An Assessment of the Life-Cycle Cost of the Boeing 767 and Airbus A330

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The Boeing Company
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Prepared By:

AeroStrategy Management Consulting
Ann Arbor, MI ● Amersham, UK ● Singapore
Executive Summary

The United States Air Force is conducting a competition to replace the 50-year old KC-135. Two competitors, The Boeing Company and the European Aeronautic Defence and Space Company (EADS) have each offered a refueling tanker derived from a currently available commercial airliner. Boeing offered a tanker based on the Boeing 767; whereas, EADS offered a tanker based on the Airbus A330. The Air Force will award a contract for 179 aircraft with deliveries between 2014 and 2026 which are expected to have at least a 40-year life before retirement. This analysis compares the lifecycle cost of a fleet of 179 Boeing 767-200ER aircraft equipped with Pratt & Whitney PW4000-94 engines with the lifecycle cost of the Airbus A330-200 equipped with GE CF6-80E engines. AeroStrategy has been collecting and analyzing aircraft maintenance costs since 2003 on behalf of major clients in the aerospace and aviation industry. The analysis concludes:

- Significant life cycle cost savings are accrued by a Boeing 767 in the areas of fuel usage, the full spectrum of maintenance activities from day-to-day flightline maintenance to depot-level maintenance and inspections, and initial investment for tools and spare parts.
- Depending on aircraft usage rates and fuel prices, total life cycle cost savings for a fleet of 179 Boeing 767 aircraft compared to a fleet of 179 EADS Airbus A330 aircraft are 20-25% and range from $11 billion to $36 billion dollars.

A total of six cost categories were included in the analysis: (1) the cost of fuel for flying the aircraft over 40 years, (2) the cost of overhauling the engines at their respective intervals, (3) line maintenance activities up to and including A-checks, (4) airframe heavy maintenance, (5) component repair, and (6) the initial investment required in spare parts and maintenance tooling. Because the KC-X tanker is expected to operate for at least 40 years, these fuel and maintenance cost drivers can be as much as 60-80% of the total program costs from initial aircraft acquisition through aircraft retirement.

Ten different scenarios were analyzed with variations in annual aircraft utilization, fuel price escalation and aircraft maintenance programs. The variations in aircraft utilization included a typical commercial airline utilization of 4,000 flying hours per year and two utilization levels that would be more typical of military use – 489 hours per year, which is the level specified in the Air Force’s current requirements and 750 hours per year which would reflect a higher operations tempo experienced during conflicts such as during operations in Iraq, Afghanistan and Kosovo. Given the KC-X’s multi-role capabilities and high availability rate, a higher utilization rate – 750 hours per year – is not unreasonable to expect. In fact, the Air Force’s stated requirement for KC-X tanker flight hours per year during the previous tanker competition was 750 hours per year. As a point of comparison, the C-17 airlift aircraft averages nearly 1,000 flight hours per year.

Two approaches were evaluated to determine the cost of fuel over time. In the first approach, indices provided by the Air Force were used to calculate the fuel price for any given year. Over 40 years, the average annual escalation in fuel price is approximately 2.5%. The second approach used a market-based industry composite derived from various sources such as the Department of Energy and the International Energy Agency with an annual escalation of 5.1%, a level that reflects potential actual fuel price growth given increasing demand for and declining supply of oil.
Conclusions

The EADS A330 aircraft is over 50 percent larger and 25 percent heavier than the Boeing 767; therefore, it consumes substantially more fuel, costs more to perform line and heavy maintenance and requires more initial upfront investment than the 767. In all ten scenarios analyzed, the life-cycle cost of the A330 was at least 20% higher than that for the 767. However, the three scenarios referenced below most closely approximate potential Air Force KC-X tanker utilization rates and maintenance plans.

• Scenario 1 considers the Air Force provided aircraft utilization rate (489 flying hours/year) and annual fuel price escalation (2.5% escalation). In this scenario, the Total Program Life-Cycle Cost in then-year dollars for the A330 is $11 billion (20%) more than the Boeing 767.

