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Global Aerospace Industries: Rapid Changes Ahead?

12 March 2012

by

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Abstract

This report focuses on aspects of the Boeing-EADS rivalry—in both commercial and military markets. Indeed, the Boeing-EADS relationship is one of the major constellations in the international firmament of defense industrial affairs.

In this report, we discuss the U.S. Air Force selection of the Boeing KC-46 over the EADS KC-45 in 2011, seeking to understand connections between the associated events. In Chapter II, we also seek to find useful explanatory models for Boeing's success.

In Chapter III, we consider the narrow-body airliner market—currently a Boeing-EADS duopoly. Narrow-body airliners have been a central to the firms' rivalry, as well as a major source of profits for both. As such, these narrow-body families have provided a resource foundation for a number of wide-body developments, some of which have become part of the defense marketplace.

The narrow-body market has been so profitable that other firms are positioning themselves to mount major challenges to the two market incumbents. These outlying firms have already made the market, in some sense, more competitive.

If the potential challengers become successful entrants, then Boeing and EADS will have lower profits— with potentially major repercussions for both their commercial and defense product lines.

Keywords: EADS, Boeing, Airbus EADS-Boeing Rivalry, Boeing KC-46, EADS KC-45, KC-X, Airbus A320, Boeing 737

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I. Introduction

This report continues an ongoing project aimed at contributing to a better understanding of the international defense marketplace—an increasingly complex environment. Our intent has been threefold: to understand current defense industrial developments, place those developments in context, and find paradigms suitable for better explanation of those ongoing developments.

Our first report in this series, *Echoes Across the Pond: Understanding EU–US Defense Industrial Relationships* (Franck, Lewis, & Udis, 2008a), considered three current episodes in the transatlantic defense-industrial complexes. The cases under consideration were the F-35 Joint Strike Fighter (JSF), the UK Defence Industrial Strategy, and the European Aeronautic Defence and Space Company (EADS)–Airbus[1] KC-30 aerial tanker proposal. We also discussed three well-known analytical perspectives as candidates for understanding those cases: offsets in international defense trade, transaction cost economics (TCE), and corporate strategy models. In the style of Graham Allison (1971; Allison & Zelikow, 1999), we essayed explanations of all of our cases using all three paradigms. We assessed the offsets perspective as best for understanding the JSF, TCE for the UK's Defence Industrial Strategy, and corporate strategy models for the EADS-Northrop Grumman KC-30 proposal.

Our second report, *New Patterns of Collaboration and Rivalry in the US and European Defense and Aerospace Industries* (Franck, Lewis, & Udis, 2008b), emphasized defense industrial firms—with consideration of Boeing's Model 787 development and production; the KC-45 (or KC-X) competition (through the summer of 2008), which involved the EADS-Northrop Grumman alliance and the Boeing Company; and European defense firms' strategies (BAE Systems, EADS,

[1] Airbus is a division of EADS.

Finmeccanica) for entering the North American defense market through direct investment. Two major themes that emerged were (1) the increasing technical and managerial complexity in modern aerospace systems and (2) the increasing power of relatively agile defense suppliers relative to their increasingly bureaucratic customers.

Our third report, *Global Cooperation and Competition in the Defense and Aerospace Industries* (Franck, Lewis, & Udis, 2010), continued inquiries along the same general lines of this overall project. We continued our exploration of the international defense industrial "terrain," and our search for useful paradigms. The KC-X competition (third installment) considered the explanatory power of two views of the defense establishment customers in the defense marketplace: the traditional model of the sovereign monopsonist versus the governmental politics perspective (Model III) offered by Graham 1(1977; Allison & Zelikow, 1999). We considered the remarkable travails of the A-400M military transport development effort—which came in very late and much over budget. The A-400M (military) was a useful companion piece to our previous Boeing 787 (commercial). Both cases illustrate the increasing complexity of large, international development projects—and the problems that can emerge. A potentially significant change in the structure of the international defense marketplace is the possibly-emerging Nordic defense bloc. In this instance, we found a rather complex situation —with significant attractions to the other Nordic states but also close and useful relationships with partners outside the Nordic region (especially the United States).

Our fourth report, *Emerging Patterns in the Global Defense Industry* (Franck, Lewis, Matthews, Udis, 2011) concerned three topics with the same general aims as previously discussed: the ongoing KC-X story, the C-27, and unmanned aerial vehicles (UAVs). The prolonged KC-X source selection was clearly not a case of delays due to technological immaturity. The KC-X—whether based on Boeing or Airbus designs—is well known, with tanker conversions of the A330 (or A310) and B767 already operational in other air forces. The KC-X case continues to illustrate

the bureaucratic, legal, and political obstacles to acquisition in the United States – as well as their potential for sidetracking the acquisition process.

The C-27, a small air transport of Italian design, is a good example of increasingly international projects in the aerospace industry and the sometimes complicated relationships between aerospace enterprises and their defense customers. It remains a good example, even though the US version (called the C-27J Spartan) has been cancelled.

UAVs involve a range of designs for reconnaissance, or both reconnaissance and strike. We attempted to place the rapid growth of UAVs in context – as a major development both in military affairs and in the defense industrial base. UAVs are an important part of the two ongoing Revolutions in Military Affairs (RMAs). Within that context, UAVs are an important continuation of the reconnaissance-strike embodiment of the information technology (IT)-enabled RMA first demonstrated in the Gulf War of 1991. They are also useful countermeasures against the IT-enabled RMA practiced by terrorist and insurgent groups such as Al-Qaeda and the Taliban.

The effect on the international defense marketplace has, quite possibly, been even more profound. The relative simplicity and cheapness of UAVs means that these systems can be developed with company resources outside the “normal” defense acquisition system, with its highly complex and potentially burdensome processes. A closely related point is that defense systems in this realm are open to a much wider range of suppliers. In fact, a large number of enterprises have been able to finance UAV development projects with their own funds. Countries with high technology and small size, such as Israel, are world leaders in unmanned systems.

In this report, we continue our inquiry into the international defense marketplace and industrial base by focusing on the less-than-cordial rivalry between the EADS and Boeing. The two have competed strenuously in the commercial transport aircraft market, with Boeing’s 737 series against the Airbus A320 family being a centerpiece of that rivalry.

However, the competition extends into military hardware. For example, the EADS Eurofighter (Typhoon) and the Boeing F/A-18 (Super Hornet) both submitted unsuccessful proposals for India's next tactical fighter. Also, the EADS A400M has taken dead aim at the Boeing C-17 military transport aircraft (as well as the Lockheed C-130).

However, the largest military aircraft contest involving Boeing and EADS was the prolonged source selection process for the KC-X. In a real sense, this was a competition between an EADS commercial product, the A330, and Boeing's, the 767. In 2011, the prolonged story of KC-X source selection apparently ended with the US Air Force Boeing KC-46 being chosen. We consider the issues associated with this last source selection iteration in Chapter II of this report. Among other things, it appears that the quarrelsome committee (especially the industrial players) so evident in previous iterations (Franck, Lewis, & Udis, 2010; Franck, Lewis, Matthews, & Udis, 2011) had grown weary of conflict—or perhaps the Air Force and Department of Defense (DoD) had become more adept at working around the dynamics of that committee.

In a larger context, the Boeing-EADS rivalry has become one of the major features in the structure of the global aerospace industry. But that ground may be shifting. The most profitable product lines for both companies have been the narrow-body airliners, the Boeing 737 and the A320 (manufactured by Airbus). Although this part of the EADS-Boeing rivalry has been pursued as strenuously as the others, the international market has provided ample opportunities for both. In fact, narrow-body sales have provided the profits that make possible the wide-body commercial developments—such as the A350 and 380 and the B-787 and 747-8.

But that market is becoming more "contestable." (as defined in Baumol et al., 1982). A number of regional jet manufacturers in Brazil, Canada, China, and Russia are seeking ways to enter the market niche now thoroughly occupied by Boeing and EADS. If serious competition develops for the B737 and A320, then there are potentially big changes ahead for the aerospace industry (both civilian and military).

In Chapter III, we discuss the nature of the Boeing-Airbus narrow-body duopoly; the plans and progress of the aspiring new competitors; and also the incumbents' responses. Finally, Chapter IV essays some concluding comments, particularly on some useful explanatory models.

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II. The KC-X Saga (Continued)

Since power projection and long-range strike is key to US Air Force doctrine, aerial refueling is a key competency for that service. Having high confidence in this mission capability is accordingly a matter of high priority for US military aviation.

This is certainly not new thinking for the US air arms. Serious experimentation in aerial refueling dates back to 1923. After World War II, aerial refueling became an integral part of the US military's operational repertoire. The first operational US. tankers were bomber derivatives—KB-29 and KB-50. These aircraft had retired from active service by the mid-1960s.[2] Variations of transport aircraft proved a better solution (Smith, 1998, especially pp. 1, 43–47).

The first transport-derivative aerial tanker for the US was the KC-97 (closely related to the Boeing Model 377 Stratocruiser), which served from 1950 to 1978, and then the highly successful KC-135 (first delivery in 1957) which remains in service today (Smith, 1998, esp., pp. 43–47). What is firmly settled is that effective aerial tankers are more like transport aircraft than bombers.

Since the last KC-135 delivery occurred in 1965, the Air Force accordingly has become concerned in this last decade with problems and risks associated with age. This motivated the first Air Force attempt to first supplement and then replace KC-135s with a newer design, the Boeing 767.[3]

The ideal tanker aircraft to replace the KC-135 is likely a brand-new version of the KC-135. But that could be very expensive. Accordingly, the Air Force sensibly stuck to off-the-shelf commercial transport designs in later attempts at source selection —the Boeing KC-767 (KC-46) and the EADS A320 (KC-45).

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[2] Tankers as bomber variants continued for a period thereafter in other air forces—such as Victor (Royal Air Force) and Badger and Bison (Soviet Air Force).

[3] A number of good summaries of these concerns (such as Gertler, 2010) are available.

