Flexibility in Large Commercial Aircraft Program Valuation

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Executive Summary

With increasing pressure to reduce the environmental impacts of aviation, and the near completion of Boeing's 787 and Airbus's A380 large commercial aircrafts, manufacturers will search for the next program to undertake. The purpose of this report is to evaluate the impact of incorporating flexibility in large commercial aircraft program design.

The development and production of a new single aisle aircraft was investigated. A stochastic demand model was calibrated using historical data to simulate demand over the next 20 years. An aircraft program valuation model was developed using numerous assumptions based on the literature, news clippings, and consultation with industry experts.

An inflexible design was compared to two flexible designs. For the inflexible design, the production facility was built large with the capacity to produce 600 aircraft per year. For the flexible design, the production facility was built small, with the capacity to produce 300 aircraft per year, but with the option to expand in the future. Two different decision rules were tested: (1) to expand capacity if demand exceeded capacity for two consecutive years, and (2) to expand capacity if the rate of increase in demand over the past year, projected forward one year using a linear interpolation, exceeded current capacity.

It was found that the expected net present value of both flexible options exceeded that of the inflexible option. Rule 1 yielded an E(NPV) of $10.4 billion, Rule 2 $9.6 billion, and the Build Large option $5.4 billion. Although the expected present value of the capital expenditure for Rule 1 was slightly larger than for the Build Large option ($9.6 vs. $9.4 billion), the return on investment for Rule 1 was 1.09 vs. 0.57 for the inflexible option. Further, the flexible designs provided protection in low demand growth scenarios, reducing the downside risk, but also included the option to take advantage of upside opportunities.

It was found that flexibility yielded significant value to aircraft programs due to the high volatility in demand for single aisle aircraft and the uncertainty in future demand growth. It is recommended that managers seek opportunities to incorporate flexibility in the design of future large commercial aircraft programs.

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1.0 Introduction

Competition between Airbus and Boeing has been called the greatest rivalry on earth. As a duopoly in which both manufacturers have full product lines that span the 100 to 500+ seat, short-, medium-, and long-range markets, competitors attempt to gain market share by producing aircraft that outperform their rival's. But the development and production of a new aircraft involves large capital outlays, long payback periods, and are akin to betting the company (Busch, 1999). Managers require an accurate understanding of how to increase the value of aircraft programs by reducing downside risk and taking advantage of upside opportunities the market may present.

With the entry into service of Airbus' A380, and the expected completion of the Boeing 787 in early 2011, manufacturers will investigate the next aircraft development project that will result in environmental improvements and operating cost savings. Single aisle, 150-185 seat aircraft form the backbone of the world's air transportation system. With nearly 15,000 new aircraft expected to be delivered in the next 20 years (Boeing, 2010), single aisle aircraft are the largest commercial segment. Airbus' A320 entered service in 1988, while the first Boeing 737 was delivered in 1968 and most recently updated in the late 1990s. As environmental concerns mount and airline profits suffer from increased fuel costs, the next program will likely provide fuel burn improvements to the single-aisle market.

To make critical decisions, managers at Boeing, Airbus, and new market entrants from China, Russia, and Canada will need to design aircraft development and production programs that reap maximum value in a cyclical market with volatile demand. The purpose of this report is to analyze the impact of incorporating flexibility in large commercial aircraft program design.

1.1 System Definition

The system to be analyzed is the development and production of a new single aisle aircraft in the 150-185 seat short- to medium range market. Uncertainty in the system comes from varying demand for aircraft, as measured by aircraft deliveries per year. Combinations of exogenous and endogenous factors lead to this uncertainty. Passenger and freight demand for air transportation is correlated with growth in GDP, resulting in demand for aircraft from airlines and leasing companies. Labor union action, competitive strategies, and other management decisions impact deliveries per year. The uncertainty in demand is calibrated using historical data to encompass these various factors.

2.0 Modeling Uncertainty

The primary source of uncertainty in the system is demand for single aisle aircraft over the next 20 years (which is assumed to be the program lifetime).

2.1 Historical Demand Trends

Narrow body aircraft deliveries are cyclical, with high volatility. Figure 1 shows deliveries for narrow body aircraft over the past 20 years:

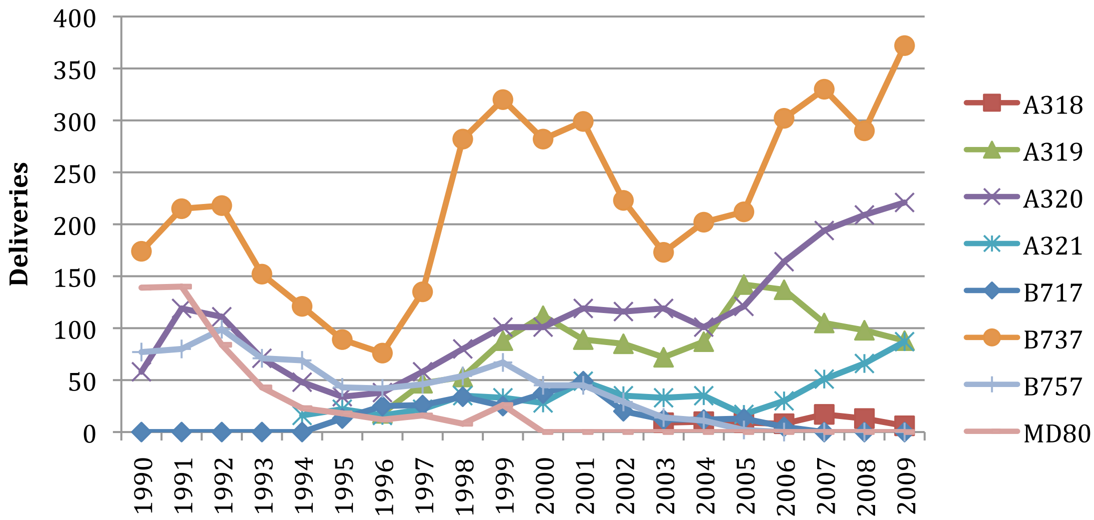

Figure 1: Narrow body deliveries, 1990-2009 (Boeing and Airbus (2010))

Figure 2 shows the annual percent change in deliveries of Boeing 737s and Airbus A320 – the market for which this project is focused.