• Scenario 2 considers a higher, but realistic, utilization rate consistent with Air Force stated requirements in the previous KC-X tanker competition (750 flying hours/year) and the Air Force issued annual fuel price escalation (2.5%). In this scenario, the life-cycle cost in then year dollars of the A330 is $16 billion (22%) more than the Boeing 767.

• Finally, Scenario 3 considers a 750 flying hour/year utilization rate and, an industry composite fuel price annual escalation forecast (5.1%). In this scenario, A330 life-cycle costs are $36 billion (25%) more than the Boeing 767.
Introduction

This analysis compares the lifecycle cost of a fleet of 179 Boeing 767-200ER aircraft equipped with Pratt & Whitney PW4000-94 engines with the lifecycle cost of the Airbus A330-200 equipped with GE CF6-80E engines. The Airbus A330-200 and the Boeing 767-200ER are both twin-aisle, long-haul aircraft used extensively in the air transport fleet. There are almost 900 B767s flying, about 200 with the 52,000 pound thrust (lbf) PW4000-94 engine. There are nearly 750 A330s flying, with about 140 of those being A330-200s with the 67,500 to 72,000 lb f GE CF6-80E1.

Along with the balance of the fleet, AeroStrategy has been analyzing the maintenance costs of these aircraft since 2003 when an annual assessment of the Commercial Aviation Maintenance Repair & Overhaul (MRO) market was launched by AeroStrategy’s UK office with more than 25 blue-chip clients. In addition, AeroStrategy has performed numerous specific assignments and surveys over the years which have contributed to an underlying set of maintenance cost assumptions which were used in this analysis.

Analysis Approach and Assumptions

A total of six cost categories were included in the analysis, which are shown below. Because the KC-X tanker is expected to operate for at least 40 years, these fuel and maintenance cost drivers can be as much as 60-80% of the total program costs from initial aircraft acquisition through aircraft retirement.

<table>
<thead>
<tr>
<th>Cost</th>
<th>Description</th>
</tr>
</thead>
</table>
| Fuel                  | • Includes the cost of fuel consumed under different utilization scenarios with two different future fuel price schedules:  
                          − A schedule provided by the Air Force as part of the tanker RFP with escalation only at the rate of inflation (2.5% annually).  
                          − A market-based industry composite derived from sources such as the Department of Energy and the International Energy Agency, using an annual escalation of 5.1%, a level that reflects potential actual fuel price growth given increasing demand for and declining supply of oil. |
| Engine Overhaul       | • Includes off-aircraft repair and overhaul of engines, and hot section inspections.  
                          • Excludes on-wing engine related activity, engine fleet and work scope management, cost of spare engines/modules and major engine modification programs. |
| Line Maintenance      | • Includes labor (mechanics and management) and material costs for line maintenance.                                                                                                                     |
| Airframe Heavy        | • Includes labor and material for required airframe heavy maintenance checks (C-checks and D-checks), plus typical service bulletins that are normally incorporated during heavy checks.  
                          • Excludes major modifications.                                                                                                                                                                       |
| Component Repair      | • Includes component overhaul and repair spend.  
                          • Excludes cost of managing inventory (warehousing, administration) and logistics.                                                                                                               |
| Initial Investment    | • Includes initial investment in spare parts (rotables and consumables), spare engines, and maintenance tooling (special tools to support Line checks, A checks, daily servicing, limited troubleshooting, aircraft jacking and some unscheduled maintenance including wheels/tires/brakes changes and avionics systems checks, etc.)  
                          • Does not include investment required to set up in-house heavy check or engine overhaul capabilities.                                                                                           |