A. The Prolonged KC-X Competition: Version 3[4]

The third (and final) KC-X competition began officially on 24 September 2009, with the release of the draft RFP for the KC-X (Defense Industry Daily [DID], 7 March 2011). Despite the negative comment from the Northrop Grumman-EADS team, the final RFP was released on 24 February 2010 with only minor changes. (This part of the KC-X saga is discussed in more detail in one of our previous reports, Franck, Lewis, & Udis, 2010, especially pp. 6–8.)

The announced schedule was 90 days for the competitors to respond (subsequently extended), followed by 120 days for the DoD to evaluate those proposals. Not surprisingly, both Boeing (767) and EADS (A330, without Northrop Grumman) responded in early July 2010. A source selection was therefore to be expected in November.

The Air Force adopted a deliberately measured approach to evaluating the proposals, stating the need to get source selection done right rather than quickly. The Air Force Chief of Staff endorsed this approach and repeatedly declined to commit to a source selection date (Tiron, 2010, 12 October). And November indeed came and went without a source selection announcement or an estimated selection date (Scully, 2010, November 22).

About the same time, the process was further delayed by an administrative error. In November, the Air Force sent the results of the operational effectiveness assessment to Boeing and EADS. However, the mailings were mixed up and each party received the assessment applying to the other's aircraft (Drew, 2010, 1December).

The predictable result was another delay in the competition. Given the political dimensions of this competition, Congress demanded hearings about the

[4] If one counts the aborted attempt at an expedited recompetition in 2008, this would be the fourth try.

incident. (Bennett, 2011, 23 January) The DoD Inspector General also investigated the incident, determining that no actionable misconduct had occurred—with an announcement on 18 February. (Shalal-Esa, 2011, 18 February).

The misrouted operational assessments also complicated the competition. The Air Force chose to level the playing field by giving both sides both operational assessments. (Drew, 2010, 1 December) Since a major selection criterion was operational effectiveness, both parties had significantly more information than was intended from which to base their revised offers (an issue we discuss in Section II.D.).

B. EADS' KC-45 as the Clear Favorite

Even without a U.S. partner, EADS was rated a solid favorite to win the much-delayed source selection announcement. The A330 tanker had won international competitions against Boeing 767 for service with the air forces of the UK, Saudi Arabia, Australia, and the UAE (28 total aircraft; Rothman 2010, 17 December; Airbus Military, n.d.).[5] By comparison, the Boeing 767 was chosen by Italy and Japan (8 total aircraft). However, Israel Aircraft Industries has started a program to convert 767 airframes to "multi-mission tanker transports"; one such aircraft recently entered service with the Colombian Air Force (Trimble, 2010; Eshel, 2010).

In addition, the previous NG-EADS entry (KC-45) was chosen in the 2008 competition—with some commentators[6] noting a 6% price advantage. The increased rate of A330 production since then (from 76 per year in 2007 to 87 in

[5] However, this comparison can be overdone. The countries mentioned intend to have one model of aerial tanker in service. The US intends to have three. So, while an A330 tanker may be a better general-purpose aerial tanker (plus transport, etc.), a B767 tanker may well be a better choice for what is regarded generally as a KC-135 replacement—as part of a tanker force structure with multiple aircraft types. In addition, the US has a large and varied airlift fleet, making multi-role transport aircraft a less appealing choice.

[6] Much of the details in these competitions in not yet available—for good reasons. Accordingly, we must rely on press reports, company statements, press conferences, and the like.

2010) might well lower the EADS tanker costs (and bid price; Smith, 2011). By comparison, the Boeing 767 was apparently nearing the end of its production in 2010, with production rates 7 per year in 2007 and 20 in 2011[7] (Boeing B767, 2012, which contains links to underlying data). In addition, the A330 had 349 orders outstanding at the end of 2011, while the 767 had 72 (Airbus A330, 2012, with links).[8]

The A330 can carry (and offload) more fuel (Fulghum, 2010), giving it an advantage in the form of reduced adjusted cost according to the revised source selection criteria (Lynn, Carter, & Donley, 2009). The operational assessment model (Integrated Fleet Air Refueling Assessment, or IFARA) imputed greater effectiveness to the A330 tanker—with the unit bid price adjusted downward accordingly.[9]

The A330's greater operational capacity as a tanker was viewed by all concerned as a major, perhaps decisive, factor. As a result of the Air Force mistakenly sending the A330 IFARA model's assessment to Boeing, the B767 assessment to EADS, both parties ended up receiving both assessments—as discussed previously. With this information available, Boeing leadership was reported to be "downright alarmed." The operational effectiveness appeared to give the EADS tanker a decisive edge. (Gates, 2010, 7 December)

Boeing complained publicly about the Air Force use of the IFARA model, citing assumptions that were said to minimize the basing advantage of the 767 tanker (due primarily to less weight and ramp space needed). In addition, Boeing charged serious underestimates of fuel-savings differences between the two aircraft

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[7] Moreover, at least some of the increased 767 deliveries after 2008 reflected delays in the Boeing 787 program.

[8] We're not so sure. While the A330 production rate increased by 14% from 2007 to 2011, B767 production doubled. In addition, while Airbus had 837 airframes on its learning curve at the end of 2011, Boeing had 1014.

[9] Using the widely publicized refueling effectiveness ratio of 1.2:1 for the A330 versus the B767 (e.g., Belote, 2008), the bid price would be adjusted downward by 17% in making the source selection.

(over a 40-year operational life) and choice of notional home bases, which were used to estimate support infrastructure costs (Gates, 2010, 7 December; Boeing. n.d.d.)

Even if the Boeing charges had merit, few observers, if any, expected they would prevent the inevitable EADS victory. Perhaps most telling to outside observers was the general opinion expressed in the press. Even the *Seattle Times*—Boeing's hometown newspaper and a reliable supporter— echoed the consensus. The *Times* reported that the EADS entry was likely to win the KC-X competition. The *Times* also reported that Boeing itself expected to lose the KC-X competition. (Gates, 2010, 7 December)

C. The Final Offers

Because of those inadvertent operational assessment data disclosures discussed previously, both Boeing and EADS were unusually well-informed regarding the situation (Muradian, 2010, 19 November). Judging from press reports, both parties had reasonably complete knowledge of how the Air Force would proceed from the bid price to the Total Evaluated Price for its KC-X proposal (Lynn et al., 2009). And Boeing was especially well-informed because part of the debriefing following the 2008 KC-45 award to the NG-EADS team included the pricing strategy associated with the winning bid. (Reed, 2009) It is very likely that Boeing had calculated that their bid would not win the competition without a significant revision.

EADS appeared highly confident of the strength of its proposal. This confidence was reflected in both public statements and press reports. In early February 2011, EADS stated that it did not intend to adjust its bid. (Siebold, 2011,5 February) In mid-February, that position was changed slightly with a somewhat lower price selected for EADS' best and final offer (BAFO;. Smith, 2011, 16 February)

Boeing, on the other hand, had a serious problem in preparation of its BAFO (Agence France Presse [AFP], 2011, 1 February) Their choices were among evils: losing the competition, or committing to an uncomfortably low bid. Boeing chose the latter. It revised its bid price to a level that was undoubtedly close to the bare minimum for the firm. The bid was publicly described as being "aggressive," while sufficiently prudent to safeguard shareholders' interests. (Hepher & Shalal-Esa, 2011, 25 February) As Boeing's CEO put it, "I think the (shareholders) would be glad if we won at the bid level we put in and would be happy if we lost at a lower level" (Drew, 2011, 24 February)

For the end game of the competition, EADS acted as if it had a very good hand. Boeing did considerable soul-searching over what it would take to win the source selection. The result turned out to be a winning bid, but with definite risks to Boeing's bottom line.

D. Boeing's BAFO Business Case Analysis: A Plausible Reconstruction

While there's unlikely ever to be complete disclosure as to how Boeing reached its final offer, it's possible to construct a plausible rationale for that decision, using business case analysis (BCA) methodology. Boeing's BCA undoubtedly addressed three basic questions (Franck, 2012):

1) Is the proposed course of action consistent with the Boeing's corporate mission, vision, and strategy?

2) Is Boeing capable of executing the contract?

3) Will Boeing make money (and serve its shareholders) by making an aggressive bid?

In reverse order, the answers to those questions are roughly as follows. The company's decision makers must have known the answer to Question 3 was not a lot. In fact, Boeing had serious concerns about the profitability of the KC-X program even before it submitted a bid in 2010 (Muradian & Reed, 2010, 16 May).

Boeing clearly had the capability to execute the contract (Question 2). The technical pieces were pretty much assembled—based on the KC-767 program experience, and the cockpit displays developed for the B787 program.

As an issue of vision (Question 1), winning the KC-X competition was central to Boeing's view of itself as an aircraft manufacturer. Boeing had been the main tanker supplier to the U.S. Air Force for many decades.[10] While perhaps debatable as a strategic move, it was clearly part of Boeing's image of itself, and integral to the corporate vision. As one well-informed and highly placed DoD official put it, "Boeing's final offer was an existential moment" for the company.[11]

Other strategic issues were involved. Given the size and winner-take-all nature of the competition, an unsuccessful bid meant decades outside the aerial tanker market. Being forced out was especially a worry for Boeing; EADS, by comparison, had been more successful in selling tanker variants of the A330 to other nations.[12]

Since EADS had tied its proposed US production facility to success in the KC-X competition, winning the contract would likely keep Airbus production facilities outside the United States for a considerable time. Also, a KC-X win would keep Boeing's 767 production line open for more than a decade. Boeing would then have the opportunity to make other 767 sales—with aircraft benefitting from the cockpit improvements developed for the KC-46. These aircraft were generally called the Boeing 767-2C (Sirak, 2011 17 October; Butler, 2011, 22 September) Also, keeping the 767 production line open longer would provide an alternative to the Boeing 787 and help contain damage from that program's delays.

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[10] The Boeing aerial tanker lineage included the KB-29 first operational in the late 1940s, through the KB-50, KC-97, KC-135, and KC-10. The last was a McDonnell-Douglas product, but Boeing merged with the latter firm in 1997.