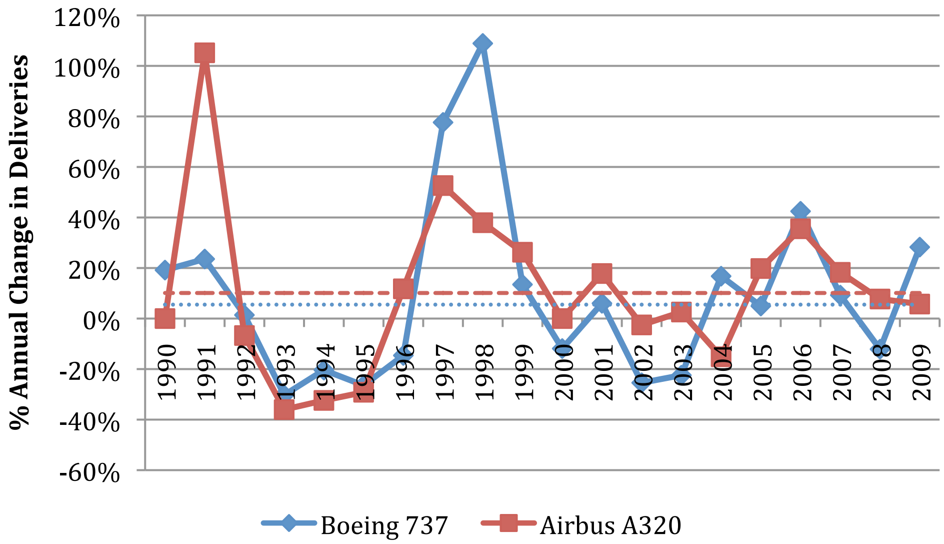

Figure 2: Annual % change in 737 and A320 deliveries, 1990-2009
(Boeing and Airbus, 2010)

This figure shows significant volatility in annual delivery growth rates around the means of 10% for the A320s and 5.5% for the 737s.

2.2 Demand Forecasts

Market demand forecasts are notoriously inaccurate. Every year, aircraft manufacturers release a 20-year demand forecast that outlines their expectations for the market and forms the basis of their strategic moves.

To assess the uncertainty in forecasts for jetliner demand, the *Boeing Current Market Outlooks* between 1991 and 2010 were investigated. The forecast is broken down by geographic region and aircraft market segment, including: regional jets (<90 seats), single-aisle, twin-aisle, and large jets. The market outlook is based on proprietary models and produces forecasts for demand in each region and market segment, as well as the expected dollar value of each market. Figure 3 shows the 20-year forecasts released each year from 1991-2010:

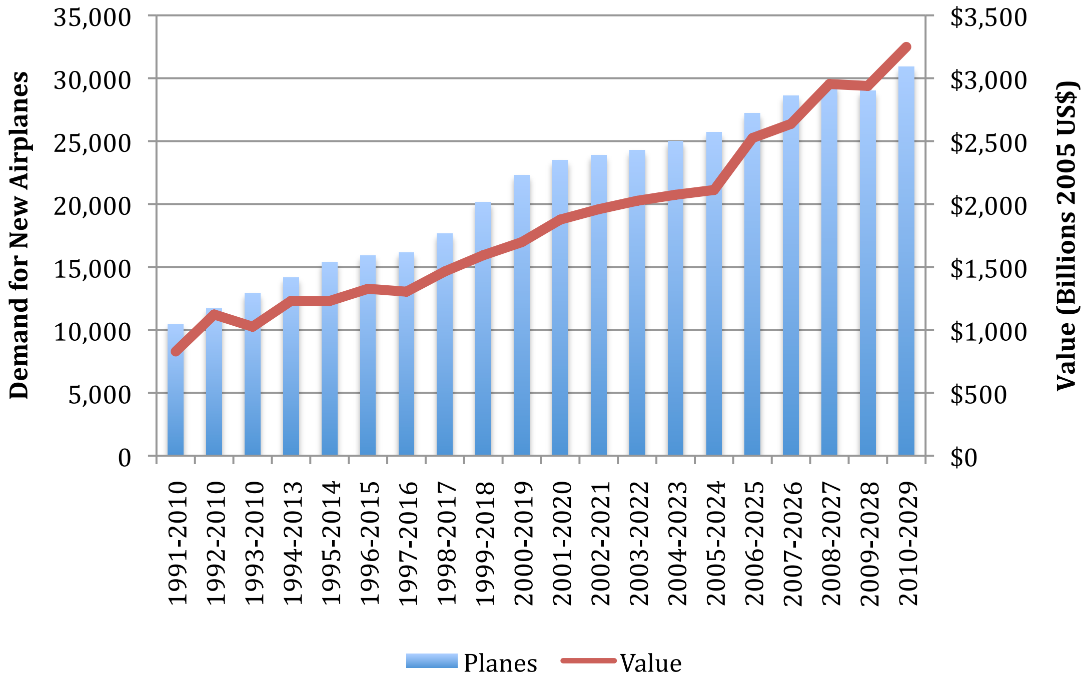

Figure 3: Boeing Current Market Outlook, 1991-2010[1]

Making the crude assumption that deliveries from each year's 20-year forecast are evenly spread over the 20-year period (i.e. if the 20-year forecast is for 10,000 airplanes, it is assumed that 500 airplanes are forecasted to be delivered per year), Figure 3 shows the shortfall in actual, from forecasted, deliveries:

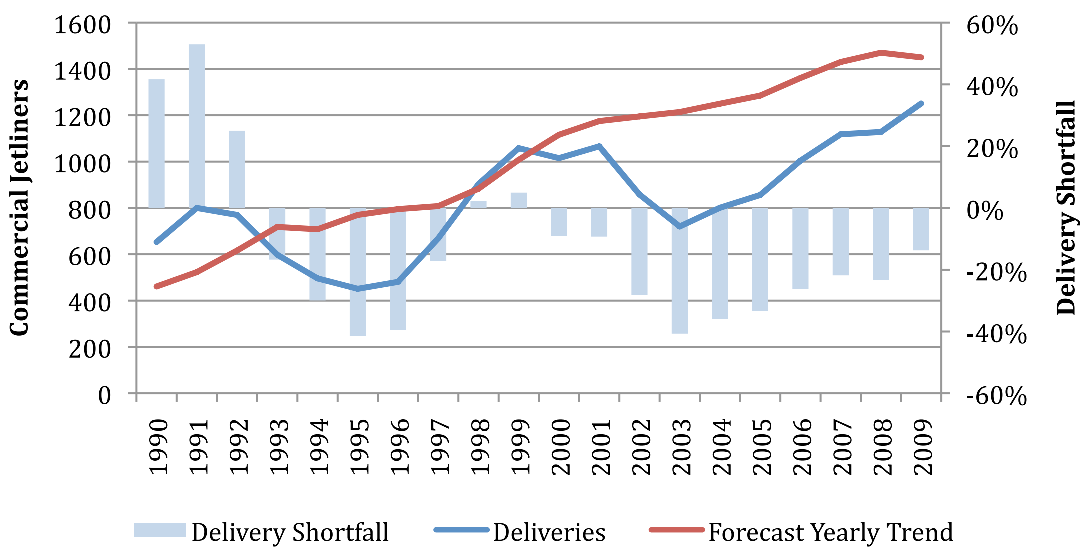

Figure 4: Shortfall in Deliveries from Boeing's Yearly 20-Year Forecast[2]

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[1] Forecast values adjusted to 2005 US$ using data from the Bureau of Economic Analysis (BEA).

[2] The Boeing Current Market Outlook includes forecasts for regional jet deliveries. As shown in the Appendix, Boeing and Airbus data for actual deliveries were easily obtainable, but other

Table 1 provides summary statistics on the accuracy of the forecasts:

	Relative Difference	Absolute Difference
Mean	-13%	-177
SD	27%	222
Minimum	-41%	-494
Maximum	53%	277

Table 1: Summary of Forecast Uncertainty

Taking the absolute value of the percent difference between the forecasted deliveries and the actual deliveries yields a mean difference of 26% with a standard deviation of 14% and a maximum difference of 53%. Figure 4 shows the cumulative percent probability of the forecast being accurate within a percentage range:

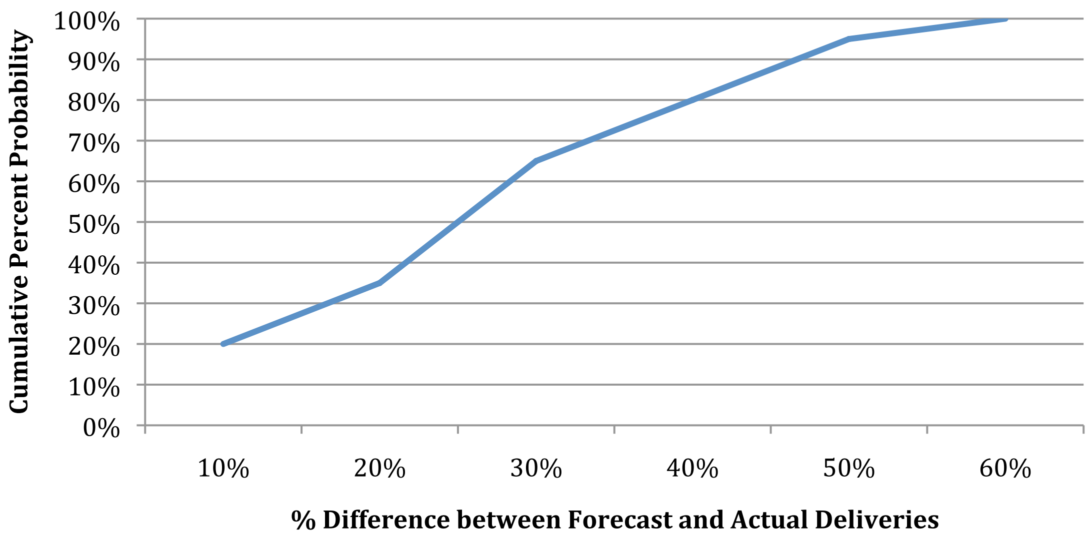

Figure 5: Cumulative Percent Probability of Forecast Accuracy

Therefore, it can be concluded that on a year-to-year basis, Boeing's long-term industry forecasts have significant uncertainty.

A few comments about this conclusion should be made:

- First, the long-term forecast does not take into account industry cycles that are clearly visible in the actual deliveries shown in Figure 3. These cycles increase the standard deviation of the forecasts from the actuals even though the forecasts aim to track the long-term trend instead of short-term deviations from the trend.

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manufacturer's data was not available on their websites. These values were estimated with questionable accuracy.

- Second, this analysis was based on the crude assumption that aircraft were delivered in equal numbers over the course of the 20-year forecast, which was likely not one of the forecaster's assumptions.
- Third, only the aggregate numbers in the Boeing forecast were analyzed. The annual forecast is broken down into several geographic regions and aircraft markets. It could be that the variance observed in the aggregate forecast was largely due to certain sub-market forecasts.

Unfortunately, with the data available, there is only one 20-year forecast period to compare against actual aircraft delivered: in 1990, Boeing forecasted ~9225 aircraft to be delivered between 1990 and 2009. The actual number of aircraft delivered was ~16,696, a difference of ~45%.

2.3 Stochastic Demand Model

For the overall market, uncertainties in the demand for single aisle jetliners can be considered exogenous to the actions of aircraft manufacturers. The overall demand growth is generally derived from population growth, economic growth, and changes in the propensity to travel due to cultural and economic factors.

If manufacturer's produced an aircraft with substantial operating cost improvements, this would result in lower air fares, stimulating demand for air travel, and resulting in increased demand for aircraft, but it is assumed that the time lag in this feedback loop is longer than the 20-year time horizon of this analysis.

Managers can influence the market share they capture by altering sale prices or developing an aircraft that is superior to the competition's aircraft. In the current duopoly competition between Boeing and Airbus, it is assumed that the market is split 50/50, and will continue to be split 50/50 for the duration of the new aircraft program. This assumption may be invalid as if one manufacturer introduced a new aircraft in this market segment, but the other did not, the mover would likely increase their market share. This complexity is not taken into account in this analysis.