Table 1 – Cost Categories Included In The Life Cycle Cost Analysis
Ten different scenarios were analyzed with variations in annual aircraft utilization, fuel price escalation and aircraft maintenance programs. The variations in aircraft utilization included a typical commercial airline utilization of 4,000 flying hours per year and two utilization levels that would be more typical of military use – 489 hours per year, which is the level specified in the Air Force’s current requirements and 750 hours per year which would reflect a higher operations tempo experienced during conflicts such as during operations in Iraq, Afghanistan and Kosovo. Given the KC-X’s multi-role capabilities and high availability rate, a higher utilization rate – 750 hours per year – is not unreasonable to expect. In fact, the Air Force’s stated requirement for KC-X tanker flight hours per year during the previous tanker competition was 750 hours per year.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Utilization (Annual Hours Per A/C)</th>
<th>Fuel</th>
<th>Maintenance Plan</th>
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<tbody>
<tr>
<td>1</td>
<td>489</td>
<td>Air Force</td>
<td>Standard</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>750</td>
<td>Industry Composite</td>
<td>Standard</td>
</tr>
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<td>Industry Composite</td>
<td>Standard</td>
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<td>Air Force</td>
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<td>Air Force</td>
<td>Boeing Low Utilization Maintenance Plan</td>
</tr>
<tr>
<td>8</td>
<td>750</td>
<td>Industry Composite</td>
<td>Boeing Low Utilization Maintenance Plan</td>
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<tr>
<td>9</td>
<td>489</td>
<td>Air Force</td>
<td>Boeing Low Utilization Maintenance Plan</td>
</tr>
<tr>
<td>10</td>
<td>489</td>
<td>Industry Composite</td>
<td>Boeing Low Utilization Maintenance Plan</td>
</tr>
</tbody>
</table>

Table 2 - Scenarios

Two approaches were evaluated to determine the cost of fuel over time. In the first approach, indices provided by the Air Force were used to calculate the fuel price for any given year. Over 40 years, the average annual escalation in fuel price is approximately 2.5%. The second approach used a market-based industry composite derived from various sources such as the Department of Energy and the International Energy Agency with an annual escalation of 5.1%, a level that reflects potential actual fuel price growth given increasing demand for and declining supply of oil. Baseline fuel consumption data was gathered from The Airline Monitor, a leading independent source of commercial airline data.

A standard commercial maintenance plan was used in the analysis of both aircraft types. In addition, the B767 was also evaluated using a Low Utilization Maintenance Plan (LUMP), which is approved and planned for implementation by Boeing and its international KC-767A tanker customers; however, since a similar plan was not available for the A330, the results presented here reflect scenarios using the standard commercial maintenance plan.
This report will focus on the findings for the three scenarios that most closely approximate the Air Force’s KC-X tanker program.

There are several assumptions that are consistent across all of the scenarios. These are the number of aircraft delivered, the useful life of the aircraft, the length of a typical flight (hours per cycle), the discount rate for calculation of the present value of the stream of costs, and finally, the rate of inflation. Additionally, the standard commercial maintenance plan is used in all three of these scenarios. These can be seen in Tables 3, 4 and 5 which provide the assumptions for the three scenarios summarized here.

In the first scenario, the annual aircraft utilization (flight hours) is 489 hours per aircraft per year and the fuel price assumptions are those provided by the Air Force for the tanker RFP. The Air Force fuel cost schedule begins with a cost of $2.83 per gallon for 2010 and it increases at an average escalation rate of approximately 2.5% over the next 40 years.

In the second scenario, the fuel price schedule is kept consistent while utilization is increased to 750 hours per aircraft per year, a level which would reflect a higher operations tempo experienced during conflicts such as during operations in Iraq, Afghanistan and Kosovo. Given the KC-X’s multi-role capabilities and high availability rate, a higher utilization rate – 750 hours per year – is not unreasonable to expect. In fact, the Air Force’s stated requirement for KC-X tanker flight hours per year during the previous tanker competition was 750 hours per year. As a point of comparison, the C-17 airlift aircraft averages nearly 1,000 flight hours per year.