[11] This discussion took place a few months after the Boeing KC-46 selection and was understood as being not for attribution.

[12] And, among other things, is a dead lock for the French Air Force replacement of its KC-135s.

E. Explaining the KC-46 Selection

However, the expert consensus was dead wrong. How did Boeing's KC-46 become the Air Force's choice? The remainder of this section offers multiple explanations.

1. Why the KC-46? The Story Viewed from the Request for Proposal (RFP)

The KC-46 is a tanker variant of the Boeing 767-200ER, whose 2012 "average list price" is $150million. (Boeing, 2012) The Boeing proposal was priced out at $21.4 billion (Butler, 2011, 7 March); this was a present value (PV) calculation of the stream of procurement costs associated with the program. This works out to an Average Unit Price (AUP) of about $145 million (in real terms). While list prices are typically starting points for negotiating downward, this nonetheless seems a very low price per aircraft. When one considers the development costs attached to the KC-46 and included in the TPP, Boeing's offer was indeed aggressive, if not downright low-ball.

Similarly, EADS' BAFO was calculated at $23.4 billion. (Butler, 2011, 7 March); AUP was about $160 million (plus adjustments for inflation). The EADS KC-45 proposal involved an airframe based on the A330 MRTT (Multi-Role Tanker Transport). The January 2012 list price for the A330-200 is about $200 million (Airbus, 2012, January). Thus, if Boeing's BAFO was aggressively priced, then so was EADS'.

According to the rules in the proposals were evaluated in three consecutive phases (ASC, 2010, February 24, esp. pp. 1-11).[13] These phases are summarized in the following text. In addition, the evaluation process is depicted in Table 1.

[13] The phases were "consecutive" in the sense that proceeding to the next (N+1) phase could occur only if both proposals were still in the running after phase N.

First, proposals were screened for acceptability against 372 requirements, with an assessment of "acceptable" needed for all of them. (That is, any proposal with an assessment of "unacceptable" for any of those 372 requirements was eliminated from further consideration.)

Second, the Total Proposed Prices were adjusted for (a) operational effectiveness, (b) fuel costs, and (c) basing infrastructure costs. The superior proposal in each category received a downward adjustment to reach a Total Evaluated Price (TEP). This second phase of the evaluation is depicted in the table below. If the lowest TEP differed by more than 1% from the other, then the award would go to the proposal with the lowest TEP. (This is what happened—with Boeing's TEP being about 9% lower than EADS'.) The adjustments were determined as follows.

- Both aircraft were assessed for *operational effectiveness* with respect to an operational scenario (taken from the 2005 Mobility Requirements Study). The comparison was based on the number of aircraft needed to meet peak requirements in the scenario.[14] The AUP adjustment was calculated with the following formula for the more effective entry (KC-45):

AUP % adjustment = 1 – [(least effective candidate rating) / (evaluated candidate rating)]. For example, if the KC-45 received a 1.62 rating and the KC-46 a 1.35 rating, then the KC-45 would receive a 17% price adjustment [1-(1.35/1.62) = 17%].

- *Fuel adjustment* was based on expected annual flying hours per aircraft over a 40-year operational life. The candidate with lower estimated fuel costs (KC-46) received an adjustment to reflect the discounted fuel savings.

[14] This approach was at least somewhat problematic. One methodological shortcoming was the apparently fictional operational context. The winning aircraft would be in a mixed aerial tanker fleet which included some KC-135Rs, and the KC-10s (near term), also with notional KC-Ys and KC-Zs (long term). Having KC-135s in the scenario would probably have favored the KC-45. Having KC-10s included would likely have favored the KC-46.

- *Base infrastructure* cost comparisons were based on a notional set of 10 bases with a notional deployment schedule. The candidate with lower infrastructure costs (KC-46) received a credit based on the discounted savings in military construction costs.

Third, if the TPPs were within 1%, then the evaluation would proceed to the last phase—something of a tie breaker. Both candidates would then be assessed with respect to 93 "non-mandatory" requirements (an apparent oxymoron).

As the evaluation played out, the adjustments to the TPPs were reported as stated in Table 1.

Table 1. Getting to Total Evaluated Prices (TEPs) for the KC-45 and -46
Butler (2011, 7 March and 11 April)

CATEGORY	BOEING (KC-46)	EADS (KC-45)
TOTAL PROPOSED PRICE (TPP)	21.4	23.4
FUEL SAVINGS	(0.5)	0
BASING INFRASTRUCTURE	(0.3)	0
WARFIGHTING EFFECTIVENESS	0	(0.8)
TOTAL EVALUATED PRICE (TEP)	20.6	22.6

However, suppose the estimated operational effectiveness of the KC-45 were indeed 20% more than the KC-46 (as was widely reported). The KC-45 should have then received a 17% [1-(1/1.2)] reduction due to greater operational effectiveness. That would have been an adjustment of $3.9 billion—leading to a TEP of $19.5 billion or a clear win for the EADS KC-45. The $800 million actually attributed to the KC-45 implies operational effectiveness of only about 4% more than the KC-46.

The point of this discussion is not to critique the Air Force selection process. For a number of good reasons (to include protection of proprietary information), complete disclosure of the mechanics of the selection process is impractical.

However, it's worth noting that the public record so far leads to a number of questions but provides fewer answers.

Moreover, it seems to us that if the EADS KC-45 had won, and the rationale for the source selection had been similarly opaque, that program would face considerable difficulties—especially in Congress.

2. Why the KC-46? Changing Rules

Some commentators (e.g., Drew, 2011, 25 February) attributed changes in the selection criteria (2010 versus 2007) for Boeing's selection. There's something to be said for this perspective. Some examples of how the revised selection criteria could have improved the KC-46's chances in 2011 follow.

The 2010 selection criteria reportedly included a harder look at basing (primarily ramp space) limitations for the KC-45 and KC-46. If so, this undoubtedly favored the smaller KC-46 and would have reduced the KC-45 operational effectiveness rating due to longer transit distances to accomplish the aerial refueling mission. As one informed observer put it, the Air Force realized back in 2008 that the A330 could not perform some wartime refueling missions in a scenario-based analytic model due to lack of adequate space at forward bases. "The Air Force should have recognized the drawbacks of using such a big plane at that point, but under pressure from politicians to keep Airbus in the race, it chose to modify the model so the Airbus tanker could use bases off limits to the Boeing plane" [15] (Thompson, 2011, February 25)

The (relatively) short list of "mandatory requirements" included satisfactory or unsatisfactory assessments for each of 372 items. One item in that list was technical risk. Less technical risk was stated to be a major sorting factor for the Air

[15] This is a striking indictment of the 2008 source selection process and should not necessarily be taken at face value. Corroborations of Thompson's hypothesis by disinterested observers in the open literature are quite sparse.

Force in its KC-45 source selection of 2008. In the revised rules, both proposals were assessed as having acceptable risk—with no sorting beyond that (ASC, Section M). Moreover, given the fixed-price nature of the contract this time, the contractor would bear more of that risk, making program risk a matter of less import to the Air Force. (Butler, 2011, 11April)

Extending the evaluated operational life from 25 to 40 years was an advantage to the smaller KC-46 (Drew, 2011, 25 February). The fuel expense difference was considered over a longer period. However, this stream of cost differences was discounted (to a present value) in calculating the total evaluated price (ASC, Section M, 2010, 24 February).

Also favoring the KC-46 was the changing airlift picture. With continued procurement of C-17s, the Air Force turned out to have more-than-adequate airlift capability. The most significant capability gap revealed in the Mobility Capability Requirements Study (MCRS-16) was relatively minor refueling shortfalls in two of three evaluation scenarios (Department of Defense, MCRS-16, esp.Figure 1).

The existence of the minor refueling shortfall indicated was undoubtedly a matter of less concern than most aerial refueling capability currently residing in aging KC-135s. This could well have been sufficient to shift attention toward the need to simply recapitalize the aerial tanker fleet (e.g., replace the KC-135s) and away from the KC-45's greater airlift capabilities (part of the rationale offered for the KC-45 selection in 2008).

More generally, some commentators have noted that the Air Force shifted from "best" to "good enough"—or from modernization to recapitalization of its aerial tanker fleet. The fixed-price contracting approach was certainly consistent with this sort of change in acquisition strategy. As one observer put it, "[DoD is] not going to pay for bells and whistles. That's the clear message here, and everyone should be heeding that message" (Censer, 2011, March 13).

We have reservations about this last hypothesis. If the Air Force were simply looking to buy replacements for KC-135s, it seems unlikely that the operational effectiveness adjustment to Total Proposed Price would have been an adjustment in reaching the Total Evaluated Price. If, however, this means a shift toward recapitalization (versus modernization), we consider it a change for the better—a discussion for a future report.

3. Why the KC-46? Politics

A separate, and not inconsistent, view is that the competition was really predetermined by political considerations.

Thus, for example, a blogger with *The Economist* (a respected British news magazine) took a full-fledged Euro-chauvinist view (M.J.S., 2011, February 25). The basic argument was that the only way the obviously superior KC-45 could be turned down in favor of the KC-46 was that EADS was hometowned in the source selection process—to include the rules of the game. EADS, of course, got kudos for a gallant performance in a rigged contest.

On this side of the pond, political figures stepped up to claim full credit for steering the KC-X contract to Boeing. Particularly noteworthy was Representative Norm Dicks (D, WA), who insisted that fuel savings should be assessed over a 40-year operational life, versus 25 years (Drew, 2011, February 25). As Representative Dicks put it, "I got them to change the lifecycle costs from 25 years to 40 years. When you take 179 planes, and with the Airbus burning 24% more fuel than the Boeing plane, that's a big number. It could range from a $4 billion to $10 billion difference. That had to help them in a big way" (Hotakainen, 2011, February 25).

While Dicks' taking a lead in the 25-to-40 change is certainly credible, it's not clear that his efforts "steered the contract to Boeing," as some reports have stated.(Hotakainen, 2011, 25 February) Boeing's TEP included $500 million credit for lower fuel costs. But even without this fuel credit (or that credit going to the KC-45), Boeing would still have been the winner (as reference to Table 1 makes clear).