The distribution of future deliveries is likely continuous and cyclical, but has the potential for discrete jumps and drops. External competition from other aircraft manufacturers, world events (i.e. wars and outbreaks of disease), economic cycles, as well as oil market fluctuations can cause discrete changes in the demand for jetliners. Due to the potential for non-stationary processes in the evolution of demand, a simulation approach is appropriate for this market.

An alternative approach would be to use a binomial lattice model. Peoples (2004) uses this approach to model demand for narrow body and wide body aircraft. Although computationally efficient, this approach excludes the potential for a "game changing" aircraft to be produced by a competitor, or for shifts in demand for air travel to occur. In the case in which a competitor produces a superior aircraft, or a new entrant enters the market and takes market share from an incumbent manufacturer, the demand forecast for an aircraft can change with discrete jumps. Further, with the advent of affordable air transportation in India and China, there is significant potential upside in the market that could lead to scenarios of significant jumps in demand for aircraft.

To model 20-year demand for a new single aisle aircraft, simulation of a mean reverting process has been selected. The following equation was used to calibrate the mean reverting process (Blanco and Soronow, 2001):

$$X_{t+1} - X_t = \kappa(\mu - X_t) + \sigma\varepsilon_{t+1} \qquad (1)$$

where the expected change in demand ($X_{t+1} - X_t$) was modeled as a function of:

- The mean reversion component:
  - κ – the speed of adjustment coefficient.
  - μ – the long run mean value of annual percent change in deliveries
- The random component:
  - σ – demand volatility
  - ε – the value of the random shock independent of X

The three parameters required to calibrate the process are: (1) speed of adjustment coefficient, (2) demand volatility, and (3) long run mean.

Based on the assumption that demand in the industry will evolve over the next 20 years in much the same manner as demand over the past 10 years has evolved, historical demand can be used to calibrate the speed of adjustment coefficient and the demand volatility parameters. The past 10 years are used to calibrate these parameters as Figure 2 shows significant differences in the delivery reference modes between the periods 1990-1999 and 2000-2009. It is assumed that manufacturers made adjustments that have dampened fluctuations in yearly deliveries.

The long run mean growth rate is calibrated using 2009-2028 market forecasts from Boeing, Airbus, Embraer and Bombardier, as summarized in Figure 6. Based the current order backlog, it was assumed that 68% of the single aisle forecast was for the 737-800 and A320 replacement aircraft that is being examined in this report.

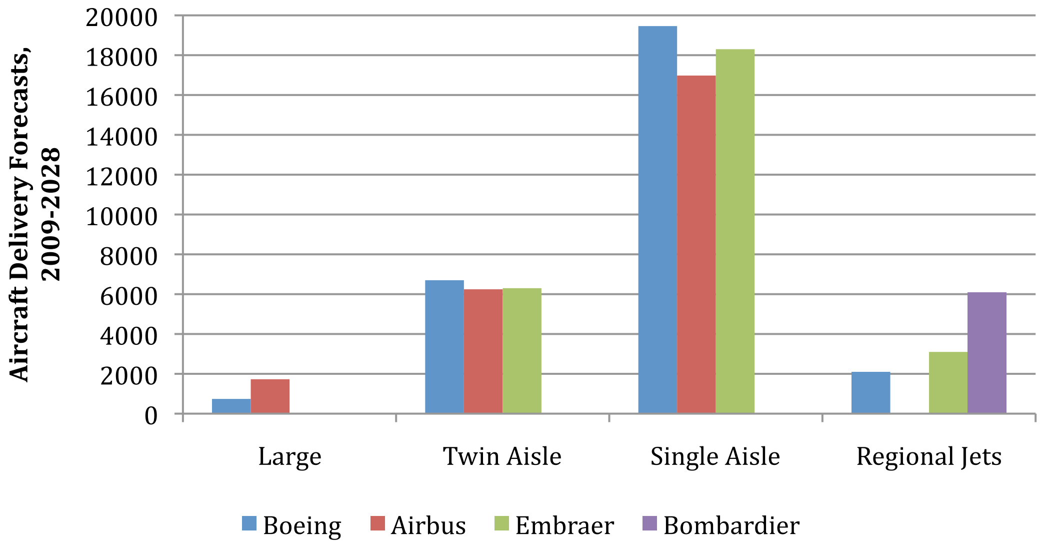

Figure 6: Summary of Aircraft Manufacturer Market Forecasts, 2009-2028.

Table 2 summarizes the model calibration parameters derived from the historical data and manufacturer forecasts:

Table 2: Mean Reversion Demand Model Calibration Parameters

Calibrated Parameter	Value	Standard Error
Initial Year Demand	462	30
Long Run Mean Demand Growth Rate (μ)	2.3%	3.9%
Speed of Adjustment Coefficient (κ)	0.94 years*	0.37 years
Demand Volatility (σ)	15.7%*	5.3%

*Significant at the 95% confidence level

The output of the 20-year demand forecast model is summarized in Figure 7 and Table 3:

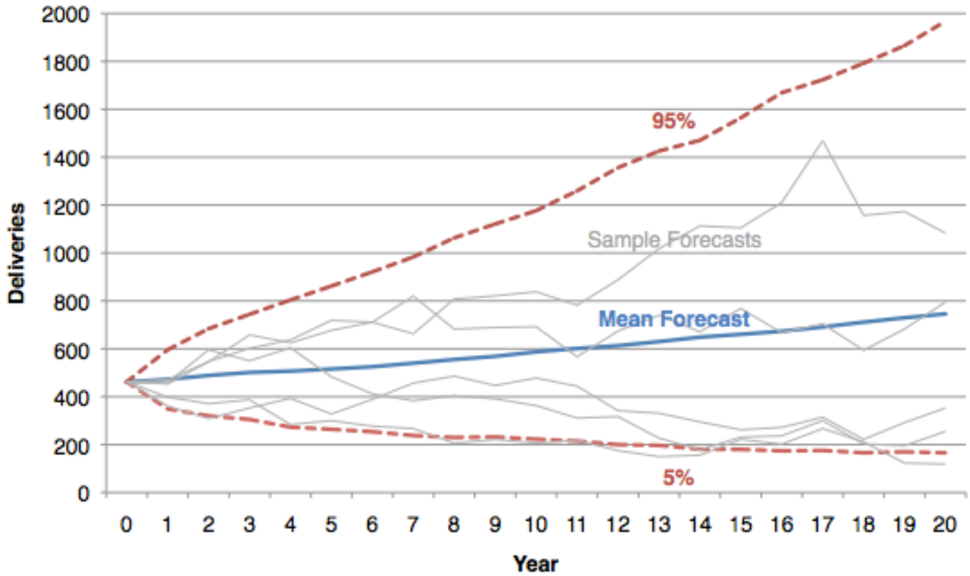

Figure 7: Narrow Body Demand Forecast Model

Table 3: Narrow Body Demand Forecast Summary Statistics

	20-year Deliveries
Mean	12,527
S.D	5,926
95%	23,502
5%	5,668

3.0 System Design

The system to be analyzed is the development and production of a new single aisle aircraft in the 150-185 seat short- to medium range market. It is assumed that managers initially have three decisions:

1) Whether or not to invest in the development and production of a new aircraft.
2) What size to initially build the production facility.
3) Whether or not to build the production facility with the flexibility to expand in the future.

If managers decide to develop a new aircraft, their available options are:

1) Build the production facility large, with capacity to produce 600 airplanes per year (the average yearly demand over the 20 year period), without the flexibility to expand.
2) Build the production facility small, with the capacity to produce 300 airplanes per year, but with the flexibility to expand the facility in the future.

3.1 Deterministic Design

To determine the value of flexibility in this problem, a deterministic design was developed first:

- The production facility is initially built large, with capacity to produce 600 airplanes per year and without the flexibility to expand. Further, the program is maintained for the duration of the expected 20-year lifetime.

A variety of assumptions went into the model, summarized in Table 4:

Table 4: Aircraft Program Valuation Model Assumptions

Variable	Assumptions	Source
Development Cost	Build Large= $12 billion Flexible Options = $10 billion	Bloomberg (2010)
Development Time	6 years	Markish (2002)
Aircraft Sale Price	$50 million	Airline Monitor (2004)
Fixed Costs of Production	$4 million/unit capacity/year	Assumed
Learning Curve Slope	Labor = 85% Other = 95%	Markish (2002)
% Production Costs	Labor = 41% Other = 59%	Markish (2002)
Theoretical First Unit Cost	$75 million	DAPCA IV (1999), Raymer (2006)
Initial Production Capacity	Build Large = 600/year Flexible Options = 300/year	Assumed
Capacity Expansion Costs	$2 billion /(100/year)	Assumed
Market Share	50%	Assumed
Initial year demand	462	2007-09 average
Long Run Mean Demand Growth Rate	2.3%	Manufacturer forecasts
Speed of Adjustment Coefficient	0.94 years	Estimated from 2000-2009 data
Demand Volatility	15.7%	Estimated from 2000-2009 data
Discount Rate	8%	IATA (2007)
Valuation Period	20 years	Assumed

Learning effects throughout an aircraft program results in substantial reductions in unit production costs (Raymer, 2006). The learning curve was modeled in the same manner as Markish (2002), using the equation:

$$UnitCost_i = TFUC \bullet Q_i^{\ln \beta / \ln 2} \qquad (2)$$

where the unit production cost of the ith aircraft produced is a function of:

- TFUC - the theoretical first unit cost calculated using the DAPCA IV aircraft program valuation statistical model based on historical commercial and military programs (Raymer, 2006).
- Q - the quantity of aircraft produced before the ith aircraft.
- β – the learning curve slope.

The development costs were distributed in the same manner as Markish (2002) using a model developed by Boeing Phantom Works:

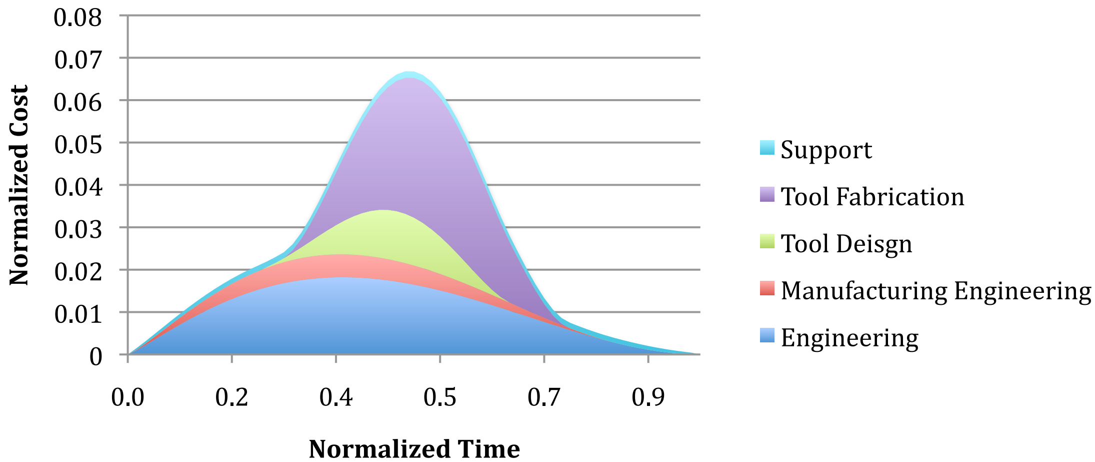

Figure 8: Distribution of Aircraft Development Costs

A spreadsheet model was developed to calculate yearly revenues (consisting of deliveries times the sale price) and yearly costs, consisting of:

- Development costs in the initial 6 years of the project
- Fixed costs of production after development had been completed
- Variable costs of production that declined with the quantity of aircraft produced, as defined by the learning curve.

Yearly revenues and costs were discounted back to year 0 to calculate the net present value. 10,000 Monte Carlo simulations were used to generate the expected net present value of the program within the possible demand scenario space.

