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Analysis of Alternatives (AoA) for KC-135 Recapitalization

Executive Summary

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Prepared for the United States Air Force

RAND PROJECT AIR FORCE

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Preface

In a February 24, 2004, memorandum to Secretary of the Air Force James Roche, Michael W. Wynne, Acting Under Secretary of Defense, Acquisition, Technology and Logistics, directed that an Analysis of Alternatives (AoA) for KC-135 Recapitalization be undertaken. He also specified that a federally funded research and development center or other independent agency conduct the study and that a Senior Steering Group, chaired by Dr. Glenn F. Lamartin, Director of Defense Systems in the Office of the Under Secretary of Defense, Acquisition, Technology and Logistics, be established to "guide and direct the work of the AoA." A subsequent memorandum, dated May 25, 2004, changed the original completion date of July 2005 to November 2004. At the first Senior Steering Group meeting, held on May 28, 2004, RAND Project AIR FORCE was chosen to conduct the AoA. The completion date was subsequently extended until December 2004.

A draft report of some 1,500 pages was delivered to the Senior Steering Group in December 2004. At a subsequent Senior Steering Group meeting on January 25, 2005, it was decided that additional work should be done on the AoA. In a memorandum dated February 28, 2005, to Secretary Roche, Mr. Wynne directed that additional work be done on the AoA. A revised draft report was delivered to the Senior Steering Group in August 2005. Between August and December 2005, this draft then underwent a Sufficiency Review conducted by the Office of the Secretary of Defense, Program Analysis and Evaluation. At the same time, it underwent a methodology and objectivity review by the Institute for Defense Analyses. These two reviews led to additional sensitivity analyses. A third-round draft final report, of some 1,900 pages, was delivered to the Senior Steering Group in December 2005.

RAND Project AIR FORCE

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Contents

Foreword

Consistent with the Department of Defense Acquisition directive, on February 24, 2004, the Acting Under Secretary of Defense, Acquisition, Technology and Logistics (USD(AT&L)), directed the Air Force to conduct an Analysis of Alternatives (AoA) for the recapitalization of the KC-135 aerial refueling tanker. In his guidance, he defined the set of alternatives and the basic assumptions for the analysis. He also established a Senior Steering Group, chaired by the Director of Defense Systems in USD(AT&L), to oversee the AoA process. The Senior Steering Group membership was drawn from a wide number of offices in the Office of the Secretary of Defense, Air Force, Navy, Marine Corps, Army, and combatant commands. The Senior Steering Group began planning for the effort, drafting and coordinating a study plan, and took measures to ensure both widespread participation in the study process and extensive independent review of its analysis and findings.

On May 25, 2004, the Acting USD(AT&L) directed that the AoA schedule be accelerated from its original due date of July 2005 to November 2004. Consistent with congressional direction that a federally funded research and development center (FFRDC) or other independent agency conduct the study, on May 28, 2004, the Senior Steering Group approved the selection of RAND Project AIR FORCE (PAF) to perform the AoA.

Working-level integrated product teams—with representatives from Senior Steering Group organizations—met almost weekly to work with RAND PAF in formulating, implementing, and validating the research throughout the process. These meetings ensured that RAND could receive data and resolve any concerns quickly and that the department could understand the analysis and ask questions as the AoA progressed.

After RAND PAF submitted its AoA report to the Senior Steering Group in December 2004, Acting USD(AT&L) determined additional time was warranted for additional analysis. Additional sensitivity analysis did not result in any material changes to the findings of December 2004. It did, however, greatly increase the Defense Department's confidence in the findings, as the additional work showed that they were robust to a wide set of alternative projections of future conditions. The final results were submitted in December 2005, and this Executive Summary describes them. A final report of some 1,900 pages was delivered in March 2006.

Two distinct independent review efforts of this AoA were conducted. In accordance with the acquisition directive, the Program Analysis and Evaluation (PA&E) directorate of the Office of the Secretary of Defense conducted a Sufficiency Review of the AoA. Additionally, the Institute for Defense Analyses (IDA), also an FFRDC, conducted an objectivity and methodology review as a second check. PA&E and IDA analysts gained early insights on their review activities during the research process, since they participated in the working-level integrated product teams. They began their final comprehensive reviews when a draft final report was submitted in August 2005. PA&E found that the AoA met the Sufficiency Review standards and criteria, and IDA found that the AoA was objective and conducted with sound methodology.

The Defense Department has high confidence that the results of this AoA, reported in this Executive Summary, are robust and provide a sound basis for KC-135 recapitalization.

Diane M. Wright
Deputy Director, Air Warfare
OUSD(AT&L)

Executive Summary

Introduction

Recapitalization of the KC-135 aerial refueling tanker is very important for U.S. national security and has a significant impact on the U.S. national budget. Aerial refueling tankers are a critical part of U.S. military and national security strategy. Without them, air power cannot be deployed to overseas theaters in a timely way; it cannot be operated at militarily required distances from overseas bases; U.S.-based strategic air forces cannot execute overseas missions; and homeland defense air patrols would lose substantial effectiveness. The KC-135 constitutes the bulk of the current tanker force, embodying about 80 percent of U.S. aerial refueling capability. The KC-135 fleet is nearing 50 years of age, and it has exhibited some technical difficulties and increased costs of operation. KC-135 recapitalization also has major budgetary implications. The total cost of both operating the KC-135s until they are retired and acquiring and operating their replacements is in the $200 billion range over the next half century.