The most persuasive point in the politics hypothesis is that choosing the KC-46 was likely the path of least political resistance. Most observers assessed the Boeing delegation in Congress to be larger and more powerful than EADS' (e.g., Butler 2011, 1 March).

4. Why the KC-46? A Note from Allison's Three Models

The previous discussion provided four separate (but not necessarily conflicting) explanations for the rather surprising selection of the Boeing KC-46. These explanations map rather nicely to some standard models of organizational behavior, including those found in Allison and Zelikow (1999). Model I (Chapter 1) posits decisions by a Unitary Rational Actor; Model II (Chapter 3, Organizational Behavior) is about action taken within a bureaucracy, following established rules and processes. Model III (Chapter 5) concerns governmental politics with outcomes determined by the interaction and bargaining among various governmental agencies and personalities.

In the previous example, the first explanation offered was that the Air Force simply followed the rules laid out in the Request for Proposal (RFP). This is a Model II explanation: a bureaucracy proceeded according to a set of agreed rules and processes. It is also the official explanation from the Air Force and DoD.

The third explanation involved governmental politics. That is, the KC-46 selection was really the result of contending factions within the US. Government—some favoring the EADS KC-45, and others favoring the KC-46. Viewed from this perspective, the main cause for the KC-46 selection is that the Boeing faction had more power than the EADS supporters.

Yet another explanation in this section is simply that Boeing decided to do whatever it took to win the competition, as a matter of long-term corporate strategy. The business case analysis discussion mentioned previously indicates that Boeing's decision is explicable from a Model I (rational actor) perspective.

Finally, the changing rules explanation can't be categorized as cleanly. To the extent that the changing rules reflected changing circumstances (like more C-17s), we have a Model I explanation. To the extent that the rule changes were the results of political maneuvering, this is a Model III explanation. To the extent that the new selection criteria reflected a bureaucratic search for an executable (and protest-resistant) set of rules and processes, we have some variation of a Model II explanation.

F. Post-Selection KC-46 Issues

As noted in Section II.C, Boeing's bid was quite low—to the point that winning the competition was apparently viewed as more important than making profits (at least in the near term). The issues that have arisen after source selection indicate thin margins for error in the KC-46. We'll summarize these risks in this section through discussion of the related issues of cost, profit, and schedule.

Since the basic KC-46 contract structure is fixed-price, the cost of the program directly affects Boeing's profits. The target price for the development program is $4.4 billion, with Boeing solely responsible for any costs exceeding $4.9 billion (Butler, 2011d; Capaccio, 2011). At present, Boeing estimates program costs at $5.1 billion, with the KC-46 Program Office estimate at $5.3 billion (Defense Acquisition Management Information Retrieval [DAMIR], 2011, 30 September, p. 34). Given this data, it's difficult to see Boeing making any profit in the development phase, although these losses would likely be recouped over the life cycle of the KC-46. And Boeing's corporate position is that it will indeed make money on the KC-46 program but is unclear about when those profits will be realized (Wilhelm, 2011, 28 November).

Adding to the complication is what appears to be a highly concurrent schedule. The DoD's Director of Test and Evaluation (DOT&E) has assessed the Boeing test schedule as "unexecutable." Among other things, the 2011 report cited (a) no calendar time allotted for correction of discrepancies, (b) high tempo for flight

tests (versus historical experience), and (c) very optimistic plan for reflights (DOT&E, 2011, December). The Air Force disagrees. However, the KC-46 program manager nonetheless is concerned with the success-oriented nature of the current program. In an e-mail reply to press inquiries: “The Air Force does acknowledge that Boeing’s overall KC-46 program schedule is considered medium risk, in part due to its aggressive flight-test schedule” (Majumdar & Weisgerber, 2012, 19 January).

In addition, Boeing has a lot of engineering tasks on its plate right now besides the KC-46. These include Model 787 development, the 747-8, and the future of the single-aisle air transport (737) product line. If the 787 and 747 engineering problems are well on the way to solution, and if the 737 MAX design problem is manageable, then Boeing likely has the technical resources to solve any KC-46 problems that arise (albeit with schedule slippages and cost overruns). But if there are engineering setbacks in other Boeing commercial aircraft product lines, then the KC-46 could also be affected. (Mecham and Norris, for example, have an update on major design challenges Boeing currently faces [2012, 12 February].)

Investment advisors have accordingly taken notice. A Standard & Poor’s assessment states, "Since the KC-46A is a very competitively bid fixed-price contract for both development and production phases, it carries some execution risks for Boeing – particularly given the company's substantial cost overruns on some of its commercial and military programs in recent years" (quoted in AFP, 2011, 26 February). According to 24/7 WallSt.com, "Given Boeing's headaches getting its new passenger planes out the door, there should be concern about the company's ability to deliver the new tanker on time and on budget" (quoted in AFP, 2011, 26 February).

Perhaps in response, the Air Force has committed to having few, if any, design changes in the KC-46 program (Majumdar, 2011, March 17). From the Boeing perspective, this helps protect the schedule but not profits. (According to an old saying, change orders provide excellent opportunities to increase suppliers’ profits).

G. Strengthened Acquisition Practices from the KC-X Experiences

The Air Force and DoD claim a number of lessons learned from the KC-X competitions that are now recognized as good practice—based in considerable measure from those lessons being disseminated throughout the DoD acquisition work force (Butler, 2011, September 19) General Norton Schwartz, Air Force Chief of Staff, stated, "We learned tough lessons in the recent KC-X air refueling tanker procurement competition, so you can expect that the recent awarding of the KC-46A contract will serve as the standard for open, fair, and disciplined acquisition as we move forward" (Schwartz, 2011, March 2). General Schwartz also stated, "[The KC-46] will be ideally the model going forward for proper requirement discipline, proper program execution, proper partnering and collaboration with the contractor …" (Weisgerber, 2012, February 27).

Those new, or strengthened, practices include the following.

- Readily understandable and transparent source selection criteria: the selection criteria were made as simple as was reasonable, with the intent of making results (and selection rationale) fully transparent to the parties concerned (Office of the Assistant Secretary of Defense [Public Affairs; OASD (PA)], 2011, 24 February; Schwartz, 2011, 2 March; Majumdar, 2011, 24 February)
- The importance of a skilled acquisition work force. Even though the KC-X source selection process of 2010–2011 was relatively simple by most standard criteria, the Air Force nonetheless chose something of an elite team to manage it. As one commentator put it, "The Pentagon expended extraordinary effort on the competition: Not only did the Air Force's procurement A-team oversee it for years, but the Defense Department also drew on expertise from the Navy and the Office of the Secretary of Defense." (Butler, 2011,19 September).Moreover, the DoD has set out to upgrade numbers and skills of its acquisition corps—reversing a course set at the end of the Cold War
- More use of fixed-price contracts when appropriate. This practice is intended to insulate the service from contract risks built into the

contractor proposals.[16] According to the Air Force Senior Acquisition Officer, David van Buren, "Capping the government's liability through a number of years was a real measure of success. The government's maximum exposure is $4.9 billion" (Butler, 2011, 19 September).

However, it seems that one overarching purpose of these initiatives is making source selections as protest-resistant as possible. As Deputy Secretary of Defense William Lynn stated, "We think we've established a clear, a transparent and an open process. We think we've executed on that, and that will not yield grounds for protest" (OASD[PA], 2011, 24 February).

H. Acquisition Practices Tested: The Light Air Support Aircraft

The Air Force is acquiring light air support (LAS) aircraft with the near-term intent of providing 20 of them to the Afghan Air Force. The initial RFP was issued in October 2010, with Embraer-Sierra Nevada and Hawker Beechcraft Defense Company (HBDC) identified as competitors based on initial proposals.[17] In October 2011, the Air Force concluded that HBDC had not rectified deficiencies in its proposal and notified the company of exclusion from the competition on 1 November 2011 – with delivery of the correspondence on 4 November. (Government Accountability Office [GAO], 2011, 22 December).

On 15 November, Hawker Beechcraft requested a debriefing from the Air Force, which declined (16 November) on the grounds that the request was not timely. On 21 November, HBDC filed a protest with the GAO, claiming among other things that the original Air Force notice was misaddressed (GAO, 2011, 22

[16] This seems related to the relative simplicity of selection criteria this time around. As discussed previously, one of the Phase 1 criteria in this last KC-X competition was technical risk— "acceptable" or not. As it turns out, Boeing put forth a fairly optimistic final offer, both in terms of schedule and cost of the development phase. In any case, the fixed-price nature of the contract limited Air Force exposure to those risks.

[17] Embraer (a Brazilian corporation) teamed with Sierra Nevada Corporation (Sparks, NV) to offer the Super Tucano A-29. HBDC offered the AT-6, Texan II.

December). According to a Hawker Beechcraft press release, “HBC's exclusion from competing for this important contract appears at this point to have been made without basis in process or fact. We are very interested in learning more about the decision and look forward to the results of the GAO's review" (Hawker Beechcraft, 2011, November 22).

On 22 December, the GAO dismissed the protest as “untimely and must be dismissed” (GAO, 2011, 22 December). Hawker Beechcraft still felt uninformed about the reasons for its disqualification and filed suit in federal court on 27 December 2011. According to Hawker Beechcraft CEO Bill Boisture, “We are disappointed in the GAO's decision as we were relying on their investigation to provide transparency into what has been a bidding process of inconsistent, irregular and constantly changing requirements. We find ourselves still without answers, which is unacceptable, and continue to believe that our exclusion from this important contract was made without basis in process or fact" (Hawker Beechcraft, 2011, 27 December).

On 30 December 2011, , the DoD announced a contract award to Sierra Nevada and Embraer for the 20 A-29s (OASD[PA], 2011, 30 December). But the Air Force subsequently issued a stop-work order to the Embraer-Sierra Nevada team on 4 January 2012 "due to litigation currently pending before the US Court of Federal Claims.” (AFA, 2012, 5 January) According to an Air Force spokesman, "The competition and source selection evaluation were fair, open, and transparent. The Air Force is confident in the merits of its contract award decision and anticipates that the litigation will be quickly resolved" (AFA, 2012, 5 January).