Figure 9 demonstrates a sample cash flow, without demand volatility, for the inflexible design:

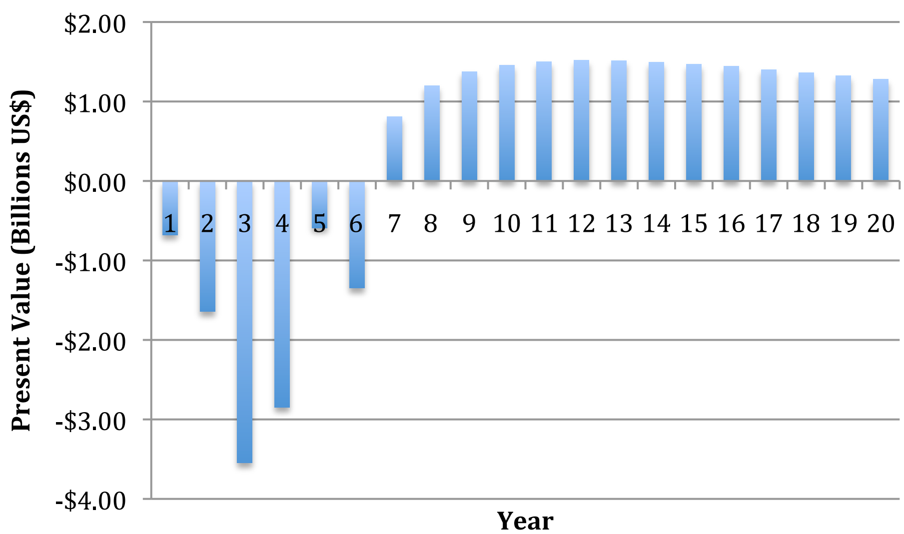

Figure 9: Sample Inflexible Design Cash Flow (without demand volatility)

In Years 1-5, capital is expended on research, development, testing, and evaluation (RDT&E) of the aircraft, as well as construction of the production facility. Year 6, fixed costs of maintaining the production facility begin, but the first aircraft is not delivered until Year 7. It takes 2-3 years to produce enough aircraft to move down the production learning curve, reducing the unit cost of production, and increasing yearly profits. Cash flows are discounted to present value terms, reducing the contribution of positive cash flows far in the future.

3.2 Flexible Design

The alternative to the deterministic design is to implement a flexible design in which managers are assumed to make decisions over the lifetime of the aircraft program. For this option the production facility is initially built smaller, but with the option to expand to meet future demand. Two types of decision rules were incorporated into the flexible model:

1) Exit the market.
2) Expand production capacity.

The decision to exit the market is made if the program is not profitable for two consecutive years after the aircraft development has been completed. Managers decide to exit the market and reassign production resources, eliminating fixed costs for the remainder of the project and limiting losses to the initial aircraft development costs.

Two decision rules were tested to trigger the expansion of production capacity:

- ***Rule 1: "Play it safe"*** **-** If demand exceeds production capacity for two years in a row, invest $2 billion to expand capacity by 100/aircraft/year.

- ***Rule 2: "Expand with the upswings"*** **-** If the rate of increase in demand over the past year, projected forward one year using a linear interpolation, exceeds current capacity, invest $2 billion to expand capacity by 100/aircraft/year.

The remaining assumptions of the flexible design are outlined in Table 4 and the previous section.

4.0 System Performance

Summary statistics of 10,000 simulations are exhibited in Table 5:

Table 5: Summary Statistics for Simulations (billions US$)

	Rule 1 *"Play it safe"*	Rule 2 *"Expand with the upswings"*	Build Large
E(NPV)	$10.4	$9.6	$5.4
Std	$13.0	$13.8	$15.1
5%	-$6.9	-$7.6	-$14.6
95%	$35.1	$36.3	$34.9

The expected net present value for Rule 1 was slightly higher than Rule 2, but both flexible options had a higher E(NPV) than the inflexible option. Rule 2 had slightly more downside (as shown by the 5% values), but less downside than the inflexible "Build Large" option. Rule 2 had the most upside with the highest 95% value.

For the 10,000 Monte Carlo simulations, Rule 1 was the best option with 53% probability, Rule 2 was with 36% probability, and the Build Large option was the best 11% of the time. Figure 10 shows the cumulative distribution functions for the three options investigated:

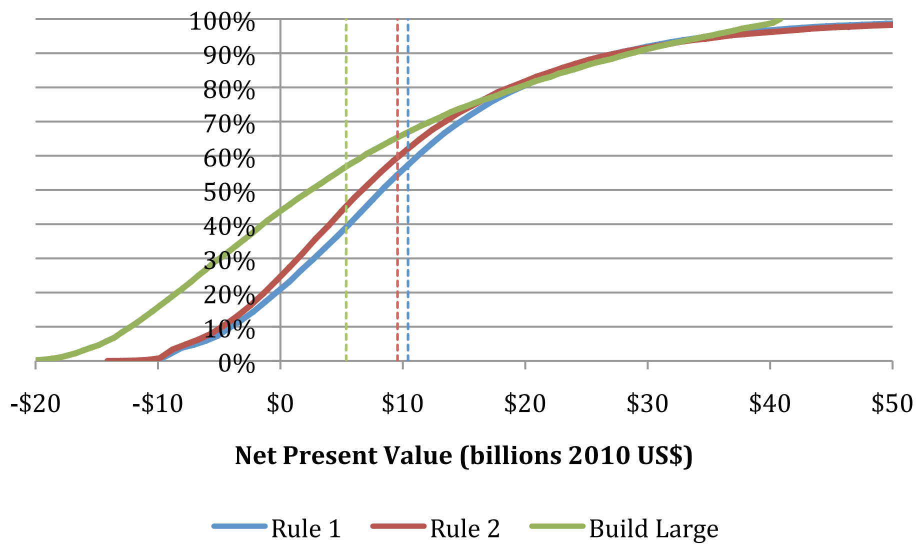

Figure 10: CDF for the Three Options Examined.