This AoA addressed the cost-effectiveness of a wide range of alternatives for KC-135 recapitalization, including a large number of replacement systems and replacement schedules. In this AoA, *the most "cost-effective" alternative* means precisely *the alternative whose effectiveness meets the military aerial refueling requirement at the lowest cost*. The AoA primarily used requirements from the Defense Department's Mobility Capabilities Study, which was completed in 2005.

History and Organization of the AoA

In a February 24, 2004, memorandum to Secretary of the Air Force James Roche, Michael W. Wynne, then Acting Under Secretary of Defense, Acquisition, Technology and Logistics (USD(AT&L)), directed that an AoA for KC-135 Recapitalization be undertaken. He also specified that a federally funded research and development center or other independent agency conduct the study and that a Senior Steering Group, chaired by Dr. Glenn F. Lamartin, Director of Defense Systems under USD(AT&L), be established to "guide and direct the work of the AoA."[1] A

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[1] The Senior Steering Group included members from the following organizations: Office of the Under Secretary of Defense, Acquisition, Technology and Logistics, Defense Systems; Office of the Under Secretary of Defense, Acquisition, Technology, and Logistics, Acquisition Resources and Analysis; Office of the Secretary of Defense, Director of Operational Test and Evaluation; Office of the Secretary of Defense, Director of Program Analysis and Evaluation; Office of the Assistant Secretary of Defense, Network and Information Integration; Joint Chiefs of Staff, Director for Force Structure, Resources, and Assessment; U.S. Army; U.S. Navy; U.S. Air Force; U.S. Marine Corps; and U.S. Transportation Command.

The Senior Steering Group also included observers from the following organizations: Air Mobility Command; Office of the Secretary of Defense, Comptroller; Office of the Secretary of Defense, Office of General Counsel; Office of the subsequent memorandum, dated May 25, 2004, changed the original deadline of July 2005 to November 2004. The deadline was subsequently extended by the Senior Steering Group to December 2004. At its first meeting, held on May 28, 2004, the Senior Steering Group approved RAND Project AIR FORCE (PAF) to conduct the AoA.[2]

At this first meeting, the Senior Steering Group also directed that an Integrating Integrated Product Team be established under the co-chairmanship of Diane M. Wright, Deputy Director of Defense Systems (Air Warfare) in OUSD(AT&L) and Col Paul Stipe, Deputy Director of Global Reach Programs in the Air Force Secretariat (SAF/AQQ), to provide day-to-day guidance for the AoA.[3] Col John Brunderman, Chief of the Mobility Division in the Directorate of Global Reach Programs (SAF/AQQM), subsequently replaced Colonel Stipe.

At its first meeting on June 7, 2004, the Integrating Integrated Product Team adopted the organizational structure illustrated in Figure 1.

For this AoA, the Senior Steering Group provided overall guidance, and the Integrating Integrated Product Team provided day-to-day guidance. RAND Project AIR FORCE led the research effort. The Alternatives, Effectiveness, and Cost Integrated Product Teams assisted RAND by reviewing the overall research approach and results and by providing many specific inputs on the assessment of the performance and cost characteristics of the alternatives.[4]

Secretary of Defense, Legislative Affairs; Office of Management and Budget; and Office of the Assistant Secretary of the Air Force for Acquisition.

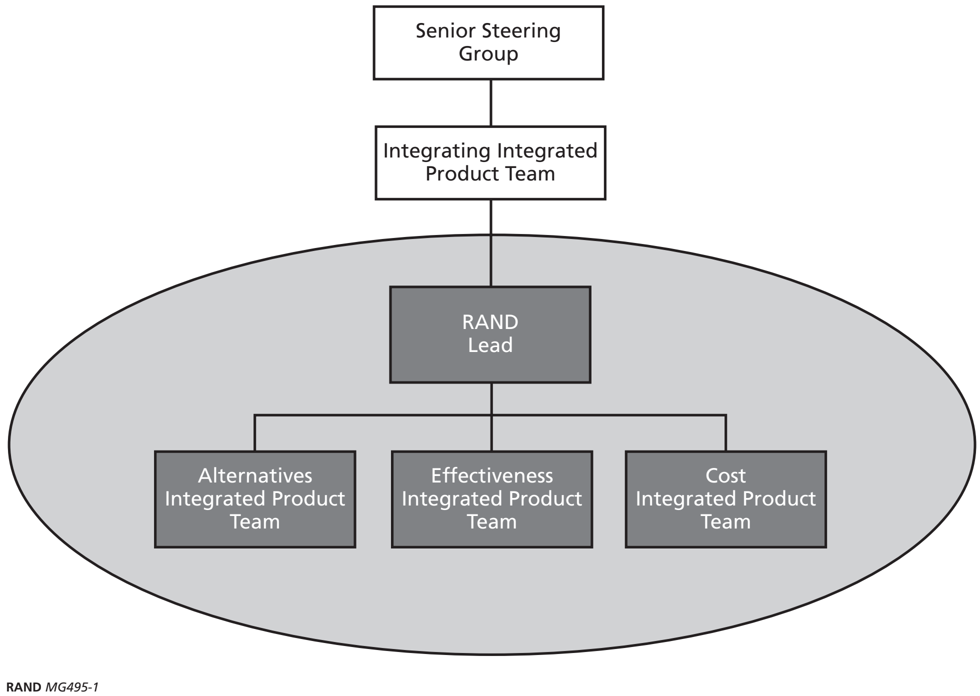
[2] Before May 28, 2004, a decision had not been made regarding who would carry out the study. Therefore, no one from the RAND Corporation attended this meeting.