The complications in the LAS competition seem to provide a good test of the Air Force’s renewed commitment to improved acquisition practices. Taken at face value, the Hawker Beechcraft allegations directly rebut the Air Force claim of open, fair, and transparent competitions.

Subsequent to the stop-work order, the Air Force set aside the selection award to the Sierra Nevada-Embraer team, effective March 2, 2012. In addition, the HBDC AT-6 was reinstated to the competition (Hegeman, 2012, 28 February). The reason for this action was, according to Secretary of the Air Force Donley, "the Air Force senior acquisition executive, David Van Buren, is not satisfied with the quality of the documentation supporting the award decision" (Hodge, 2012,29 February).

The Air Force Chief of Staff, General Norton Schwartz, called the result an "embarrassment" and promised to work toward a rework of the selection process "with all dispatch" (AFP, 2012,29 February). An unkind, but reasonable, interpretation is that the Air Force discovered that the LAS source selection process would not stand up to the light of day; that is, the era of transparent, fair, and open source selections is not yet here.

A quick and favorable resolution of the Hawker Beechcraft litigation would indeed have provided a useful demonstration of the Air Force's strengthened commitment to fairness, openness, and transparency in its acquisition practices. As it stands now, the LAS source selection shows uncomfortable similarities to the KC-X process of 2008. Initial award goes to international team. Domestic competitor protests ensue. Initial award is set aside, with a promise to quickly restart the competition. This puts us about where we were with the KC-X in the summer of 2008. (Butler and Warwick [2012, 5 March] make similar observations.) There's reason to believe we haven't yet reached the goal of universally fair, open, and transparent competitions.

III. Airbus and Boeing: Beleaguered Dupolists?

A. Introduction

Most short-to-medium range airline trips take place using a plane from one of two narrow-body aircraft families: the Airbus A320 and the Boeing 737. Over 7,000 examples of both families are currently in service, with order backlogs at both manufacturers still in the thousands, although these aircraft are no longer representative of state-of-the-art aviation technology.

Perhaps in response to perceived inertia on the part of the two global giants of aviation, a number of aircraft manufacturers that have traditionally built smaller aircraft are developing potential competitors to the A320 and Boeing 737. In this chapter, we will discuss the origins of today's narrow-body aircraft as well as describe the key features of the products offered by the new entrants.

Our discussion begins with the first commercially-successful jet airliner, the Boeing 707, and the lineage that led to the Boeing 737 and the development of the competing Airbus A320. We will then continue by reviewing the aircraft developed by the new entrants into the mainline narrow-body market: Bombardier (Canada), Embraer (Brazil), Comac (China), and Sukkhoi and Irkut (Russia).

Since World War II, aircraft, both military and commercial, have always been at the forefront in demanding the latest in information technology, propulsion systems, engineering, aerodynamics, advanced materials, manufacturing techniques, fuel efficiency, reliability, as well as minimization of capital and operating costs while allowing for varying degrees of passenger comfort. The advent of mass airline travel, which took place in two stages following the introduction of the Boeing 707 in 1954 and the Airline Deregulation Act of 1978, has significantly increased the size of the airliner market while raising the stakes for any new model of aircraft.

The enormous success of the A320 and Boeing 737 (the latter being the most successful aircraft ever built) created a volume-oriented manufacturing culture at both Airbus and Boeing, which served to cross-subsidize the development and production of wide-body aircraft, which are produced in smaller quantities and with more variants. The two global leaders may be facing a new era where this financial advantage is no longer as strong. However, the enormous number of Airbus and Boeing airliners in service has created a global system of aircraft support that any new entrant would find to be a formidable capability to match. We will explore these issues in this chapter.

B. Origins of the Boeing 737

The Boeing 707, which went into service in 1954, was the first commercially successful jet airliner. The 707 was a modification of the four-engine U.S. Air Force KC-135 Stratotanker. Boeing slightly widened the fuselage of the KC-135, so that six-across seating (two groups of three seats divided by an aisle) would be possible. This seating density, which introduced the "middle seat" so beloved by air travelers, was necessary in order to reach an economic capacity of 141 passengers (Boeing, 2010a).

Later in the 1950s, the Douglas DC-8 and Convair 880 entered the market as competitors to the Boeing 707. The Convair 880 and its successor, the 990, were not commercially successful. (Haskin, 2004) Pratt & Whitney's first production turbofan, the JT3D, powered both the 707 and DC-8. The JT3D was a derivative of the TF33 used on military aircraft, and each turbofan provided 18,000 lbs. of thrust (Pratt & Whitney, 2010; Boeing, 2010a).

Boeing initially designed the 707 for cross-country and intercontinental service. However, the popularity of jet airliners reached the point where both Boeing and Douglas began to consider a jetliner with fewer than four engines that would fly shorter distances and replace propeller aircraft. Propeller aircraft flew slower and created high noise levels in the cabin.

However, Boeing and Douglas took radically different approaches to creating a smaller, shorter-range version of the 707 and DC-8. In 1963, Boeing launched the 727, powered by three JT8D engines mounted on the sides and top of the rear fuselage. Capacity was 149 (727-100) or 189 (727-200) passengers, with a range of 1400–1800 nautical miles. Boeing used the 707 fuselage as a basis for the 727, maintaining the six-across seating pattern (Jane's, 1991–1992). With the 727, the first "downsized" jet airliner for short-range routes was born.[18]

In contrast, Douglas decided not to use the DC-8 (six-across) fuselage on the DC-9, which was launched in 1965, with an initial seating capacity of 90 (DC-9-10) (growing to 135 on the DC-9-50 model, all featuring 3+2 seating). Two JT8D engines mounted on the sides of the rear fuselage provided a maximum of 1,685 nautical miles of range. Douglas designed the DC-9 as a smaller, shorter-range aircraft than the Boeing 727, carrying fewer passengers over a significantly shorter distance. A key innovation was that while the DC-9's flight deck instrumentation was very similar to that of the DC-8, the DC-9 was one of the first aircraft to eliminate the position of flight engineer, further enhancing the economics of short-haul jet transportation (Boeing, 2010b).

Following a 1967 acquisition of Douglas by McDonnell and the subsequent 2007 purchase of McDonnell Douglas by Boeing, the DC-9 continued in production as the MD-80, with the last version being designated as the Boeing 717. The 717, which was an updated and stretched DC-9 with the same JT8D engines, was only a limited success, with the last delivery in 2006 (Boeing, 2010b). The DC-9 was

[18] Our discussion of airliners (often referred to nowadays as "mainline" airliners to provide a distinction from regional jets) provides some background for the emergence of the regional jet. Accordingly, for purposes of brevity, we have excluded the large number of jet airliners produced in Europe during the 1960s and early 1970s. These airliners included the Sud-Aviation Caravelle (similar to the DC-9 and notably purchased by United), the BAC 1-11 and Trident (similar to the DC-9 and B727), and the Dassault Mercure (much like the B737). While Europe enjoyed an undisputed advantage in turboprop technology in the postwar period, it was late to effectively compete with U.S. manufacturers on single-aisle jet aircraft, prior to the creation of Airbus and the first flight of the A320 on March 28, 1988 (Jane's, 2010c).

perhaps the precursor of today's regional jets, demonstrating that downsizing a four-engine intercontinental jetliner into a short-range, two-engine aircraft was possible.

Before turning to the rise of true regional jets, we will first discuss the Boeing 737 and the competing A320 family.[19] These two aircraft represent today the state of the art in short-range jetliner design based on traditional "mainline" aircraft.

C. Boeing 737: The Most Popular Jetliner in History

The Boeing 737 entered service in 1968 with Lufthansa. Nicknamed "Fat Albert," the aircraft used a shortened B707 fuselage combined with two JT8D engines. Typical seating capacity in two-class configuration was 110. Boeing delivered the first 737-300 to Southwest Airlines in 1984. The updated aircraft replaced the JT8D engines with the GE/Snecma (CFM International) CFM56 and a high-bypass turbofan and reduced the flight deck crew to two.

The 737 is the most successful airliner ever built. Since 1968, Boeing has delivered over 6,000 units and has an order backlog exceeding 3,000 as of October 2010. Since the beginning of 2010, Boeing more than tripled its 737 sales (to 472), compared with all of 2009 (Ray, 2010).

The six-across 1950s seating with 17-inch-wide coach seats is a bane of travelers (a result of sticking with the B707 fuselage after more than 50 years). However, the plane's relatively low capital and operating costs and wide availability of parts make it popular with both full-service and discount carriers. There are also a number of military variants throughout the world, most recently the U.S. Navy's P-8A Poseidon and the Royal Australian Air Force's Wedgetail.

[19] The A320 family includes aircraft in the A318–A321 series. The principal difference is in fuselage length, passenger capacity, and range.

The most recent commercial model in service is the 737-900ER, which entered service in 2007. The 737-900ERl can carry 215 passengers in a single-class configuration with a range of 3,200 nautical miles.

All B737s beginning with the -300 variant have used the CFM56 engine. The bottom of the CFM56's engine nacelle is slightly flattened on the B737. This results from the need to fit a modern high-bypass turbofan engine under a wing that extends from the fuselage at an approximately 90° angle. The flat bottom ensures adequate ground clearance, particularly on takeoff and landing. The CFM56 variant used on the A320, a more modern aircraft, has a larger and entirely circular cowling. High-bypass turbofans have been standard on new aircraft from over 25 years, but the even B737-900ER remains at its heart a small straight wing Boeing 707. This design limitation restricts the power and fuel efficiency of the 737. We will return to this issue following a discussion of the Airbus A320 family and the emergence of regional jets (Boeing, 2010c; Jane's, 2010e; Norris, Wall, & Anselmo, 2010).