Figure 11 shows the probability distributions for the three options examined:

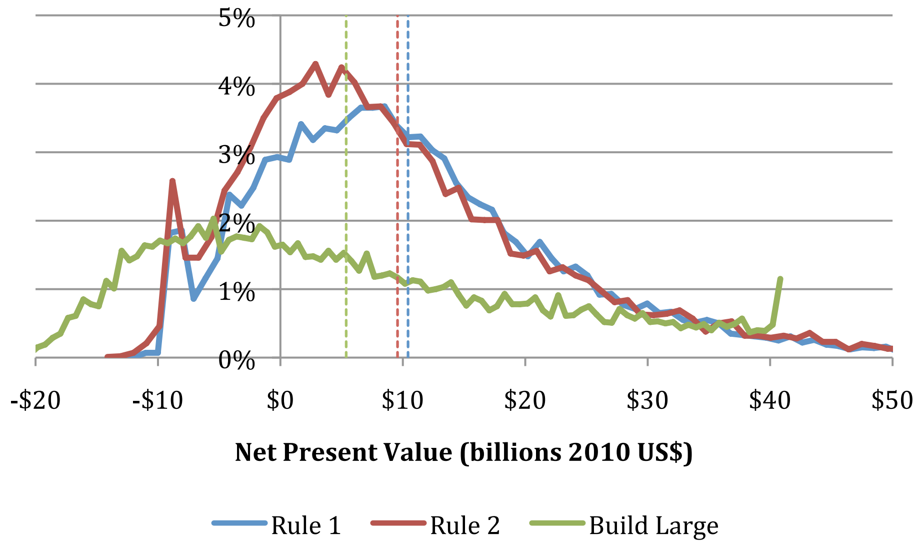

Figure 11: Probability Distribution for the Three Options.

The figures show that the inflexible option had more downside than either of the flexible options, and did not take advantage of the upside opportunities in the volatile market for aircraft.

The option to exit the market if demand did not meet expectations once the aircraft development was completed resulted in a bump in Figure 11 for Rule 1 and 2 around -$9 billion. If managers exercised the option to exit the market, losses were limited to the initial aircraft development investment. The option was exercise 6.1% of the time for Rule 1 and 7.2% of the time for Rule 2. The reduction in the downside risk with respect to the Build Large option is also shown in the 5% NPV values shown in Table 5. The Build Large option had significantly more downside risk than either of the flexible options.

Table 6 shows the capital expenditures required for each of the options investigated. In present value terms, building large had the smallest expected present value CapEx, but 59% of the time Rule 1 had a lower present value CapEx, and 41% of the time Rule 2 had a lower CapEx than the inflexible option. The flexible options enabled managers to expand the production facilities when demand exceeded capacity. The average capacity in both of the flexible options in Year 20 were comparable to the Build Large option (480 and 544 aircraft/year vs. 600 aircraft/year), but the 95th percentile of Year 20 capacity shows that managers were able to take advantage of increased demand by tripling production capacity over the 20-year aircraft program life in high demand scenarios.

Table 6: Capital Expenditure Summary (billions US$)

	Rule 1 ***"Play it safe"***	**Rule 2** ***"Expand with the upswings"***	**Build Large**
E(PV(CapEx))	$9.6	$10.4	$9.4
Std	$2.1	$2.5	$0
5%	$7.8	$7.8	$9.4
95%	$13.8	$15.2	$9.4
Year 1 Capacity	300 /year	300 /year	600 /year
E(Y_{20} Capacity)	483	547	600
Std	226	249	0
5%	300	300	600
95%	900	1000	600

Expanding the production rate would likely have other consequences not examined in this analysis, such as impacts on worker hiring and training rates. Figure 12 shows the probability of expansion in four 5-year periods, as well as the average capacity expansion within each of the 5-year periods:

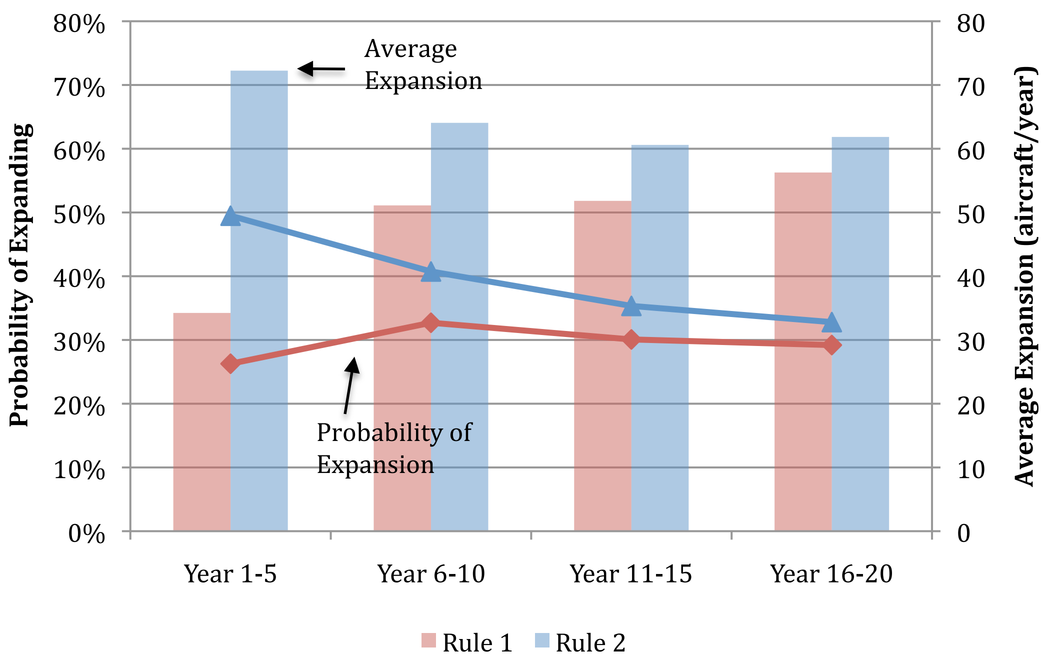

Figure 12: Probability of Expansion within 5 year Periods, by Decision Rule

For Rule 2, 49% of the time capacity was expanded within the first five years, while this was the case 34% of the time when Rule 1 was followed, leading to larger average expansions through the initial periods when Rule 2 was used. Expansions continued to take place throughout the project, into the final years. A different expansion rule could be developed to reduce the number of expansions towards the end of the project that may not be profitable due to the shorter production period following the expansion.