[3] The Integrating Integrated Product Team included members from the following organizations: Office of the Under Secretary of Defense, Acquisition, Technology and Logistics; Air Mobility Command; U.S. Transportation Command; Joint Chiefs of Staff, Director for Logistics; Joint Chiefs of Staff, Director for Force Structure, Resources, and Assessment; Office of the Assistant Secretary of the Air Force for Financial Management; Air Force Cost Analysis Agency; Office of the Assistant Secretary of the Air Force for Acquisition; Deputy Chief of Staff of the Air Force, Installations and Logistics; Deputy Chief of Staff of the Air Force, Warfighting Integration; Deputy Chief of Staff of the Air Force, Air and Space Operations; Deputy Chief of Staff of the Air Force, Plans and Programs; Air Force Studies and Analysis Agency; Office of Aerospace Studies, Air Force Materiel Command; Office of the Secretary of Defense, Director of Operational Test and Evaluation; Office of the Secretary of Defense, Comptroller; Office of the Under Secretary of Defense, Acquisition, Technology and Logistics, Defense Industrial Policy; U.S. Army; U.S. Navy; Office of the Secretary of Defense, Director of Program Analysis and Evaluation; RAND Corporation; and Institute for Defense Analyses.

[4] The Alternatives Integrated Product Team included members from the following organizations: Air Force Research Laboratory; Aeronautical Systems Center, Air Force Materiel Command; Air Mobility Command; U.S. Transportation Command; Office of the Secretary of Defense, Director of Program Analysis and Evaluation; Joint Chiefs of Staff, Director for Force Structure, Resources, and Assessment; Office of Aerospace Studies, Air Force Materiel Command; Office of the Assistant Secretary of the Air Force for Acquisition; Office of the Assistant Secretary of the Air Force for Financial Management; Deputy Chief of Staff of the Air Force, Installations and Logistics; Deputy Chief of Staff of the Air Force, Warfighting Integration; Deputy Chief of Staff of the Air Force, Air and Space Operations; Deputy Chief of Staff of the Air Force, Plans and Programs; U.S. Navy; U.S. Army; Air Combat Command; and Office of the Under Secretary of Defense, Acquisition, Technology and Logistics.

The Effectiveness Integrated Product Team included members from the following organizations: Air Mobility Command; U.S. Transportation Command; Office of the Secretary of Defense, Director of Program Analysis and Evaluation; Joint Chiefs of Staff, Director for Force Structure, Resources, and Assessment; Office of Aerospace Studies, Air Force Materiel Command; Office of the Assistant Secretary of the Air Force for Acquisition; Office of the Assistant Secretary of the Air Force for Financial Management; Deputy Chief of Staff of the Air Force, Installations and Logistics; Deputy Chief of Staff of the Air Force, Warfighting Integration; Deputy Chief of Staff of the Air Force, Air and Space Operations; Deputy Chief of Staff of the Air Force, Plans and Programs; U.S. Navy; U.S. Army; Air Combat Command; and Office of the Under Secretary of Defense, Acquisition, Technology and Logistics.

Figure 1
Organizational Structure of the AoA



In addition to the meeting on May 28, 2004, the Senior Steering Group met six more times between June 2004 and July 2005. There were 36 Integrating Integrated Product Team meetings during that period, approximately three per month. During the same period, the Alternatives and Effectiveness Integrated Product Teams each met four times, and the Cost Integrated Product Team five times.

The RAND research team had extensive additional interaction with many persons and organizations cognizant of tanker policy issues. In particular, the heads of the Alternatives and Effectiveness Integrated Product Teams held regular meetings with Office of the Secretary of Defense, Program Analysis and Evaluation analysts to discuss analytic issues. USD(AT&L) contracted with the Institute for Defense Analyses to review the methodology and objectivity of the AoA while it was under way. This review process began in July 2004, with the participation

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The Cost Integrated Product Teams included members from the following organizations: Air Mobility Command; Aeronautical Systems Center, Air Force Materiel Command; Air Force Cost Analysis Agency; Headquarters, Air Force Materiel Command; Office of the Assistant Secretary of the Air Force for Acquisition; Deputy Chief of Staff of the Air Force, Air and Space Operations; Air Force Studies and Analysis Agency; Oklahoma City Air Logistics Center; Office of Aerospace Studies, Air Force Materiel Command; Office of the Under Secretary of Defense, Acquisition, Technology and Logistics, Defense, Industrial Policy; U.S. Army; U.S. Navy; Office of the Secretary of Defense, Director of Program Analysis and Evaluation; and Office of the Under Secretary of Defense, Acquisition, Technology and Logistics.

of the Institute for Defense Analyses in the integrated product teams, and ended with a detailed evaluation of the final RAND analysis.