The third scenario builds on the second – the annual utilization remains 750 hours per aircraft, but rather than the Air Force supplied fuel price schedule, this scenario uses instead a market-based, industry composite fuel price schedule derived from various sources such as the Department of Energy and the International Energy Agency. This schedule has an annual escalation of 5.1%, a level that reflects potential actual fuel price growth given increasing demand for and declining supply of oil. In fact, a previous fuel consumption analysis performed for Boeing by Conklin & deDecker showed the historical rate of fuel price increase over the past 21 years as 5.7%, so 5.1% could be considered a bit conservative. In this fuel price schedule, prices again started at $2.83, but increase at 5.1% annually.
Fuel Cost Analysis

Fuel is the single largest driver of life-cycle cost analyzed. Two approaches were evaluated to determine the cost of fuel over time. In the first approach, indices provided by the Air Force were used to calculate the fuel price for any given year. Over 40 years, the average annual escalation in fuel price is approximately 2.5%. The second approach used a market-based industry composite derived from various sources such as the Department of Energy and the International Energy Agency. This approach yielded an annual escalation of 5.1%, a level that reflects potential actual fuel price growth given increasing demand for and declining supply of oil.

In Scenario 1, using the Air Force fuel price schedule, total life-cycle expenditures on fuel in then-year dollars (including inflation) are $29.5B for the B767 and $38.2B for the A330. Thus, over the life of the fleet, an additional $8.6 billion would be spent on fuel for the A330 or 29.5% more than would have been spent on the B767 fleet.

Assuming the same mission profile as the op tempo increases, the fuel burn rates for both aircraft remain the same for each scenario. Thus, in Scenario 2, an increase in annual utilization from 489 hours per aircraft to 750 hours per aircraft drives fuel consumption up proportionally. Given the lower fuel burn rate of the B767, the life-cycle differential increases to $13.3 billion while the percentage difference remains 29.5%.

However, the more significant change is driven by using the industry composite fuel price schedule in Scenario 3. This change drives a significant increase in total life-cycle fuel cost to $149 billion for the A330 and $115 billion for the B767, nearly a three-fold increase in fuel costs over Scenario 1 using 489 hours and the Air Force fuel price schedule. Again, the cost difference between the B767 and the A330 increases proportionally to nearly $34 billion. This analysis drives home the point that the results are quite sensitive to fuel prices and utilization rates. Conflict situations with high utilization often are accompanied by higher fuel prices, both of which magnify the difference in cost between the two aircraft.

Aircraft Maintenance Cost Analysis

In total, the A330 Maintenance Life-Cycle costs are 8.8% higher for Scenario 1 (489 hours) and 8.2% higher for Scenarios 2 and 3 (750 hours), just over $2 billion higher in both cases. Figure 3 shows only two sets of scenario data since utilization – and thus the maintenance costs – are the same for both scenarios 2 and 3.
Aircraft maintenance can be subdivided into four distinct categories of maintenance. The first is \textit{airframe heavy maintenance} which consists of a series of intensive inspections performed in the hangar. There are minor checks, sometimes known as C-checks, and heavy checks which are often referred to as D-checks or sometime 4C-checks, an indication of the sequence of heavy maintenance checks. The standard Maintenance Planning Document (MPD) intervals for C-checks and D-checks are the same for the B767 and the A330 at 6,000 flight hours or 18 months for C-checks and 24,000 flight hours or 72 months for the D-checks.

Aircraft also require more maintenance as they age, so heavy checks performed later in an aircraft’s life require more man-hours than those performed early on. This is because as an aircraft ages, more discrepancies are found during the inspection tasks of a check and more effort is required to correct those discrepancies. C-checks early in an aircraft life require 2,000 - 4,000 man-hours while those later in the life-cycle may require more than 10,000 man-hours.

The airframe heavy maintenance costs are the same for all three of the scenarios being summarized here. Neither the increase in fuel prices nor the increased utilization has an impact on the airframe heavy maintenance costs. This is because the checks are all calendar driven when utilization is low and the calendar limit is reached well before the flight hour limit. In this analysis, using a standard maintenance plan for both the A330 and the B767, there is approximately a 15% difference in the costs. More than $10.7 billion in then-year dollars will be spent on the airframe heavy maintenance for the A330. In contrast, $9.3 billion will be spent on heavy maintenance for the B767, a difference of $1.4 billion. This difference is primarily driven by the lower number of man-hours required for a B767 C-check compared to those required for an A330 C-check. Given the size and weight difference, this result is certainly consistent with expectations.

