T E S T I M O N Y

RAND

# *Aging Aircraft: Implications for Programmed Depot Maintenance and Engine-Support Costs*

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**Project AIR FORCE**

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**BEFORE THE PROCUREMENT SUBCOMMITTEE OF THE**

**HOUSE ARMED SERVICES COMMITTEE**

**24 February 1999**

I would like to thank the members of the Procurement Subcommittee for the opportunity to discuss the increasing age of the Air Force's aircraft fleet and the implications for future readiness and cost. I am fortunate to be joined today by my colleagues, Dr. Laura Baldwin, Dr. Jean Gebman, and Mr. Hyman Shulman, each of whom made important contributions to this study.

RAND Project AIR FORCE's long-term interest in the topic of aging aircraft was rekindled in 1994, when we participated in the Air Force Scientific Advisory Board Summer Study [1] that raised technical concerns about the viability of retaining certain aircraft past their original design lives. In 1997, the National Research Council's report [2] on aging USAF aircraft reinforced those concerns. At that time, we initiated a modest Air Force-sponsored research effort focused on emerging technical challenges for aircraft maintenance activities. Last summer we built on that technical background to examine the potential effects that aging aircraft would have on the costs of programmed depot maintenance (PDM) and engine support. The results of that work are documented in the annotated briefing [3] that has been made available to the subcommittee. This year, we have broadened our review to cover other support and modernization activities where aircraft age may affect costs and readiness.

**SUPPORT COSTS WILL GROW IF CURRENT TRENDS CONTINUE**

As one of several efforts to control costs in the face of both higher unit prices for aircraft and constrained military budgets, the Air Force has slowed the pace of modernizing its aircraft fleet. It has reduced the rate of new aircraft procurement and simultaneously extended the service-life objectives of several existing Mission Design Series.

Although that policy aims to cut costs in procurement accounts, we found that, if previous cost-growth trends were to continue, annual PDM and engine-support costs would increase $5-6 billion by 2020.

Our results were based on reviews of historical PDM cost growth and on a previous analysis of engine life-cycle costs [4]. In particular, we reviewed historical and planned heavy-maintenance workloads for the KC-135, 727, 737, DC-9, and DC-10.[1] In each case, heavy-maintenance workload increased from five- to nine-fold over a 40-year span. Figure 1 depicts this growth rate for a range of average fleet ages. The growth rate is expressed as a ratio of heavy-maintenance workload over time to the workload at the first heavy-maintenance inspection. (Future research will address whether growth rates for smaller fighter aircraft differ.) From those data, we created cost-growth relationships that bound the upper and lower costs, also depicted in Figure 1.

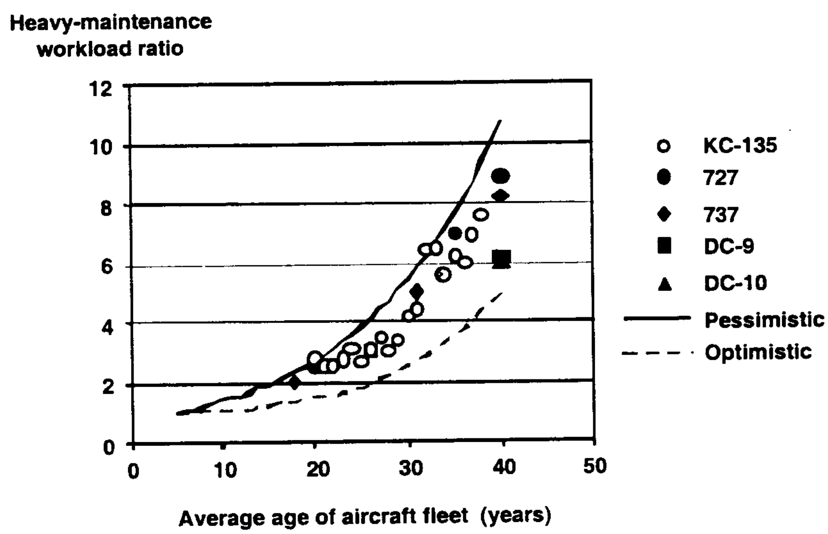


**Figure 1. Heavy-Maintenance Workload for Large Aircraft Grows Over Time**

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[1] We are indebted to Mr. D. Pearce of the Oklahoma City Air Logistics Center for the KC-135 histories and to Mr. M. Donato of the Boeing Company for the historical and planned workload growth factors for the commercial aircraft.

The heavy maintenance workloads for commercial aircraft in their 40th year are Boeing's current projections for those aircraft, based on currently planned workload requirements. Those aircraft are only now approaching age 40.