The RAND research team had extensive interactions with representatives of industry and other organizations. In response to a series of requests for data, Boeing, the European Aeronautic Defence and Space Company, Lockheed Martin, and Northrop Grumman proposed many of the specific alternatives assessed in the AoA. The RAND research team had several meetings with personnel from each of these companies covering a broad range of topics, including preferred aircraft configurations, performance data, and cost data. The RAND research team received data from, and discussed issues with, representatives of the engine manufacturers, General Electric and Pratt & Whitney.

The Air Force's Aeronautical Systems Center, part of Air Force Materiel Command, proposed three new-design tankers that were included in the AoA and made significant contributions to the AoA's technical assessments of all the alternatives. The Air Mobility Command's Studies and Analysis Division (AMC/A59) made significant contributions to the AoA's effectiveness analysis, especially in the detailed modeling of tanker operations.

The RAND research team discussed issues relating to used-aircraft acquisition and conversion and commercial sources of refueling within the continental United States with staff from the following companies and organizations:

- United Kingdom Ministry of Defence and AirTanker (regarding the Future Strategic Tanker Aircraft program and the associated Private Finance Initiative)
- Omega
- Evergreen (regarding acquisition and conversion of used aircraft and the Global Airtanker Service, in which they were then a partner)
- Federal Express
- Atlas
- International Air Systems
- Consolidated Air Support Systems.

The AoA was completed within the prescribed six months, and a draft final report was delivered to the Senior Steering Group in December 2004. After staff review of the analysis, the Senior Steering Group decided at its meeting on January 25, 2005, that there was time for important additional work to be done on the AoA. The additional work would provide depth that was not possible given the initial accelerated time frame of the AoA. In a memorandum dated February 28, 2005, to Secretary Roche, Mr. Wynne directed that the additional work be done. A new draft final report that included the additional work was delivered to the Senior Steering Group in August 2005. Between August and December 2005, the Office of the Secretary of Defense, Program Analysis and Evaluation, completed its Sufficiency Review of the AoA. At the same time, the Institute for Defense Analyses completed its independent review of the AoA's methodology and objectivity. These two reviews led to some additional analysis during the review period, primarily in the form of additional sensitivity analyses. A final draft report that included the additional analysis requested during the review period was delivered to the Senior Steering Group in December 2005.

This executive summary presents the overall findings of the AoA. Specific data supporting the findings, much of which is proprietary or otherwise restricted, is contained in the 16-volume, 1,900-page final report, delivered in March 2006, which is not available to the general public.

Research Questions and Approach

In the AoA for KC-135 Recapitalization, two questions were analyzed:

1. What is the most cost-effective alternative for recapitalizing the KC-135 fleet? (Here, an "alternative" can be a fleet consisting of a single type of aircraft or a fleet consisting of more than one type.) Again, in this AoA, *the most "cost-effective" alternative* means precisely *the alternative whose effectiveness meets the aerial refueling requirement at the lowest cost*.
2. When should the recapitalization assets be acquired?

The answer to the second question is logically subsequent to the answer to the first, because the *cost* of the recapitalization is one of the determinants of the most cost-effective *timing* of the recapitalization.

Assessing the Cost-Effectiveness of Alternatives

Addressing the first question of the AoA, the RAND research team assessed *the cost-effectiveness in the aerial refueling role* of a large number of alternatives. The alternatives are

- newly purchased commercial-derivative tankers based on the Airbus 321, 330, 340, and 380 airliners and the Boeing 737, 767, 787, 777, and 747 airliners
- used commercial-derivative tankers based on the Airbus 310 and 330 airliners and on the Boeing 757, 767, DC-10, MD-11, and 747 airliners
- newly purchased military-derivative tankers based on the Lockheed Martin C-130J, the European Aeronautic Defence and Space Company A400M, and the Boeing C-17 military transport aircraft
- new-design tankers proposed by Boeing, Lockheed Martin, Northrop Grumman, and the Aeronautical Systems Center, which would be developed as entirely new aircraft in the future, as opposed to being derivatives of existing aircraft

- unmanned aerial vehicles as tankers
- stealthy tankers that would have improved survivability in contested airspace relative to commercial-derivative tankers
- fleets containing mixes of the above
- commercial sources for refueling within the continental United States.

Aircraft in the AoA were categorized into the following size categories:

- small—less than 300,000 pounds maximum gross takeoff weight
- medium—300,000 to 550,000 pounds maximum gross takeoff weight
- large—550,000 to 1,000,000 pounds maximum gross takeoff weight
- very large—greater than 1,000,000 pounds maximum gross takeoff weight.

This taxonomy was devised during the AoA as a useful tool for characterizing and summarizing results; these are not formal categories used by the aviation industry.

The RAND research team assessed the aerial refueling cost-effectiveness of each of the alternatives in up to four different configurations. The configuration differences are the aircraft's electronic survivability in a nuclear environment and their cargo- and passenger-carrying capability.

