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REPORT

Upgrading the Extender

Which Options Are Cost-Effective for Modernizing the KC-10?

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Summary

The Air Force asked RAND Project AIR FORCE to undertake a study to provide objective insight into the cost-effectiveness of modernizing the KC-10 "Extender" air refueling (AR) tanker aircraft. The study analyzed the cost-effectiveness of modernizing the KC-10 in the areas of avionics (CNS capabilities for ATM), NVIS compatibility, C2 (specifically, tactical data-link [TDL] capability), additional multipoint refueling capability, defensive protection, and reliability and safety upgrades.

We assessed the cost-effectiveness of the various modernization options by estimating each option's total life-cycle cost and comparing that cost with its quantitative benefit. The quantitative benefit of each option was determined by valuing the number of tanker aircraft saved because of the KC-10's increased wartime mission effectiveness and the effects on peacetime operating costs after modernization. In some cases, modernization options provide benefits that do not directly affect the cost or effectiveness of the KC-10 but, rather, improve commanders' operational flexibility in employing the KC-10 or improve the effectiveness of other weapon systems. In such cases, we highlight these additional benefits or implications. (See pp. 5–7.)

The context for evaluating changes to peacetime operating costs is 11 years of KC-10 operational flying data. To evaluate the impact on executing wartime missions, we used representative missions vetted in RAND's KC-135 recapitalization analysis of alternatives (AoA) (see Kennedy et al., 2006) and the *Mobility Capabilities Study* (DoD and JCS, 2005), supported by tanker doctrine. These missions include homeland defense, air bridge, national reserve, global strike, theater employment, deployment, and Operations Plan (OPLAN) 8010 (Strategic Deterrence and Global Strike). We use the mission title *air bridge* to capture the missions of global strike: air bridge, OPLAN 8010, and national reserve. Although these three missions vary in their overall military purpose and goals, they are very similar from the perspective of the tanker operations required to support them. Thus, our analysis modeled requirements and matched the selected modernization options to four broad mission types: homeland defense, theater employment, deployment, and air bridge. (See pp. 9–15.)

The modernization options provide benefits to operations in different ways for different missions. Not all options benefit all missions. For example, defensive systems may allow tankers to base closer to AR locations and to conduct AR closer to threats than without the systems. However, defensive systems do nothing to improve the rate at which receivers cycle across the boom or baskets. The benefits provided by each modernization option through various types of missions are shown in Table S.1. (See pp. 15–18.)

Using a value for the KC-10 based on cost research in RAND's KC-135 recapitalization AoA (see Kennedy et al., 2006), we determined the value of improvements in effectiveness,

Table S.1
Modernization Options, Missions, and Tanker Efficiency Benefits

	Benefit and Mission			
Modernization Option	**AR Orbits Farther Forward**	**Tanker Bases Closer to AR Orbits**	**More Efficient Planning and Operations**	**Faster Receiver Cycle Times**
TDL	Employment		Homeland defense Employment Deployment Air bridge	
Additional multipoint refueling capability				Employment Deployment
Defensive systems	Employment	Employment		
NVIS-compatible lighting				Employment

reliability, and safety, which are shown in Table S.2. We evaluated changes in effectiveness for each of the system modernization options. Changes in reliability and safety were not explicitly analyzed for each modernization option but can be used to determine the price that the Air Force should be willing to pay for these improvements. (See pp. 15–17.)

After examining the costs and benefits of each of the modernization options,[1] we compared their relative merits, ordering the options by cost-effectiveness ratio and the ratio of improvement in wartime effectiveness to the modernization cost of each option, including any change to operating costs. The cost-effectiveness ratio shows not only how the options compare in terms of best value per dollar but also at what point the returns on modernization spending begin to decrease. This approach of comparing the options does not capture costs or benefits that are inherently not quantifiable but may be important considerations when deciding to upgrade the KC-10 fleet. In those cases, we review the important considerations for each of the options. (See pp. 19–28.)

The modernization options in order of the greatest to least cost-effectiveness are adding a TDL, CNS/ATM, additional multipoint refueling, defensive systems, and NVIS-compatible lighting. The first three—TDL, CNS/ATM, and additional multipoint refueling—all have

Table S.2
Value of Changes in Effectiveness, Reliability, and Safety

Change	**Value (FY 2009 $ millions)**
1% effectiveness increase	2.9
1% not-mission-capable rate decrease	2.5
1% depot-possessed rate decrease	2.4
0.1% attrition rate reduction	2.8

[1] We estimated the costs of each modernization option independently. If some options are implemented simultaneously, there could be reduced costs because of overlapping access requirements (i.e, TDL and CNS/ATM both require access to the cockpit). However, given historical cost growth of programs and uncertainty in cost estimates, our approach is conservative.

positive net present values (NPVs), meaning that the overall benefit is greater than the cost to procure these upgrades. Upgrades for defensive systems could be cost-effective (i.e., have a positive NPV) if either (1) KC-10s are used heavily for employment missions and can be based significantly closer to AR orbit locations or (2) KC-10s are used to offset C-17s in an airlift role. NVIS-compatible lighting is not cost-effective for the KC-10. Table S.3 shows the cost and benefit of each of the modernization options. The benefits in Table S.3 are based on the average of two mission mixes that represent different ways in which the KC-10 could be used in wartime: one weighted toward theater employment missions, the other weighted toward deploying fighter-sized aircraft to theater. (See pp. 73–75.)

Of the options, adding a TDL to the KC-10 has the greatest cost-effectiveness ratio. The data link is a relatively inexpensive upgrade compared with the other options. Among other capabilities, a TDL would provide the KC-10 with position and mission information on receiver aircraft without relying on voice communication. This information would allow the reduction of planned overlap times and facilitate faster rendezvous with receiver aircraft, making the KC-10 more effective. (See pp. 29–37.)