Previous Project AIR FORCE research [4] had addressed the effects of age and other factors on engine-support costs. Although that work did not include modular engines for fighters, results indicated annual age-driven growth rates of 4.5 percent and 5.3 percent for depot and base-level engine repair, respectively. Thus, over a 35-year period, engine-support costs would increase five- to six-fold, depending on the balance between depot and base-level workloads.

The Air Force intends to replace many fighter aircraft over the next 20 years. However, current plans call for retaining the existing fleets of bomber, tanker, command and control, and cargo aircraft for much longer periods, sometimes for more than 70 years. To understand how continued PDM and engine-support cost growth might affect future budgets, we extrapolated our upper and lower estimates of PDM workloads to cover a 70-year period. We combined those projections, the engine-support workload, 1994 PDM expenditures [5], and the Air Force's time-phased aircraft fleet composition plans (including the reserve component) to estimate annual PDM and engine-support costs from 1998 to 2022. Our results indicate that, if recent trends continued, annual costs for those two activities would initially rise at a modest rate. Then, in the second decade of the next century, they would accelerate, mainly because of the increasing age of the cargo and tanker fleets. Figure 2 depicts our high and low estimates of those annual costs.

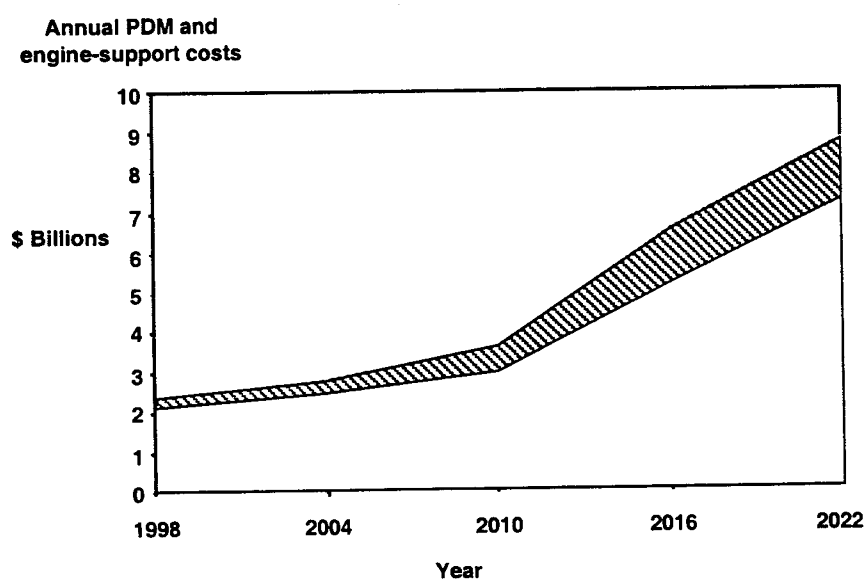


**Figure 2. Projected Cost Growth of PDM and Engine-Support Workload**

## CURRENT WORKLOAD GROWTH TRENDS MAY CHANGE

Of course, neither the Air Force nor U.S. commercial airlines have ever before operated aircraft for such a long time. Therefore, no one knows whether these trends will continue. However, faced with the possibility of escalating maintenance and support costs, the Air Force has already begun to implement management initiatives intended to moderate workload growth rates.

### New Support Challenges May Emerge

Cautious observers argue that the Air Force will encounter new flight-safety, cost, and readiness challenges as it seeks to extend the service lives of its existing fleets. In particular, major problems may result from corrosion, insulation cracking, composite delamination, and other material degradation processes for which there are no scientific aging models or relevant historical experience. For examples, one need look no further than the C-141 weephole, the VC-137 corrosion workload, and the more recent C-5 horizontal stabilator tie box fitting. If this were to occur, workload growth rates could exceed our high PDM and engine cost-growth estimates.

In any case, high costs will be incurred for modernization. Over the next decade, the Air Force will need to retrofit existing aircraft to meet new international standards for navigation, noise, and pollution. Further, the increasing peacetime exposure of tankers and cargo aircraft to potentially hostile actions increases the likelihood that continuing threat-related modifications to those aircraft will be required, to say nothing of the modifications needed for bombers, fighters, and attack aircraft.

Production obsolescence for uniquely military components may drive up costs even further. In general, the declining market for military aircraft and related materials has combined with the rapid technological advances of the past few decades to make production of many older military components unprofitable, thereby causing vendors to leave the marketplace entirely. Some older components simply cannot be manufactured any longer. Functionally equivalent replacement components must be designed, tested, and produced at considerably higher costs than the originals.