The primary metric for assessing any given alternative in the AoA is its cost-effectiveness in the aerial refueling role. The measure of the cost-effectiveness of each alternative is the cost of a fleet of that alternative that is sized to meet any given aerial refueling requirement, and the most cost-effective alternative is the one that meets the requirement at the lowest cost. Thus, the cost-effectiveness of the alternatives depends on the nature—the size and composition—of the specific requirement used in the analysis.

Another way of saying this is that the AoA took an "equal-effectiveness, varying-cost" approach to cost-effectiveness assessment. In the analysis, each alternative fleet was sized to meet the specified requirement, and the cost of that fleet was then estimated. The alternative whose fleet incurred the lowest cost while meeting the requirement is the most cost-effective for that requirement. Varying the size and composition of the requirement in the sensitivity analyses also made it possible to identify which alternatives are *robust* across different possible future requirements—that is, which have superior cost-effectiveness across the range of requirements considered.

The AoA primarily used various requirements cases from the Department of Defense Mobility Capabilities Study, which was completed in 2005.

The requirement is defined by the amount of fuel that aerial refuelers must supply, at specific times and locations, in a set of mission categories in future military scenarios. The mission categories include homeland defense, deployment of military aircraft to theater locations, employment of military aircraft in theater, strike missions from outside any given theater, and support for additional contingencies that may arise. The amount of fuel that must be supplied and its distribution over time and across geographical space are determined by the mission profiles of the receiver aircraft—the fighter, attack, bomber, intelligence, surveillance, reconnaissance, and transport aircraft that require aerial refueling to carry out their missions. This AoA included the fuel offload demands of U.S. Air Force, U.S. Navy, U.S. Marine Corps, and allied air forces' military aircraft. The specific refueling modes of these aircraft—some are refueled from a tanker boom into a receiver receptacle, others from a tanker hose/drogue unit into a receiver probe—were specifically addressed in the AoA analysis.

The cost of any given fleet is defined as the present value of all the life-cycle research and development, procurement, military construction, operations and support, modification, and disposal costs for the fleet. For convenience, the rest of this executive summary will refer to this set of costs as the "costs of acquiring and operating" the fleet, and this phrase should be understood strictly to include all of the cost categories in the last sentence. Present value means the level of a single cost incurred today that would have the same value as the entire future stream of costs incurred to acquire and operate the fleet. This is less than the simple sum of the future costs (even if expressed in dollars of constant purchasing power, that is, dollars adjusted for inflation) because a given amount of funds available today can be invested at a positive real rate of return to result in a larger amount of funds in the future. As the rate of return, also called the discount rate, this AoA used 3.1 percent, consistent with the December 2005 Office of Management and Budget direction for long-term U.S. government investments.

In addition to the cost-effectiveness analysis, the AoA addressed two further issues for senior decisionmakers to consider when choosing among alternatives. First, tanker alternatives differ in how much airfield parking area they require and from what airfields they can be operated. This is a feature of interest because there can be constraints on available airfield area in some theaters of operation. Smaller aircraft use less area but carry less fuel, so parking area requirements are specific both to the aircraft and the theater. How to value the airfield parking and access characteristics of the alternatives is a matter for senior decisionmaker judgment.

Second, tanker alternatives differ in how much cargo or how many passengers they can carry. In the AoA, *cost-effectiveness assessments were made only in the aerial refueling role, but the analysis did include configurations in which all, or a significant part of, the fleet had cargo- and passenger-carrying capability*. Adding cargo- and passenger-carrying capability to the tanker fleet requires additional aircraft structure and systems, which increase the cost of each aircraft. In addition, more aircraft are required in the fleet to meet the aerial refueling requirement because the weight of the additional structure and systems means that each aircraft can carry less fuel. Whether the resulting increased costs outweigh the increased military utility and flexibility that comes from cargo- and passenger-carrying capability is a matter for senior decisionmaker judgment. The commercial-derivative tanker alternatives with no cargo- or passenger-carrying capability have only a catwalk and crossbeam structure in the rear of the aircraft and no floor at all.

Assessing the Timing of Recapitalization

The second question of the AoA concerns the policy effects of alternative timing patterns for KC-135 recapitalization, including both when it starts and how quickly it proceeds. Specifically, the AoA analysis included *alternative dates for beginning recapitalization*, defined as the date of first delivery of the replacement tanker. The effects of start dates between 2011 and 2041 were analyzed. In addition, the AoA analysis included *alternative durations of recapitalization*, defined as the period over which the entire replacement fleet is delivered. The effects of durations between 10 and 40 years were analyzed. The combinations of start dates and durations in the AoA were subject to the *constraint that the delivery of replacement tankers end no later than 2050*, which is equivalent to saying that all the KC-135s will be retired and that their capability will be replaced by then.

The primary cost metric for assessing recapitalization timing is the present value of **both** operating the KC-135s until they are retired **and** acquiring and operating the replacement fleet. Delaying or slowing down recapitalization raises the former part of this cost, both because the KC-135 fleet is operated longer and because KC-135 costs are projected to rise as the fleet ages. Delaying or slowing down recapitalization lowers the latter part of this cost because there is a present-value benefit to delaying the costs of acquiring and operating the replacement fleet.