Rule 1 was able to match production capacity to demand more frequently than the other two options, resulting in reduced fixed costs. Table 7 shows the average number of years the production facility was 100 or more units overcapacity, as well as the average number of units over capacity the facility was over the course of the program, for each option:

Table 7: Over Capacity of the Production Facility

	Rule 1 ***"Play it safe"***	**Rule 2** ***"Expand with the upswings"***	**Build Large**
Average Years 100+ Over Capacity	8.5	11.7	17.8
Std	5.6	4.5	3.9
Average Amount Over Capacity	81	125	298
Std	64	54	148

The return on investment for each of the options is evaluated using the metric expected net present value divided by the expected present value of the capital expenditures, as shown in Table 8:

Table 8: Return on Investment

	ROI E(NPV)/E(PV(CapEx))
Rule 1 – *"Play it safe"*	1.09
Rule 2 – *"Expand with the upswings"*	0.92
Build Large	0.57

By this metric, Rule 1 is preferred to Rule 2 and the Build Large options.

The performance results show that both flexible design options for the production facility provided value above the inflexible "Build Large" option. Rule 1 was generally preferred to Rule 2 for each of the measures investigated. The expected NPV of the program with Rule 1 was higher, the CapEx was lower, and the return on investment was higher. Rule 2 did enable slightly more upside than Rule 1, as demonstrated by the 95% E(NPV), but in general Rule 2 led to more rapid expansion of the production facilities in the early years of the program, which resulted in a relatively larger number of years, on average, in which the facility was overcapacity.

Discovering the best set of decision rules would require a more detailed search and a greater understanding of the investor's risk preferences. Simulations of a number of different potential decision rules could be implemented to quantify which rule yields the best results, in line with the investor's risk preferences.

5.0 Conclusion

Incorporating flexibility into the design of new aircraft programs can unleash substantial value for manufacturers. This report demonstrated that incorporating flexibility into the construction of a production facility yields an expected present value increase of $5 billion – nearly doubling this measure. The flexible approach to the design of this system is valuable due to the uncertainty in future demand for aircraft. Growth in demand is caused by exogenous factors, such as population growth, growth in the broader economy, and increased propensity for air travel, while the volatility in demand for new aircraft results from external shocks to the airline industry (such as disease and fuel costs) as well as fleet planning decisions made by airlines. To adapt to this uncertain and volatile market, manufacturers must incorporate flexibility to limit the downside of their programs and take advantage of the upside.

I have gained an increased understanding of how to value projects that span over time, and how investment decisions can be made under uncertain forecasts. Further, the value of flexibility in many projects is much greater than one would first suspect. I have learned to look for opportunities to incorporate flexibility into projects that will yield higher expected payoffs, and reduce the probability of losses.

6.0 Appendix

Table 9 shows the aircraft delivery data used in this analysis. Data highlighted in red was created by the author (based on assumptions) as it was not easily obtainable from the aircraft manufacturer's websites.

Table 9: Aircraft Delivery Data

	Boeing/Douglas	Airbus	Bombardier	Embraer	Fokker	Total Deliveries
1990	527	95			31	653
1991	606	163			31	800
1992	572	157	10		31	770
1993	409	138	20		31	598
1994	312	123	30		31	496
1995	256	124	40		31	451
1996	271	126	50	3	31	481
1997	375	182	60	21	31	669
1998	564	229	70	40		903
1999	620	294	80	64		1058
2000	492	311	106	106		1015
2001	527	325	107	107		1066
2002	381	303	87	87		858
2003	281	305	67	67		720
2004	285	320	98	98		801
2005	290	378	94	94		856
2006	398	434	86	86		1004
2007	441	453	112	112		1118
2008	375	483	135	135		1128
2009	481	498	110	162		1251
					Total =	16696

7.0 References

Airbus (2009). *Global Market Forecast 2009-2028*. Retrieved September 19, 2010 from http://www.airbus.com/en/corporate/gmf2009/

Airbus (2010). *Orders and Deliveries.* Retrieved September 18, 2010 from http://www.airbus.com/en/corporate/orders-and-deliveries/

The Airline Monitor (2004). *Commercial Aircraft Average Price.* http://www.airlinemonitor.com/

Blanco, Carlos and David Soronow (2001). "Mean Reverting Processes – Energy Price Processes Used For Derivatives Pricing & Risk Management." *Commodities Now*, p. 68-72.

Boeing (1990-2010). *Current Market Outlook*. Retrieved September 19, 2010 from http://www.boeing.com/commercial/cmo/, from various Boeing press releases available at http://www.boeing.com/news/releases/archive.html, from Boeing Annual Reports available at http://www.boeing.com/companyoffices/financial/quarterly.htm, and from the SEC at http://www.sec.gov/edgar/searchedgar/webusers.htm

Boeing (2010). *Orders and Deliveries*. Retrieved September 18, 2010 from http://active.boeing.com/commercial/orders/index.cfm?content=userdefinedselection.cfm&pageid=m15527

Busch, Marc L. (1999). *Trade Warriors: States Firms, and Strategic-Trade Policy in High-Technology Competition*. Cambridge University Press.

Markish, Jacob (2002). *Valuation Techniques for Commercial Aircraft Program Design*. SM Thesis, Massachusetts Institute of Technology.

Pearce, Brian (2007). *The Case for Liberalization*. International Air Transport Association (IATA). Retrieved November 19, 2010 from http://www.iata.org/whatwedo/economics/Pages/issue_briefing_new.aspx

Peoples, Ryan E. (2004). *Value-Based Multidisciplinary Optimization for Commercial Aircraft Program Design*. SM Thesis, Massachusetts Institute of Technology.

Raymer, Daniel P. (2006). *Aircraft Design: A Conceptual Approach*. Washington, D.C.: American Institute of Aeronautics and Astronautics.

Rothman, Andrea (October 15, 2010). *Airbus Said to Delay Decision on New Engines for A320 Planes*. Bloomberg News. Retrieved October 15, 2010 from http://www.bloomberg.com/news/2010-10-15/airbus-said-to-delay-decision-on-new-engines-for-a320-planes.html