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In Scenario 1, 489 hours of utilization and the Air Force fuel cost schedule, the line maintenance costs in then-year dollars for the A330 are $7.2 billion, compared with $7.0 billion for the B767 or a net difference of $200 million. There is a minor increase in the line maintenance life-cycle cost for the 750 hour scenarios – Scenarios 2 and 3. Most of the line maintenance checks are calendar driven with the exception of the transit checks which are directly proportional to the number of flights in a year. So, given an increase in utilization from 489 flight hours to 750 flight hours and fixed-flight duration of four hours, the number of transit checks will increase and the total life-cycle costs will increase for both aircraft types by about $400 million.

In the air transport Maintenance Repair & Overhaul (MRO) market, engine overhaul is the largest maintenance cost segment. However, wide-body aircraft in the air transport market typically fly 4,000 hours per year, many times the utilization of military aircraft. Since engine maintenance is “on-condition” and not calendar driven, a reliable commercial engine used in a low-flight hour environment might stay on wing many years before removal for overhaul.

However, the shop visit intervals for engines operating in a military environment are often much shorter than those for the same engines in the more benign air transport environment. AeroStrategy has data on other engines that suggest that the shop visit interval might be a little as half of the typical commercial interval. One might argue that this is not the case for the engines on a tanker which tends to be flown more like a commercial jet than a military transport which might be landing on rugged airfields in a hostile environment where maximum power is often used on takeoff until reaching a safe altitude. On the other hand, using the typical commercial intervals for the CF6-80E and the PW4000-94, which are more than 20,000 and 22,500 hours respectively, would suggest that the engines would only come off wing once in the 750 hour scenarios and not at all in the 489 hour scenario. This seems unreasonable and, as such, AeroStrategy chose to scale back the shop visit intervals and made the intervals equal for both engines, even though the B767’s engine (PW4000-94) historically has more time on wing. That way, the number of shop visits over a forty-year life seems more reasonable.

The shop visit costs for the two engine types are actually quite similar - $2.12 million for the first PW4000-94 (B767) shop visit and $2.16 million for the CF6-80E’s first shop visit. In Scenario 1, 489 hours of utilization and the Air Force fuel cost schedule, the engine overhaul costs in then-year dollars for the A330 are $4.7 billion, compared with $4.6 billion for the B767 or a net difference of $100 million. Total life cycle engine overhaul costs for the 750 hour scenarios increase proportionally to $6.7 billion for the A330 and $6.6 billion for the B767.

Component repair is the diverse business of repairing pumps, valves, actuators, auxiliary power units (APUs), landing gear, thrust reversers and a variety of other components. Over the past eight years, AeroStrategy has collected data from Original Equipment Manufacturers (OEMs), operators, and Maintenance Repair & Overhaul providers to allow the accurate estimate of the average cost per flight hour for most components categories (or Air
Transport Association Chapters). Event forecasts similar to engine overhaul, are used for several component categories including APUs, thrust reversers, and landing gear. Given that most component categories are analyzed using a cost-per-flight-hour basis, component repair spend tends to be fairly proportional to aircraft utilization. This is evident in the results for the two levels of utilization in the three scenarios being summarized here. In Scenario 1 with 489 hours of annual utilization, the total life-cycle cost of component repair in then-year dollars is $3.7 billion for the A330 and $2.9 billion for the B767, so the A330 is $900 million or 29.6% more costly over the life of the program than the B767.

In the 750 hour scenarios, this logic continues and the cost benefit the B767 shows increases slightly to $1.0 billion over the life of the program.