Most important, many of the problems associated with aging material have emerged with little or no warning. This raises the concern that an unexpected phenomenon may suddenly jeopardize an entire fleet's flight safety, mission readiness, or support costs, and that an extended time period may be required to design, test, and field a replacement aircraft.

**Management Initiatives May Control or Eliminate Some Cost Growth**

Optimistic observers hold out the promise that maintenance and modification initiatives (e.g., new corrosion-prevention compounds and procedures, improved failure tracking) now underway will successfully control age-related and many other support costs. Several one-time, semipermanent fixes currently taking place (e.g., selective rewiring, selective component replacement, and redesign of obsolete components) aim to substantially reduce the likelihood of future technical surprises while offsetting some effects of age. In addition, improved information systems that compile historical data on maintenance workload should provide additional insights about how the phenomena of aging are affecting specific fleets of aircraft.

These management initiatives are intended to ensure that most surprises are detected early and that focused, one-time maintenance "rework" actions are applied. If effective, those actions should reduce current workload growth rates.

**AIR FORCE OPTIONS TO MANAGE READINESS AND COST UNCERTAINTIES**

Both sides are right. New, unforeseen failure mechanisms will emerge and old failure mechanisms will accelerate, sometimes with little or no warning. At the same time, proactive implementation of targeted maintenance and modification initiatives will reduce the potential negative effects on flight safety, readiness and cost, at least in cases where the scientific and technical community has sufficient understanding of those effects.

The larger issues, then, are (1) the extent to which the management initiatives will succeed and (2) what additional strategies the Air Force can employ to help control age-related failures and their effects on readiness and cost.

To help the Air Force address these issues, we have identified three broad strategies: selective risk management, development of contingency plans for aging aircraft fleets, and mission-area portfolio management. These strategies complement one another. The first would reduce uncertainties; the other two would mitigate the effects of surprises.

- ***Selective risk management*** embodies and extends the approach implicit in the current management initiatives. This strategy seeks to identify and catalog specific age-related hazards that may affect future costs, characterize the relationships between those hazards and the risks to readiness and cost, and then develop specific technical solutions to reduce exposure to the hazards or to control their effects on cost and readiness. Current Air Force science and technology research and development initiatives in the areas of fatigue, high-cycle fatigue, corrosion, and other material science areas typify that solution direction, as do investments to gather additional technical data from maintenance activities. Accurate and detailed records of failures are also a key component of this strategy.

- ***Contingency plans for aging aircraft fleets*** reflect the Air Force's recognition that uncertainty can never be eradicated. Such plans would seek to reduce aircraft design and production lead times (e.g., by modifying a commercial aircraft design or developing early conceptual designs) for older aircraft fleets that may be subject to unforeseen events. These plans would be implemented if a surprise occurred, such as sharply escalating PDM costs, an expensive modification, or a readiness shortfall. Contingency plans for different fleets might require different approaches, depending on the size of the fleet and the risk to the mission.

- ***Mission-area portfolio management*** would seek to implement acquisition and retirement plans that balance fleet ages within a particular mission area. Achieving this balance would reduce the risk of degraded mission capability by making the Air Force less dependent on a particular fleet of aircraft. For example, if today's C-5A fleet were unexpectedly grounded, the C-5B fleet, which is 15 years younger, could perform the outsize cargo mission, although at a diminished capacity. And because new materials will continue to introduce unknown hazards into each new aircraft design, this strategy may be an effective long-term hedge against such hazards.

**PROJECT AIR FORCE WILL REFINE READINESS AND COST-GROWTH FORECASTS**

In concert with the Air Force's Aging Aircraft Integrated Process Team (AAIPT), RAND Project AIR FORCE is helping to formulate, refine and evaluate all three strategies. The AAIPT aims to develop Air Force processes to manage aging fleets and, as a first step, it will assess the current system's readiness and cost performance. We will extend and refine our initial analysis of PDM and engine-support costs to help carry out that assessment. We will then use those analytic methods to evaluate alternate maintenance solutions to particular age-related hazards (selective risk management), to assess alternate fleet replacement plans (fleet contingency planning), and to determine the cost effectiveness of alternate mission-area procurement strategies (mission-area portfolio management).

We continue to work in partnership with the Air Force to address the aging-aircraft issues identified in the AFSAB and the NRC reports. It may appear that these issues will not reach crisis proportions for many years. However, the problem is extensive, complex and susceptible to surprises. Long-term solutions will require considerable time to develop and implement. We are confident that the Air Force will continue to exert steady and sustained effort to find ways of meeting these challenges.

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