The analysis began with the AoA-guidance-specified KC-135 fleet (73 KC-135Es and 417 KC-135R/Ts). If the level of the requirement is below or equal to the effectiveness of this AoA-guidance KC-135 fleet, excess KC-135s are immediately retired (in the analysis) until the resulting fleet meets the requirement. None, of course, are retired if the guidance fleet exactly meets the requirement—in this case, the “excess” is zero. The remaining KC-135s are then retired only as replacement tankers are delivered, and they are retired then at a rate that keeps overall refueling effectiveness (from both the remaining KC-135s and the replacement fleet) equal to the required level. Thus, for this case, recapitalization timing has only cost consequences because it keeps the overall level of refueling effectiveness constant regardless of the timing of the procurement of replacement tankers. The most cost-effective timing policy (start and duration of recapitalization) in this case is the one that minimizes the total life-cycle costs for both the remaining KC-135s and the replacement tankers. *However, all this assumes that there is no sudden decrease in the availability of the KC-135 as a result of unforeseen technical difficulties. This is discussed further below.*

A requirement level that is above the effectiveness of the AoA-guidance KC-135 fleet has both cost and effectiveness implications for the alternative recapitalization timing policies. In this case, no KC-135s are retired (in the analysis) until enough new tankers have been delivered for the combined fleet of KC-135s and new tankers to meet the requirement. KC-135s are then subsequently retired only when still more replacement tankers are delivered, and as in the case above, the KC-135s are retired at a rate that keeps overall refueling effectiveness (from both the remaining KC-135 and the replacement fleets) equal to the required level.

Thus, in the case in which the requirement exceeds the capability of the AoA-guidance KC-135 fleet, delaying or slowing down acquisition of the new tanker affects both effectiveness and cost. The later, or the more slowly, that new tankers are procured, the longer it takes to fill the gap between required and existing effectiveness, and so the worse the effectiveness outcome. However, delaying procurement of the new tanker lowers overall costs in this case because a number of new tankers must be delivered before any KC-135s are retired.

Because the timing decision partly depends on the cost of effectively sustaining the KC-135 fleet into the future, the technical condition of this fleet was also assessed in the AoA. The average age of the fleet in 2006 is 46 years, and continued operation to 2050 would result in a 90-year-old fleet. A fleet of this age and size is unprecedented in aviation history. The AoA undertook an investigation of all the available evidence that was relevant to determining what technical issues might arise that could make continued operation problematic for the KC-135 fleet. "Problematic" might mean anything from costs well in excess of those currently (December 2005) forecast to excessive unreliability or flight safety risk for the fleet. In this investigation, the AoA reviewed a very large set of technical and engineering data and evaluations spanning the entire history of the KC-135 structure and systems. The AoA also addressed ways to improve the technical management of this aging fleet as long as it is operated, including ways to improve the nation's knowledge of its technical condition.

Sensitivity Analysis

The AoA assessed the sensitivity of the results to a wide range of alternative projections of future conditions. These included projections of the following:

- the overall level and composition by mission type of military aerial refueling requirements
- operational characteristics of the missions, including the flight profiles of the receiver aircraft
- the technical performance of the replacement alternatives
- the configuration patterns of the alternative replacement aircraft, i.e., whether they have cargo- and passenger-carrying capability or electronic survivability in a nuclear environment
- cost projections for both the KC-135 and the alternative replacement aircraft
- planning horizons for the analysis, that is, how far into the future costs are accumulated.

All the findings of the AoA, except in the one case noted below, are insensitive to the broad range of variations in these projections that were analyzed. That is, the results hold true regardless of the specific projection of the factors within the broad ranges examined.

Findings

The following subsections present the primary findings of this AoA for KC-135 Recapitalization.

Cost-Effectiveness of Alternatives

The most cost-effective tanker replacement alternative is a fleet consisting of new commercial-derivative tankers in the medium to large size range (300,000 to 1,000,000 pounds maximum gross takeoff weight). The candidates in this range include tankers based on the Airbus 330, the Airbus 340, the Boeing 767, the Boeing 787, the Boeing 777, and the Boeing 747. The AoA's estimates of the cost-effectiveness of these alternatives are close enough to each other that none of them should be excluded as competitive candidates, given the information developed for and analyzed in this AoA. A mixed fleet consisting of more than one of these alternative candidates also has comparable cost-effectiveness, so there is no reason to exclude *a priori* an Airbus-Boeing mixed buy on cost-effectiveness grounds.

In addition, the specific *cost-effectiveness* of each of these alternatives is *highly sensitive* to their "green" aircraft price, that is, the price charged for the part of the aircraft that is common with the commercial version. This sensitivity supports a competitive acquisition strategy whose goal would be to elicit the lowest such green aircraft price. This is the one case in which the results were highly sensitive to the projected future conditions, namely, the green aircraft prices.

Commercial-derivative tankers that are either smaller (Boeing 737 or Airbus 321) or larger (Airbus 380) are not cost-effective, even in mixed fleets that include other candidates in other size categories.