D. The A320 Family: Unprecedented Competition

Airbus' first commercial airline products were the A300/A310 wide-bodies launched during the 1970s. At this point, Boeing's U.S. competitors were diminishing. Lockheed (now Lockheed Martin) had discontinued the wide-body L1011 Tristar, and McDonnell Douglas was producing only the DC-10 and MD-80, whose ultimate versions were the MD-11 and MD-80 (formerly the DC-9 Super 80). The only narrow-body competition for the B737 was the stalwart DC-9.

There was no competition in the short-to-medium-range jet market in the 100-to-150-passenger range. Airbus launched the A320 family in response. The first delivery of the A320-100 (to Air France) took place in 1988. Since then, Airbus has delivered 4,425 units of this narrow-body transport, with over 2,000 more on order. Seating is six-across but with seats 1.5 inches wider than on the Boeing 707 derivatives.

Notably, the A320 is the first subsonic commercial aircraft equipped for fly-by-wire (FBW) throughout the entire normal flight regime. This feature, which saves a great deal of weight, also permits joystick (rather than yoke) control of the primary functions of the aircraft. The FBW and joystick were controversial but have since become standard on commercial airliners. The two engines are a more fuel-efficient, high-bypass version of the CFM56 due to the higher wing compared to the B737.

International Aero Engines (IAE)[20] also offers its V2500 engine; all power plants on the A320 have 22,000–25,000 pounds of thrust, but the higher bypass ratio and FBW make it a more fuel-efficient aircraft than the B737. The A320 and B737 continue to compete vigorously in the commercial market for narrow-body aircraft, despite the fact that the original designs are aging.

Both Airbus and Boeing have recognized that re-engining and other possible changes are prerequisites to continued sales, but the high order backlogs on both models and heavy investments and development problems on larger aircraft such as the B747-8, B787, A350, and A400M have made decisions about the future of these two popular transports particularly difficult for both firms (Airbus, 2012a; Jane's, 2010c; Airbus v Boeing, 2010; Wall, Norris, & Flottau, 2010).

While Airbus states that airlines are clamoring for a re-engined A320, Steven Udvar-Hazy, chairman of International Lease Finance Corporation, the world's largest aircraft leasing firm, does not share that view. An influential figure in the aviation industry, Udvar-Hazy expressed the opinion that re-engining the A320 (and, by analogy, the 737) would offer only "a very slim margin" of benefits to aircraft operators. Airbus Sales Chief John Leahy responded: "Almost all airlines are requesting" the new engine option. If we followed the advice of some leasing companies, i.e., 'No Change,' we would still be flying 727s and consuming twice as

[20] IAE is a partnership of Pratt & Whitney, Rolls-Royce, Japanese Aero Engine Corporation, and Germany's MTU Aero Engines (International Aero Engines, 2010).

much fuel. We, as an industry, have an obligation to be as fuel efficient and environmentally friendly as possible." Airbus, based in Toulouse in southern France, says the new engines offer 15% in fuel efficiency, translating into added value per plane of $7 million to $9 million. Udvar-Hazy said the actual benefit to carriers is much lower, partly because Airbus and engine-makers will seek to recoup some of their investments (Rothman, 2010, 21 October).

Airbus mentioned that an announcement would be forthcoming on an A320 New Engine Option (NEO) before the end of 2010 but had not done so at the time of writing (Sanders, 2010b). The NEO features the Pratt & Whitney PW1000G Geared Turbofan (GTF), which is expected to bring a double-digit reduction in fuel burn. The GTF has yet to be proven and certificated. In 2010, the redesigned A320 also included "sharklet" wingtip devices on the A320 for a further 3.5% efficiency gain.

Potential NEO launch customer Qatar Airways is in talks with Pratt & Whitney with respect to the NEO. However, Qatar is also holding discussions with Bombardier for its upcoming CSeries regional jet (Kinglsey-Jones, Compart, & Flottau, 2010). As discussed in the next section, Boeing did not have a realistic option of re-engining without a redesigned (or entirely new) aircraft to compete with the A320neo and regional jet competition.

E. Design Limits of the 737 vs. Impetus for Change

We mentioned previously that the 707's fuselage served as a basis for the 737. In addition, the wings extend from the fuselage in an essentially straight manner. We also mentioned that the CFM56 engine must fit into a flattened nacelle in order to maintain adequate ground clearance. Newer aircraft such as the A320 have their wings tilted up, both to accommodate the newer, more powerful, and fuel-efficient high-bypass engines and to improve aerodynamics.

Boeing's 737-800 (seating 162) delivered to Continental Airlines in October 2010 included a slightly more efficient CFM56 engine variant that represented the apparent limit of what could be done in combination with the 737 fuselage. Boeing

also redesigned wheel fairings, exhaust duct doors, wing surfaces, and anti-collision lights in order to reduce drag. The total impact of these engine and structural changes improve fuel efficiency by about 2%. However, customers do just not want minor improvement increases in fuel in fuel consumption but also the reliability that comes with a proven engine (in the case of the CFM56, 99.98%) as well as "quantum leaps in efficiency" (Sanders, 2010b).

During September 2010, Boeing was clear that the 737 was an obsolete design. The plane could not be further tweaked to improve fuel efficiency or operating cost:

> Boeing provided its strongest indication yet that it will not re-engine the 737. CFO James Bell says a new engine would provide only a single-digit improvement in efficiency once the cost and weight gain from a new design are factored in, far below the 15-20% that airlines are likely to be seeking. "Our customers have not shown a real interest in a re-engined airplane," Bell said. Meanwhile, Louis Chenevert, CEO of Pratt & Whitney parent United Technologies, predicted that Airbus will announce a re-engining of the A320 by year-end. ("Re-Engine No-Go?," 2010)

During October 2010, Boeing management decided that Airbus' expected announcement of a re-engined A320 needed to be taken seriously. Boeing could simply not continue to turn away customers searching for an efficient new narrow-body aircraft without offering something in return. At that time, the firm committed to a completely new 737 rather than solely to engine replacement:

> Boeing Co. said it favors an all-new 737 single-aisle jet over an upgrade of the existing version and is studying whether to add more seats to help reduce carbon emissions per passenger. "Our job is to improve the operating efficiency," Jim Albaugh, chief executive officer of Boeing Commercial Airplanes, said yesterday after the company reported earnings. "Re- engining is one way to do it, but quite frankly the business case for re-engining is not as compelling as we'd like to see." (Kingsley-Jones, Compart, & Flottau, 2010)

The difference in corporate strategy between the two manufacturers has been further explained as follows:

> Although Airbus and Boeing have since been evaluating re-engined widebodies, Airbus has always appeared the more likely manufacturer to go ahead. This is partly due to the fact that it does not see a clean-sheet narrowbody replacement offering the required step-up in technology and operating cost savings until the middle of the 2020s, whereas Boeing is more bullish that such an aircraft could be developed for service entry before the end of the current decade. (Kingsley-Jones, Compart, & Flottau, 2010)

Boeing has also commented directly on its strategy related to the 737:

> Airlines don't seem to be interested in a 737 with new engines because it would add complexity to their fleets, Nicole Piasecki, Boeing's vice president of business development, said on Nov. 3. Different engines on the same model make maintenance more complicated.
>
> There are virtually no customers I can name off the top of my head, throughout their executive suites, that are pushing us to re-engine," Piasecki said. "Right now, there is so much demand for the 737 and 777 that our primary focus, after delivering the 787 and 747-8, is getting production up."

Nonetheless, Boeing eventually changed its mind (or found new ideas). The redesign is called the Boeing 737MAX family. The redesign features are as follows:

- A version of the CFM Leap-1B turbofan with a fan diameter of 68 inches (from 62 inches). An extension of the nose gear by several inches (four to eight, depending on the source) and strengthening of the main landing gear enable installation of the new engine. (Molnar, 2011; Boeing, 2012; Kingsley-Jones, 2010)
- A fly-by-wire spoiler control system (to save weight). (Molnar, 2011)
- A more aerodynamic design (especially at the tail cone) to reduce drag. (Molnar, 2011; Boeing, 2012)

Boeing claims fuel use improvements over current 737s by 10–12%, and by 7% over "tomorrow's competition" (presumably the A320neo). First deliveries are expected in 2017, with more than 1000 "orders and commitments from 15 customers" (Boeing, 2012).

The extent to which the 737MAX is a long-term solution or just a way to buy time remains to be seen.

F. Threats to "Bread and Butter"

The 737 is Boeing's "bread and butter," in Boeing VP Piasecki's words. The company needs the jet's steady revenue stream to fund other projects, especially amid the three-year setback on the 787. Boeing will decide "within the next several months" on what to do with both the 737 and the 777, which will be threatened by Airbus's A350, Jim Albaugh, president of the company's commercial airplanes unit, said at an American Bar Association conference on 27 October 2010 "I suspect Boeing will look to a 777 replacement first, rather than the still strong-selling 737," said Doug Runte, managing director at Piper Jaffray & Co. in New York. "If this thing is going gangbusters, and people love the airplane, and they can pump out 35 a month with their eyes closed, what's the rush to re-engine or replace it?" Runte said. "I don't see it" (Ray, 2010b).

One industry observer sees increasing the size of the 737 as a possible Boeing strategy:

> Boeing and European rival Airbus SAS are weighing the merits of an upgrade for their best-selling planes after pushing back plans to develop new models, saying engine technologies aren't ripe. Boeing will decide by early next year and Airbus has promised a decision within two months. Albaugh said adding capacity is an issue that Boeing is now studying for the 737 model. The "sweet spot" is for a plane able to carry 150 or more passengers, he said. Current 737s go from 110 to 190 seats, using either stretched or shrunken versions of a plane optimized for about 150 seats.
>
> While raising the seat count to a range of 150 to 220 would create a more efficient family of the 737, the move risks exposing a flank to makers of smaller planes. They include Bombardier Inc.'s CSeries, which will seat 110 to 145, or Brasil's Embraer, which is studying a 130-seat plane. Stretched aircraft have higher profit margins and sell better than shrunk versions, as the smaller jets are proportionally heavier. (Rothman, 2010, 12 October)

The previous Boeing comment about "exposing a flank to makers of smaller planes" is significant. The world's two principal RJ makers, Bombardier of Canada and Embraer of Brazil, are developing models that exceed for the first time the approximately 100-seat threshold that has distinguished commuter or regional

aircraft from mainline jets. As stated by Jim Albaugh, president of Boeing Commercial Airplanes, unless 737 production is boosted, "we could lose customers to the [Bombardier] CSeries" (Drew & Mouawad, 2010; Wall, Norris, & Flottau, 2010).[21] In October 2010, Boeing took the interim step of offering an optional new intereion (Sky Interior) for the 737. Key features include multicolored lighting, larger overhead bins, and increased headroom and natural light. These interior changes are based largely on what will be standard features on the upcoming wide-body Boeing 787 (Sanders, 2010a).