**Introductory Investment**

The final cost category analyzed is “introductory investment”. This includes initial investment in spare parts (rotables and consumables), spare engines, and maintenance tooling (Includes special tools to support Line checks, A checks, daily servicing, limited troubleshooting, aircraft jacking and some unscheduled maintenance including wheels/tires/brakes changes, avionics systems checks, etc). For the B767, Boeing provided actual provisioning recommendations for the airframe spares and maintenance tooling. AeroStrategy estimated the A330 initial investment in airframe spares and maintenance tooling using the ratio of maintenance spend as a proxy for the ratio of investment required. For both aircraft types, AeroStrategy used a standard analysis to estimate the number of spare engines required. This analysis considers the repair turn-around time, the desired protection level, flight hours, the mean time between unscheduled removals and the quantity of engines per aircraft to estimate the number of spare engines needed.

The analysis does not include investment required to set up in-house heavy check or engine overhaul capabilities.

For the 489 hour scenario, Initial investment is estimated to be approximately $400 million for the A330 and $300 million for the B767, a $100 million difference. The percentage difference – 32.5% in this case - remains fairly consistent with other costs analyzed in this study. For the 750 hour scenarios, the initial investment required increases about $100 million for both aircraft types, the difference remains the same and the percentage difference is about 29.5%.

**Present Value Analysis**

These expenditures are spread over the period from 2014 when the first aircraft is delivered through 2066 when the last is retired, so an important measure is the present value of the respective series of costs. The discount factor used for this analysis was 4.5%, a relatively low discount factor provided in the Air Force Tanker RFP. Table 15 summarizes the present values for both aircraft, each of the cost categories and all three scenarios.

In each scenario, fuel accounts for the most significant portion of the Present Value of the life-cycle cost – 58 to 61% of the total in Scenario 1; 65 – 67% in Scenario 2 which represents higher utilization; and 80 – 82% in Scenario 3 in which an industry composite fuel price schedule.
Overall, the present value of the life cycle cost for a fleet of 179 B767s ranges from $13.4 to $32.1 billion while the values for a fleet of A330s range from $16.5 billion to $40.6 billion. Thus the difference in present value ranges from $3.1 billion to $8.4 billion.

Conclusions

As expected, since the Airbus A330 is larger and heavier, it is also a more expensive airplane to operate than the Boeing 767 and it has correspondingly higher life-cycle costs.

In Scenario 1, which most closely reflects the Air Force RFP, the total lifecycle cost in then-year dollars for the A330 is $11 billion (20%) more than the life-cycle cost of the B767.

Scenario 2 illustrates the impact on the life cycle costs of higher utilization. In this scenario, fuel becomes an even more important cost. The total lifecycle cost in then-year dollars for the A330 is $16 billion (22%) more than the life-cycle cost of the B767.

Scenario 3 builds upon Scenario 2 and addresses the impact of fuel prices that increase at a rate faster than inflation due to growing demand with increasingly limited supply. An industry composite fuel price schedule is used in which fuel prices increase at 5.1% annually rather than 2.5% as specified in the Air Force Tanker RFP. Driven by expensive fuel, total life cycle costs are $179 billion for the A330 and $143 billion for the B767, a difference of $36 billion or 25%.

In summary, the total life cycle cost in then-year dollars for a fleet of 179 B767s ranges from $11 billion to $36 billion less than for a fleet of 179 A330s as shown in Figure 4 and Table 16 on the following page. On a “per aircraft” basis, depending upon the scenario, the total life cycle cost for each B767 ranges from $60 million to $200 million in then-year dollars less than for an A330. Similarly, the present value of the life cycle cost for a fleet of 179 B767s ranges from $3.2 billion to $8.5 billion less than for the A330. On a “per aircraft” basis, depending upon the scenario, the present value of the life cycle cost for each 767 ranges from $18 million to $48 million less than for an A330.
### Table 16 - Life Cycle Cost Comparison

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Annual Utilization</th>
<th>Fuel Price Schedule</th>
<th>Total Program LCC (Then-Year Dollars)</th>
<th>Δ</th>
<th>%Δ</th>
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</thead>
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<tr>
<td>1</td>
<td>489</td>
<td>Air Force</td>
<td>$54, $65</td>
<td>$11</td>
<td>20%</td>
</tr>
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<tr>
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Figure 4 - Life Cycle Cost Comparison