Acquiring used aircraft as tankers is not as cost-effective as acquiring new aircraft. However, the AoA's estimates of the cost penalty are not great enough to exclude this option from any future competition, as long as electronic survivability in a nuclear environment is not required of them.[5] Whether this survivability is required of tanker aircraft is a matter of military judgment. *However, careful and detailed assessment of the technical condition of the used aircraft candidates would be critical in this case*. Even if such aircraft are found to be cost-effective, analysis of the numbers of suitable used aircraft likely to be available on the commercial market indicates that they would only meet between 10 and 25 percent of the total requirement, and so they would have to be part of a mixed fleet of new and used replacement aircraft.

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[5] Adding this capability to new aircraft adds less than 1 percent to the present value of their life-cycle costs, but adding it to used aircraft adds about 10 percent.

New-design tankers—i.e., aircraft developed *de novo* to be tankers—are not cost-effective. Improved aerodynamic efficiency and purpose-built tanker features can make them more effective per aircraft than commercial-derivative tankers. However, the additional effectiveness of such specialized design features does not offset their higher research and development costs and their higher production costs. Production costs are higher because there are no shared production-learning economies with a commercial version of the aircraft.

Unmanned tankers are not cost-effective. These systems would offer no cost advantages even if their peacetime attrition were at a level comparable to that of manned tankers. Moreover, the current (December 2005) peacetime attrition rates for military unmanned aerial vehicles are considerably higher than those for manned aircraft, so unmanned tankers would be considerably more expensive than manned tankers are now. One potential benefit of unmanned tankers is that human crews would not be put at wartime risk. This, however, is of very limited applicability because tankers, whether manned or unmanned, are too critical a combat resource in wartime, and too costly to replace in the longer run, to be generally used in ways that risk substantial attrition. Unmanned tankers offer no appreciable wartime benefits, and they have less operational flexibility than manned tankers.

Stealthy tankers are significantly more expensive than nonstealthy tankers, although they offer some effectiveness benefits. Stealthy tankers can extend the range of fighter support for long-range strike options. It is a military judgment whether the expense of penetrating tankers is justified by the additional military advantage.

There is no compelling reason for the Air Force to outsource aerial refueling, that is, to purchase aerial-refueling capability from private companies instead of providing it organically. In the requirements cases of the AoA, all tanker aircraft must carry a common wartime set of equipment, whether they are operated organically or by private companies. This is because the entire set of requirements consists of wartime missions, i.e., all tanker aircraft in the fleet must be capable of carrying out wartime missions. Thus, the equipment on an organically operated tanker and that on one operated by a private company would be functionally identical, and all must be capable of sustaining the high operational tempo associated with wartime. Given these requirements, there are *no demonstrable large-scale cost savings* associated with outsourcing tanker operations. Commercial sources of aerial refueling would only be *cost-competitive* with organic refueling if their air refueling assets were employed in the commercial market on a part-time basis while the Air Force's are not. The opportunity for commercial employment of assets should be neutral across potential suppliers of aerial refueling, whether private or government—i.e., if there are benefits to using some of the cargo- and passenger-carrying capacity of tankers in peacetime to serve commercial markets, that option should be equally available to all potential providers of aerial refueling services, both government and private. It is currently (December 2005) illegal for the Air Force to employ part of its tanker fleet commercially in peacetime. If it is decided to gain the financial benefits of employing military tankers in commercial markets in peacetime, the prohibition on the Air Force doing this should be revisited.

As long as it exists, it distorts an economically valid comparison of the private versus government options.

Two Additional Considerations

In addition to the refueling cost-effectiveness analysis, the AoA included airfield parking requirements and cargo- and passenger-carrying capability as potential factors for distinguishing among alternatives. *Regarding parking requirements*, in the class of medium to large commercial derivatives (the most cost-effective alternatives), *the parking area required differs among alternatives by about 30 percent*, depending on the theater scenario. How much to weigh this characteristic in choosing among alternatives is a matter of military judgment. *Regarding cargo- and passenger-carrying capability*, in the medium to large commercial-derivative class of alternatives, *a fleet in which all the aircraft have cargo- and passenger-carrying capability has a present value of life-cycle cost about 6 percent greater than that of a fleet in which none of the aircraft have cargo- or passenger-carrying capability*. A fleet with cargo- and passenger-carrying capability has the benefit of additional military utility and flexibility. How much to weigh the cost against the benefit of acquiring cargo- and passenger-carrying capability in the tanker fleet is a matter of military judgment.

Timing of Recapitalization

If the KC-135 AoA-guidance fleet meets the tanker requirement, *the present value of all life-cycle costs*, including those of the KC-135 and of its replacement, is relatively insensitive to the start date of recapitalization. Therefore, in this case, ***the decision of when to replace the KC-135s should be based on considerations other than present-value life-cycle costs***, and there are good arguments both for immediate and for delayed recapitalization.

Three considerations favor earlier tanker recapitalization. The first is concern about the technical risk of continuing to operate the current fleet of KC-135s. The finding of the AoA research is that there is considerable uncertainty about the future technical condition and sustainment cost of the KC-135, which will be further discussed below. An early replacement program would be a hedging strategy against this uncertainty. The *second* consideration favoring beginning tanker recapitalization earlier *would be the existence of a constraint on how large the annual tanker replacement procurement budget can be*, which would favor spreading the procurement of replacement tankers over a longer period. As directed by the AoA guidance, no such constraint was included in this analysis, which was done strictly on the basis of present value of future cost. Such a constraint would imply that the present-value metric does not adequately capture all the intertemporal differences in the value of money.