Both Boeing and Airbus depend on their narrow-bodies for stability, profit, and contribution to overhead costs. The 737 and A320 are sold by the thousands, as discussed previously. In comparison, larger wide-body jets are typically sold by the hundreds. The wide-bodies also tend to have more variants and shorter production runs. For example, the superjumbo Airbus A380 had received 234 orders as of 26 October 2010 (Airbus, 2010b).

The world's two largest aircraft manufacturers do not wish to abandon the large-volume narrow-body segment to RJ makers. At the same time, airlines and leasing firms do not wish to be caught empty-handed if there are delays in RJ deliveries and, as stated previously, would like Boeing in particular to keep improving the 737 (Cohen, 2010). An additional factor is that a new generation of engines is in development to accompany the new RJs. We will discuss the evolution of the RJ and its gradual growth into a competitor for mainline jets in the next sections.

[21] It is worth noting that the U.S. business jet manufacturers have not shown any inclination to compete in the RJ market. Bombardier purchased the assets of bankrupt Learjet in 1990 and revived the firm as a subsidiary. Cessna specializes in the smallest category of corporate jets. Gulfstream, the leader of the U.S. corporate jet industry, is a subsidiary of General Dynamics. Perhaps these factors explain why foreign firms dominate the RJ market.

G. Threat I: Regional Jets from 50 Seats to 150+

Our review of regional jets includes Canada's Bombardier, which is the key challenger to Boeing and Airbus in the narrow-body market, as well as Brazil's Embraer, Russia's United Aircraft Corporation (which has absorbed Sukhoi and Irkut), and China's Comac.

Since passage of the (U.S.) Airline Deregulation Act of 1978, domestic passenger loads have continued a long-term increase due to increased competition, lower fares, and more frequent and convenient service to a larger number of destinations. Similar measures undertaken by the European Union (EU) have allowed airlines registered anywhere in the EU to fly between any two points in the 27 member states.

Two trends associated with airline deregulation in the U.S. and EU, and more recently within the Asia-Pacific region, have been the rise of low-cost carriers (LCCs) and a shift of larger legacy carriers (such as United, British Airways, or Qantas) toward longer-haul flights using wide-body aircraft. This shift makes sense given the higher cost structures of these legacy carriers.

Fleet commonality has been an important tool for LCCs in their quests to keep costs and fares down. The LCCs face competition from the legacy carriers, rail service (particularly in Europe and the Northeastern U.S.), and each other. Southwest flies exclusively the 737, while the JetBlue's and Ryanair[22] fleets consist of the A320. Finally, LCCs tend to fly the newest aircraft possible in order to keep costs down, and the long production runs of the 737 and A320, combined with the effective absence of any competing mainline narrow-body aircraft, have made these two models extremely popular with LCCs.[23]

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[22] Ryanair is the dominant European LCC.

[23] JetBlue's 2005 acquisition of 100 of Embraer's E190, which seats 100, is an indicator of RJs "nipping" at the narrow-body market. Southwest's recent acquisition of AirTran included the addition

1. First Move: The Canadair Regional Jet

Bombardier introduced the first purpose-built regional jet into U.S. service in 1993. The CRJ-200 seats 50 passengers. As of June 2010, Bombardier had delivered 1,587 aircraft. Initially, there was skepticism about this adaptation of the successful Canadair Challenger business jet into a market dominated by turboprops and mainline jets. However, "the popularity of the type rose quickly. The market has spoken" (Amoult, 2001).

Despite the success of the CRJ-200, its thirst for fuel (on a per-passenger basis) made it highly volatile to fuel prices. With close to 2,000 aircraft ordered and delivered, it had, by 2010, become expense to operate. The CRJ-200 and its competitors made sense when oil was $20 a barrel and tarmac delays were not a concern. Therefore, the majority of CRJ-200s have been withdrawn from service despite their short service life. One factor in this mass retirement, also unforeseen, was that even legacy carriers have shifted away to some extent from preserving market share and hub dominance, and LCCs and other new entrant carriers are building a cost structure centered on point-to-point markets (Credeur & Schlangenstein, 2010).

The market shifted quickly to larger RJs, and Bombardier responded in 2004 with the CRJ-700, which seats about 70 passengers. However, deliveries to date have been 303 aircraft – a disappointment to Bombardier. The limits imposed by the Canadair Challenger fuselage had been reached, and a new type of RJ was needed to compete with whatever Boeing and Airbus were going to develop (Credeur & Schlangenstein, 2010; Jane's, 2010d).

Bombardier's response had initially been a further fuselage lengthening: the CRJ-1000 (also known as the BRJ-X) carrying 90–110 passengers. However, the

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of a second aircraft, the Boeing 717 (the ultimate version of the DC-9), to the Southwest fleet. Southwest management has not decided the fate of the 717, but adding a second aircraft to the fleet will certainly increase crew and maintenance costs (Jane's, 2010d; JetBlue, 2010; Maxon, 2010).

Montreal firm's management decided that a major investment was needed in a new kind of RJ, the CSeries (Jane's, 2010a).

2. Bombardier's CSeries: A Major Gamble

Bombardier maintains that it can capture roughly half of the anticipated 6,300 aircraft expected to be ordered over the next two decades in the 100–149-seat segment. The aircraft promises 15% greater fuel efficiency and 20% operational cost savings over the mainline jets it will be replacing. Bombardier also claims that the aircraft will be four times quieter than comparable aircraft. The aircraft's range will be 1,800 to 2,950 nautical miles, equivalent to the aircraft currently operating in the 100–149- seat segment (Bombardier, 2010; Deveau, 2010).

Bombardier announced the CSeries at Farnborough in 2004 but ceased development in 2006 because of perceived market conditions. However, the firm relaunched the program in 2006 with a letter of interest from Lufthansa for 60 aircraft. Only two orders have followed, one from an Irish leasing firm and another for 40 planes from Republic Airways Holdings. Entry into service is currently forecast for 2013 (Jane's, 2010a; Deveau, 2010). As stated by Fadi Chamoun of BMO Capital Markets:

> Our biggest concern with the aircraft is execution rather than being challenged by re-engineering an all-new clean sheet narrow-body aircraft from Boeing or Airbus. The CSeries occupies a segment of the market that current narrow-body aircraft do not serve in an efficient manner," Mr. Chamoun said in a note to clients. "In the immediate term, the aircraft's success is judged by how it is received in the marketplace and its ability to sign up customers. (Deveau, 2010)

Pierre Beaudoin, CEO of Bombardier, has emphasized that the CSeries (100–145 seats) is intended to compete with the A319 (125–145 passengers) rather than the A320 (150–180 seats). Boeing 737 capacity varies by model and ranges from 110 to 215 passengers, with the most recent models in the 160-seat range. Beaudoin sees a fuel savings of 9% with the next-generation A319, while the CSeries will offer 20% (Jane's, 2010e; Larocque, 2010).

The CSeries represents a huge gamble for Bombardier, even with funding from the governments of Canada, the Province of Quebec, the Northern Island, and the UK.[24] The potential impact of the aircraft has been described as follows:

> A verdict is still pending on the eventual commercial success of Bombardier's CSeries narrowbody. But one thing is already clear—the aircraft has sounded the end of the Airbus-Boeing duopoly that has dominated the market for the past two decades. The CSeries' appearance could also give airlines greater pricing leverage over aircraft manufacturers. Airline executives have long complained about their low (or nonexistent) profit margins even as aircraft suppliers generate handsome returns. (Wall, 2010)

Wing-mounted, twin-podded P&W Geared Turbofan (GTF) engines, swept low wings, and live telemetry of in-flight data[25] are the key characteristics of the CSeries. Currently, the CSeries 110 and CSeries 130 are planned, with the model number indicating approximate passenger capacity (Bombardier, 2010; Jane's, 2010a; Deveau, 2010; Keenan, 2010).

Bombardier's expectation that the model will enter commercial service in 2015 rests in great part on extensive outsourcing. In the case of the CSeries, part of the time pressure came from the requirement, discussed above, to field a new type of aircraft before Airbus or Boeing can re-engine their existing narrow-bodies or deliver entirely new models. The original production schedule and concept for the Boeing 787 featured greater outsourcing than had ever been the case for a medium-size wide-body, leading to a breakdown of the supply chain, a period of chaos, and finally a reorganization of production that included bringing a great deal of work back in-house (Franck, Lewis, & Udis, 2008b).

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[24] Shorts Brothers of Belfast is a Bombardier subsidiary.

[25] On June 1, 2009, Air France flight 447, an Airbus A330 en route from Rio de Janeiro to Paris, disappeared over the South Atlantic, with the tragic loss of 228 lives. During a 40-minute period, the aircraft did not send any automated messages or respond to controller calls (Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile, 2009). This incident led to recommendations for continuous real-time communication from aircraft, whether for operational or forensic purposes ("CSeries to be first," 2010).

