOE	Air Port of Embarkation
APU	Auxiliary Power Unit
AR	air refueling
ARCP	airfield and aerial refueling control point
ASIP	Aircraft Structural Integrity Program
BAI	back-up aircraft inventory
BF	below flyaway

BLS	Bureau of Labor Statistics
BOS	base operating services
C2	command and control
CAIG	Cost Analysis Improvement Group
CBR	California bearing ratio
CBRNE	chemical, biological, radiological, nuclear, and high-energy explosive
CC	Conventional Campaign
CDD	Capabilities Description Document; Capability Development Document
CJCS	Chairman of the Joint Chiefs of Staff
CLS	contractor logistics support
CMO	civil military operation
COCOM	combatant commander
CONOP	concept of operation
CONUS	continental United States
CORE	Cost Oriented Resource Estimating
CPD	Capability Production Document
CPLEX	linear program solver
CRAF	Civil Reserve Air Fleet
CWB	Center Wing Box
DADTA	durability and damage tolerance assessment
DASM	Discrete Airlift Simulation Model
DDG	guided missile destroyer
DESC	Defense Energy Support Center
DLR	Depot Level Reparable
DMZ	demilitarized zone
DoD	Department of Defense
DPS	Defense Planning Scenario
EAD	Earliest Arrival Date
EAGL	Efficient Affordable Global Lift
EBH	Equivalent Baseline Hour

ENAF	Emergency Nuclear Airlift Force
EPA	equitable price adjustment
ER	Extended Range
EW/GCI	early warning/ground-controlled intercept
EWP	Emergency War Planning
FCA	Future Cargo Aircraft
FCS	Future Combat System
FDO	flexible deterrent option
FFRDC	Federally Funded Research and Development Center
FH	flight hour
FMOB	full mobility
FMS	foreign military sales
FOB	forward operating base
FOL	forward operating location
FSMP	force structural maintenance plan
FY	fiscal year
GAMS	General Algebraic Modeling System
GAO	Government Accountability Office
GATES	Global Air Transport Execution System (USTRANSCOM database)
GATM	Global Air Traffic Management
GDF	Guidance for Development of the Force
GDSS	Global Deployment Support System (USTRANSCOM database)
GEF	Guidance for Employment of the Force
GWOT	Global War on Terrorism
IATP	Individual Aircraft Tracking Program
ICS	interim contractor support
ID	identification
IDA	Institute for Defense Analyses
IDIQ	Indefinite Delivery/Indefinite Quantity
IOC	Initial Operational Capability
ISB	Intermediate Staging Base
ISP	Integrated Security Posture

IW	Irregular Warfare
JACC/CP	Joint Airborne Communications Center/Command Post
JCA	Joint Cargo Aircraft
JFTL	Joint Future Theater Lift
JSGS	Joint Service Guide Specification
LCC	life cycle cost
LM	Lockheed Martin
LMA	Lockheed Martin Aeronautics
LP	linear program
MASS	Mobility Analysis Support System
MCO	Major Combat Operation
MCRS-16	Mobility Capabilities and Requirements Study 2016
MCS	Mobility Capabilities Study
MDAP	major defense acquisition program
MDS	model design series
MEFPAK	Manpower and Equipment Force Packaging
MEL	minimal equipment listing
MIL-HNDBK	Military Handbook
MIL-STD	Military Standard
MMH/FH	Maintenance Man-Hours per Flying Hour
MOG	Maximum on Ground
MPFD	Mobility Planning Factors Database
MSFD	Multi-Service Force Deployment
MTBF	mean time between failures
MTM/D	million ton miles per day
MYP	multi-year procurement
NBC	narrow body cargo
NDAA	National Defense Authorization Act
NEACDS	Naval Emergency Air Cargo Delivery System
NEO	noncombatant evacuation operation
NMC	non-Mission Capable

NPS	Naval Postgraduate School
NPV	net present value
NRMO	Naval Postgraduate School/ RAND Mobility Optimizer
O&A	over and above
O&O	out- and over-size
O&S	operating and support
OEF	Operation Enduring Freedom
OGC	other Government costs
OIF	Operation Iraqi Freedom
OPTEMPO	operational tempo
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
PA&E	Program Analysis and Evaluation
PAI	Primary Aircraft Inventory
PAX/Pax	passengers
PB	President's Budget
PDM	Programmed Depot Maintenance
PMAI	Primary Mission Aircraft Inventory
PMOB	partial mobility
PNAF	Primary Nuclear Airlift Force
POAI	primary other aircraft inventory
POR	Program of Record
PTAI	primary training aircraft inventory
QDR	Quadrennial Defense Review
QRF	Quick Reaction Force
RDD	required delivery date
RDT&E	research, development, test, and evaluation
REMIS	Reliability and Maintainability Information System
RERP	Reliability Enhancement and Re-engining Program

RFP	request for proposal
ROK	Republic of Korea
RRF	Rapid Reaction Force
SAAM	Special Assignment Airlift Mission
SAM	surface-to-air missile
SBA	Strategic Brigade Airdrop
SDD	System Design and Development
SDTE	Swiftly Defeat the Efforts
SecDef	Secretary of Defense
SET	Strategic Environment Timeline
SF	severity factor
SLEP	Service Life Extension Program
SOCOM	Special Operations Command
SOF	Special Operations Force
SOH	Strait of Hormuz
SOLL	Special Operations Low-Level
SPO	system program office
SRD	System Requirements Document
SSSP	Steady-State Security Posture
SWA	Southwest Asia
SYP	single-year procurement
TAC	tactical
TAI	Total Aircraft Inventory
TBM	tactical ballistic missile
TOGW	take-off gross weight
TPFDD	Time-Phased Force and Deployment Data
TY	then year
UDLM	Unscheduled Depot Level Maintenance
UID	unique identification
ULDM	unscheduled depot-level maintenance
USAF	U.S. Air Force
USAFRICOM	U.S. Africa Command

USNORTHCOM	U.S. Northern Command
USTRANSCOM	U.S. Transpiration Command
UTC	Unit Type Code
WBC	wide body cargo
WBP	wide body passenger
WFD	widespread fatigue damage
WMD	weapons of mass destruction
WR-ALC	Warner Robins Air Logistics Center

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