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Aging Aircraft Repair-Replacement Decisions with Depot-Level Capacity as a Policy Choice Variable

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Summary

In Keating and Dixon (2003), we presented a model for determining when it would be optimal to retire, rather than continue to repair, an aging system. This work extends Keating and Dixon along two dimensions.

First, we extend our methodology to examine whether a proposed modification (mod) is worthwhile relative to retiring an aircraft.

Second, we develop a new methodology to explore the desirability of additional investment in depot-level capacity.

Modeling the Decision to Repair or Replace an Aging Aircraft

In our model, we consider the discounted expenditure and availability flows emanating from repairing versus replacing an aging system.

If one assumes the Air Force's goal is to minimize its average cost per available year (or day), the Air Force should keep an incumbent aircraft until its incremental cost per available year exceeds the average cost per available year of a replacement system. (See pp. 5–6.)

This approach should be used prospectively. For example, one estimates ahead of time when it is thought the optimum will be achieved and has a replacement system prepared to enter service at that time.

The C-5A Modification Versus Replacement Decision

We show how our repair-replace methodology can be used to assess the desirability of modifying versus retiring an aging aircraft. We use data on the C-5A to illustrate our methodology.

The C-5 is the Air Force's largest cargo-carrying aircraft. There are currently 72 C-5As; the fleet's average age is somewhat over 30 years. The Air Force plans to retire 12 C-5As by the end of fiscal year (FY) 2006, leaving a fleet of 60 C-5As.

The C-5A fleet is scheduled to receive a major mod or Reliability Enhancement and Re-engining Program (RERP) sometime in the 2010 decade, requiring work on each aircraft's airframe, avionics, engines, landing gear, and other equipment. Tirpak (2004) cites the RERP's cost as $75 million per aircraft, so the Air Force needs to carefully consider the C-5A's future before making this commitment. If, instead, the C-5A fleet is retired in front of the mod, the Air Force could purchase additional C-17s or develop an alternative aircraft. In this study, we focus on the C-17 as a replacement for the C-5A because of the availability of data on the costs of C-17s.

To demonstrate our model, we used Air Force Total Ownership Cost (AFTOC) factors for the C-5 and the C-17. We note with concern, however, that AFTOC factors do not appropriately differentiate between C-5As and C-5Bs for our analytic purposes.

Pyles (2003) presents Air Force data that show considerable growth in the C-5A's programmed depot maintenance (PDM) package. On the other hand, the C-5A has not seen adverse trends in its on- and off-equipment maintenance costs. The C-5A has experienced only a minor decline in the fraction of the fleet that is possessed by operating commands and is mission capable (which we label the composite availability rate).

With our baseline assumptions, our model indicates that it is not optimal to undertake the proposed C-5A mod in 2015. However, the mod appears to be worthwhile if it can occur earlier, perhaps in 2010. As the mod is delayed, C-5A performance degrades and costs increase to the point, eventually, that it is not worthwhile to undertake the mod. (See pp. 8–21.)

We then undertook a robustness exploration to see which other parameters were critical in undergirding our findings. Along with date of the RERP, another key parameter is the number of C-17s it would take to acceptably replace 60 C-5As. As the number of required C-17s increases, the desirability of the C-5A RERP increases. If 70 or more C-17s are required, the 2015 C-5A RERP is worthwhile, given our other parameters. (See pp. 21–22.)

The Air Force is currently implementing the RERP on two C-5Bs and a C-5A. The virtue of undertaking the RERP on a few aircraft is that it will shed light on the magnitude of the availability gains from the project. On the other hand, our model indicates that delay in the C-5A RERP tends to diminish its desirability.

We view our C-5A findings as illustrative and suggestive, rather than definitive, particularly in light of concerns with our C-5A cost parameters.

Consideration of C-5A Depot-Level Capacity

We extend our methodology to assess the desirability of additional investment in depot-level capacity (including additional facilities, repair equipment, labor, and spare parts). We do not assess the optimal form of such investment.

We know the Air Force values having aircraft available to its operating commands. Our repair-replace calculation assumes the Air Force would be willing to someday pay the likely high costs of a replacement system. Given a belief (or inferred preference) about how much an available aircraft year is worth, we can calibrate the desirability of increases in depot-level capacity that place aircraft in operators' hands faster.

Queuing is a source of considerable delay in depot-level maintenance. Hence, we developed a model of the programmed depot-maintenance process as a multinode or multistep closed network.

Using our depot-level queuing model, we consider the effect of increasing capacity (e.g., purchasing more repair equipment, spare parts, or hiring more workers). When capacity increases, the rate at which operating commands possess aircraft increases as aircraft spend less time in depot-level queues.

Intriguingly, our model, using illustrative C-5A data, suggests that, while an increase in depot-level capacity is desirable, it does not delay the optimal retirement of the aircraft. Instead, the effect is to increase the operating command's possession rate while the aircraft is used. (See pp. 40–42.)

We think our findings are explained by the inferred preference exercise upon which this analysis is built: We assume the Air Force will eventually replace the C-5A with the C-17, a nontrivially expensive aircraft. Hence, we infer that the Air Force places high valuation on an available C-17, and hence C-5A, year. Given this inferred preference, the model is then averse to having large-scale queuing and delay in the C-5A depot maintenance system. Given the inferred value of these aircraft, it is not reasonable to have them wait in many or long depot-level queues.