The *third* consideration favoring beginning tanker recapitalization earlier is that, *even if the AoA-guidance KC-135 fleet meets the refueling requirement, it does not have all the attributes of the replacement assets that were included in the AoA*. These attributes include, for example, the capability of the tankers themselves to be refueled, to refuel receptacle-equipped and probe-equipped receivers on the same mission, to simultaneously refuel two probe-equipped receivers from dual wing-mounted pods, to serve as airborne communication network relays, and to improve their survivability against some low-level missile threats. *These all increase the flexibility and military utility of the tanker fleet*. KC-135s currently (December 2005) have, at best, limited capability in these areas. These are qualitative factors of real difference between the KC-135 and its replacement. *Their value in choosing the best replacement tanker procurement profile is a matter for senior decisionmaker judgment*.

Two considerations favor later tanker recapitalization in this case, in which the existing fleet is at, or below, the requirement. The *first is that conditions in the future might change* in such a way that decisionmakers would wish that they had acquired fewer, or no, new tankers earlier. Such conditions might include a change in the geopolitical situation or future receiver force structure that lowered the size of the tanker requirement or technical developments that made a new-design aircraft a more attractive tanker alternative. Delaying a replacement program would be a hedging strategy against this uncertainty. The *second* consideration favoring later tanker recapitalization *would be the existence of critical near-term constraints on spending that would make a major near-term acquisition program very unattractive.* Such constraints would also imply that the present-value metric does not adequately capture all the intertemporal differences in the value of money.

If the requirement is greater than the capability of the AoA-guidance fleet, the more rapidly the resulting gap between requirements and capability is closed, the higher the present value of all life-cycle costs. This is because new tankers must first be acquired, *without retiring any KC-135s,* until the resulting fleet meets the requirement. Only then can KC-135s be retired as *additional new tankers* are acquired. The sooner new tanker acquisition begins, and the faster it proceeds, the sooner the gap between requirements and capability will be closed, but the higher the resulting total cost would be. *How rapidly to close any such gap and raise the fleet's capability to the required level, and thus how much cost to bear, is a matter for senior decisionmaker judgment.*

A further question when considering the timing of recapitalization is whether it is cost-effective to convert KC-135Es to KC-135Rs. This conversion would result in a small (about 2 percent) increase in overall KC-135 fleet effectiveness. *KC-135E to KC-135R conversion only has present-value cost savings if the converted aircraft will be operated beyond the late 2030*s. If the aircraft will be retired before then, there is a net present-value loss due to conversion because the sustainment cost savings would not amortize the capital cost.

Technical Condition of the KC-135 Fleet

There are substantial technical uncertainties associated with operating the KC-135 fleet into the 2040s. The current (December 2005) assessment of the flight-hour life of the KC-135 fleet and the expected future flying-hour programs together imply that these aircraft can operate into the

2040s. It cannot be said with high confidence that this is *not* the case, although there are risks associated with a fleet whose age is in the 80- to 90-year range. It can also not be said with high confidence that the current fleet *can* indeed operate into the 2040s without major cost increases or operational shortfalls, up to and including grounding of large parts of the fleet for substantial lengths of time, due to currently unknown technical problems that may arise. The nation does not currently have sufficient knowledge about the state of the KC-135 fleet to project its technical condition over the next several decades with high confidence.

A major scientific and engineering effort to increase the state of knowledge about the technical condition of the KC-135 fleet would improve the nation's understanding of the future costs and risks associated with operating the KC-135 fleet for the next 40 years. This effort might include full-scale fatigue testing and teardown inspections of some aircraft. Such an effort would improve the scientific basis for assessing the technical condition of the fleet.

Conclusion

The primary findings of the AoA are as follows:

- **A fleet of medium to large (300,000 to 1,000,000 pounds maximum gross takeoff weight) commercial derivatives is the most cost-effective alternative for KC-135 recapitalization.** That is, such a fleet would provide the required refueling capability at the lowest overall cost, defined as the present value of all future production and operating costs. Fleets consisting of just one kind of such aircraft or consisting of two kinds of them have comparable cost-effectiveness.
- **If the AoA-guidance KC-135 fleet meets or exceeds the future aerial refueling requirement, the present value of all life-cycle costs, both of operating the KC-135s until they are retired and of acquiring and operating the replacement aircraft, is relatively insensitive to the timing of recapitalization.** In this case, *the decision of when to recapitalize should be based on considerations other than the present value of life-cycle costs.* Arguments favoring earlier (sooner or more rapid) recapitalization include hedging against the technical risk associated with the KC-135 fleet, the existence of future constraints on annual procurement budgets, and the additional capabilities of the new tankers. Arguments favoring delayed (later or less rapid) recapitalization include hedging against uncertainties that could reduce the desirability of new tankers and the existence of very near-term budget constraints.
- **If additional tankers must be acquired to meet the future requirement, a higher cost will be associated with closing the resulting gap between capabilities and requirements more rapidly.** How rapidly to close the gap, i.e., how quickly to raise the capability level to the requirement, and thus how much higher a cost to bear, is a matter for senior decisionmaker judgment.