Modifying the KC-10 avionics upgrades to be compliant with upcoming worldwide equipage mandates has the next-highest cost-effectiveness ratio. Most of the CNS/ATM upgrade benefit is the avoidance of fuel penalties because the equipment is mandated to access the most fuel-efficient altitudes. Under a broad range of assumptions regarding savings and fuel costs, the CNS/ATM upgrade is cost-effective based on peacetime savings only. However, the findings show that, even under a worst-case cost scenario, the savings resulting from KC-10 fleet modernization would exceed the cost of the upgrade long before the fleet is retired in 2045. That research is detailed in *Assessing the Cost-Effectiveness of Modernizing the KC-10 to Meet Global Air Traffic Management Mandates* (Rosello et al., 2009).

Additional multipoint refueling capability increases effectiveness primarily in the employment mission when refueling multiple strike and air defense aircraft, with a lesser benefit for the deployment mission. The number of aircraft allowed to fly in refueling formation with the tanker limits the potential effectiveness gain from multipoint in the deployment mission. Our research suggests that eight receivers is a reasonable maximum, and that number is the basis

Table S.3
Costs and Average Benefits of Each Modernization Option

	FY 2009 $ Millions/ Total Aircraft Inventory	
Modernization Option	**Cost**	**Benefit**
TDL	0.7	6.5
Additional multipoint refueling capability	4.2	11.6
Defensive systems	21.4	10.2
NVIS-compatible lighting	3.6	0.1
CNS/ATM	7.5	26.1

NOTE: All costs and benefits are presented in terms of millions of FY 2009 dollars per aircraft. We express this as FY 2009 $ millions/total aircraft inventory to indicate that these per-aircraft values were calculated using the entire KC-10 fleet size.

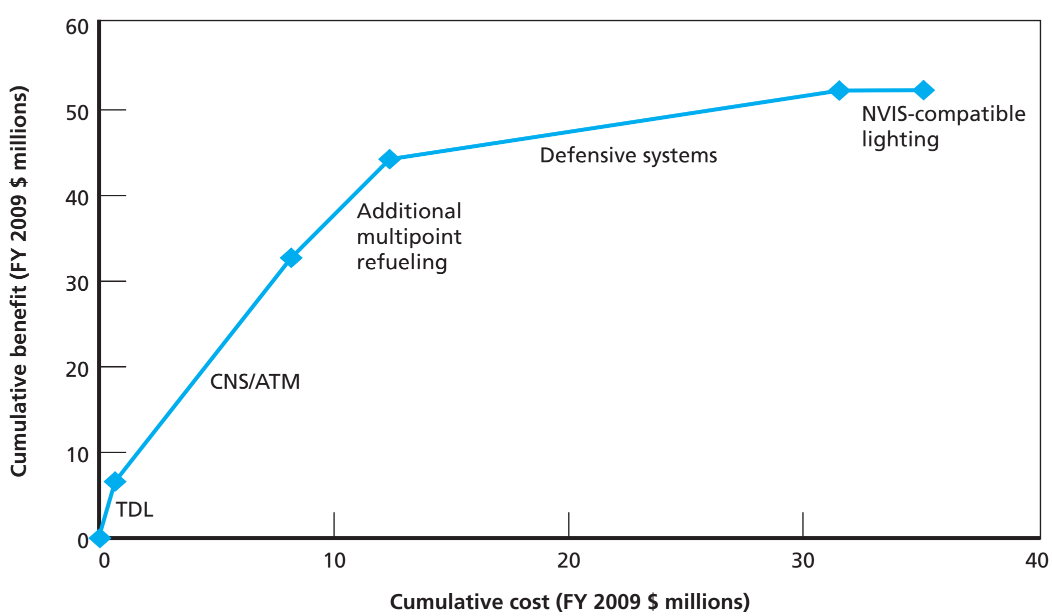
for the benefit presented here. Values for six and 12 receivers are also presented in Chapter Six. (See pp. 39–50.)

Defensive system upgrades are cost-effective only if these systems allow the KC-10 to be based significantly closer to wartime operational AR locations than established in planning documents and practiced in recent conflicts. Defensive systems may also be cost-effective by allowing the KC-10 to be used more in an airlift role, thus freeing a number of large defensive system–equipped airlifters (C-17s or C-5s, for example) to conduct other missions for which they are best suited. Our values are based on adding the proposed defensive system suite and basing the KC-10s 200 nautical miles (nm) closer to AR orbits. The rationale for the 200 nm stems from basing locations in Operation Iraqi Freedom. At these values, the cost of the upgrade would be greater than the value of its benefit. In the case of defensive systems and closer basing, tanker experts and decisionmakers can trade off system cost, the extent of the upgrade, and how close they are willing to base the aircraft. The parametric analysis in Chapter Seven can help determine the trade-offs for other costs and distances. (See pp. 51–66.)

Retrofitting the KC-10 with NVIS-compatible lighting is not cost-effective because it does little to make the tanker more effective. Air Force testing and empirical safety data suggest minimal improvement in tanker mission effectiveness with NVIS-compatible lighting. (See pp. 67–71.)

Figure S.1 shows each of the modernization options in order of their cost-effectiveness in a cumulative plot of costs and benefits. As the figure shows, TDL, CNS/ATM, and multipoint refueling capability each provide more benefit than cost, and defensive systems and NVIS-compatible lighting cost more than the benefit they provide. As a package, if all the upgrades were pursued, the overall benefit would be greater than the overall cost of all the upgrades. (See pp. 73–75.)

Figure S.1
Cumulative Cost-Benefit Curve of Modernization Options



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