The CSeries, while smaller than the 787, also features some highly innovative features that shift both production and development responsibility to suppliers. We previously discussed Bombardier's decision to rely on the developmental Pratt & Whitney GTF engine. Other major suppliers outside the U.S. and Canada include the following:

- Empennage: Alenia Aeronautica, Italy
- Landing gear: Liebherr Aerospace, Germany
- Wings: Bombardier Shorts Brothers, Northern Ireland
- Fuselage: Shenyang Aircraft Corporation (SAC), China

The decision to outsource manufacturing of the entire fuselage[26] to SAC is perhaps the riskiest one:

> The fuselages, plus tail cones and doors supplied by SAC, will make an even longer journey to Montreal than the wings. They will travel across the Pacific Ocean to Long Beach, Calif., then by truck to Montreal. The choice of SAC to supply the fuselages has raised red flags with aerospace industry analysts.
>
> "There are many people you could have chosen to do the fuselage; Shenyang is not one of them," says Teal Group's Mr. [Richard] Aboulafia, pointing to the company's lack of experience in building fuselages, a space where Japan-based Mitsubishi Heavy Industry Inc., Spirit AeroSystems Inc. of Wichita, Kan., and Italy-based Finmeccanica are established players.
>
> Shenyang is far from a new kid on the aerospace block - its website boasts a photo of Mao Zedong inspecting the cockpit of a new F5 fighter jet in 1958 - but it's new to the fuselage business. The choice of SAC was a strategic move, designed in part to help the C Series penetrate the Chinese market. China already accounts for about 40 per cent of Asia's air traffic and forecasts suggest it will represent 15 per cent of the world aviation market in 15 to 20 years. Bombardier hopes that doing such major assembly in China will give it added sway with Chinese airlines. (Keenan, 2010)

The fuselage outsourcing decision is emblematic of the globalization of the aerospace industry. In this case, Bombardier avoided established suppliers (as well

[26] Bombardier is building the cockpit section in-house, at a facility close to the main assembly plant.

as possible in-house production) and chose an inexperienced (and distant) Chinese source due to the expectation of eventual higher sales of the finished aircraft in China. With so much at risk, the decision seems poorly considered, particularly given the difficulties initially faced in Boeing 787 production.

3. Embraer: Not Necessarily a Competitor

Embraer (Empresa Brasileira de Aeronáutica) has emerged over the last 20 years as one of the world's principal aircraft manufacturers, with annual sales of about $1 billion. The firm produces regional jets, business aircraft, and military trainers, tankers, and special mission aircraft. Embraer's current offerings include the E170/E190 series, with the E190 seating 114 passengers (Jane's 2010c; Embraer, 2010).

For the time being, Embraer has chosen to avoid competing directly with the mainline manufacturers. The Brazilian firm will continue to develop its RJs (Jane's, 2010c; Wall, Norris, & Flottau, 2010). In an interesting development, EADS (the parent company of Airbus) is exploring cooperation with Embraer, although EADS does not plan to inject any equity. It may be that Embraer and Airbus decide to develop complementary, rather than competing, product lines. Embraer is currently deciding whether to re-engine the E190 or begin development of a larger aircraft, competing directly with Airbus and Boeing.

Embraer has also stated that it wants no part of the fight between its traditional rival, Bombardier, and Airbus/Boeing. According to an Embraer representative, "We want to be complementary to the Airbus and Boeing fleets" and not competing with the two large firms (Sanders, 2010a; Flottau & Wall, 2010). Embraer's interest in collaboration rather than competition recently became known on a related front. Embraer is interested in technology exchange and sales with Europe related to its KC-390 tanker. At this point, Embraer would appear to have little to gain from direct competition with Airbus, its customers, or its suppliers (Warwick, 2010).

H. Threat II: China Enters the Race

The entry of China into the global airliner market is a well-developed component of the Communist Party's central planning, with an eye toward benefits for the People's Liberation Army. China's strategy is described as follows:

> The government also realized that the renminbi's inevitable appreciation would eventually render China's low-tech exports uncompetitive, and that their manufacture would shift to countries such as Indonesia, Malaysia, Thailand, and Vietnam. To keep its economy growing at around 9%, provide jobs for the next generation of better-educated workers, and boost income levels, the state had to ensure that Chinese companies develop, manufacture, and export advanced products. However, Chinese enterprises, such as the aircraft manufacturer Aviation Industry Corporation of China (AVIC), the wind energy companies Sinovel and Goldwind, and the rail-transport-equipment companies CSR and CNR, were unable to compete technologically with Western, Japanese, and South Korean market leaders.
>
> The Chinese government therefore developed a three-pronged plan to contain foreign companies and enable its companies to create advanced technologies. One, the state has ensured that it will be both buyer and seller in certain key industries, by retaining ownership of customers and suppliers alike. For instance, the Chinese government owns CSR and China Railways, AVIC and China Eastern Airlines. This gives the state a great deal of influence over equipment purchases, sales, and technology development. Two, the government has consolidated several manufacturers into a few national champions, to generate economies of scale and concentrate learning. CSR and AVIC both resulted from the mergers of several smaller, loss-making enterprises.
>
> Three, Chinese officials have learned to tackle multinational companies, often forcing them to form joint ventures with its national champions and transfer the latest technology in exchange for current and future business opportunities. Companies that resist are simply excluded from projects. The Chinese government uses the restrictions to drive wedges between foreign rivals vying to land big projects in the country and induce them to transfer the technologies that state-owned enterprises need to catch up. Executives working for multinational companies in China privately acknowledge that making official complaints or filing lawsuits usually does little good. (Hout & Ghermawat, 2010)

China's Comac remains a longer-term player with its development of the C919, described as an eventual competitor to the 737 and A320, with superior

technology to these long-standing aircraft at the time the C919 enters service. The C919 is expected to have capacity of 168–190 passengers. Bombardier has established a partnership with Comac to assist with development of the C919, which is larger than any anticipated variant of the CSeries (Larocque, 2010). The aircraft is still at the mock-up stage, and China's weak intellectual property protections remain a major barrier for western suppliers of systems.

Richard Aboulafia of the Teal Group, a noted airline analyst, has also expressed concern that the C919, if fielded, could ever have technology and performance similar to that of future versions of the 737 and A320 (Perrett, 2010a). Comac launched the C919 in 2008 without any orders. The firm announced in 2010 that orders and options for 100 aircraft had been received however:

> The first orders for the Comac C919 airliner total no more than 55, a surprisingly small figure that includes a mere five for each of China's big state carriers.
>
> China Southern, Air China and China Eastern will also take options on only 15 each— suggesting an extraordinarily low degree of commitment to a project on which China is pinning its future as a commercial aircraft builder.
>
> In its announcement at the air show, Comac described the deals with all six customers as "orders," leading to widespread news reporting of the inflated figure. (Perrett, 2010a)

The C919 remains a developmental aircraft, although Comac claims the first deliveries will occur in 2016. At the time of writing, the aircraft is about five tons overweight; industry observers view this as a surprise given China's current state of technological expertise. Also, much of Comac's management and technical staff continue to grapple with the challenges of the firm's ARJ-21

In terms of national prestige, the Chinese quest to develop a mainline passenger jet is on a par in terms of national prestige with China's space program (Perrett, 2010b). However, little remains known about the C919's support and distribution networks. Industry observers agree on the significant growth potential of the Chinese airliner market. However, China also continues to buy foreign airliners,

placing an order for 102 Airbus products in November 2010 during a visit of the Chinese president to France (Page, 2010). China's poor record on the protection of intellectual property is a significant issue, particularly given dependence on Western suppliers.

Nonetheless China is aiming to reshape the global aviation industry with a home-grown jetliner, a direct challenge to the supremacy of Boeing and Airbus, the world's only manufacturers of large commercial aircraft.

> The communist government has staked billions of dollars and national pride on the effort. What may surprise some Americans worried about slipping U.S. competitiveness is that some well-known U.S. companies are aiding China in its quest.
>
> That partnership will be on display next week at an air show in southern China with the unveiling of a full-scale mockup of the C919. Slated for production by 2016, the 156-seat, single-aisle passenger plane would have its fuselage emblazoned with Comac, short for the state-owned Commercial Aircraft Corp. of China. But inside, the most crucial systems would bear the trademarks of some of the biggest names in Western aviation.
>
> Honeywell International Inc. will supply power units, on-board computing systems, wheels and brakes; Rockwell Collins Inc. will handle navigation systems; GE Aviation is building the avionics; Eaton Corp. is involved with fuel and hydraulics; and Parker Aerospace of Irvine is responsible for flight controls. Powering the aircraft will be two fuel-efficient engines built by CFM International, a company co-owned by GE and French conglomerate Safran.
>
> Global supply chains are common in the aviation industry: Chicago-based Boeing and Europe's Airbus rely on parts makers and assembly operations around the world. But China isn't content just to buy sophisticated gear for the C919; the government has required foreign suppliers to set up joint ventures with Chinese companies.
>
> That has put U.S. and European suppliers in a tough spot: Be willing to hand over advanced technology to Chinese firms that could one day be rivals or miss out on what's likely to be the biggest aviation bonanza of the next half a century. Honeywell alone has snagged contracts worth more than $11 billion for the project.
>
> You're faced with either being part of it or not," said Billy Lay, a Dubai-based partner at PRTM, an international consulting firm with expertise in aerospace. "I don't know what the alternatives are.

> Roger Seager, GE Aviation's vice president and general manager for China, said he was confident that his company could protect its intellectual property. But the rapid rise of another Chinese transport industry — high-speed rail — challenges that notion. After sharing technology and expertise to help China develop a network of gleaming bullet trains, Japanese and European rail firms now find themselves competing with their former Chinese joint-venture partners for new contracts, both inside and outside China. (Pierson, 2010)

A related issue is the willingness (or legality) of foreign suppliers selling aviation technology to Comac, whose sister firms produce military aircraft. While all the pieces are in place for development and production of a successful narrow-body aircraft, China's resolve in dealing with technological challenges and intellectual property issues will be major factors in the C919's success.

I. Threat III (Maybe): Russian Pretensions

There are two Russian aircraft competing for the narrow-body airliner market: the Sukhoi Superjet 100 (SSJ-100) and the Irkut MS-21 (also referred to as the MC-21). We deal with each in turn.

It is difficult to assess any information on the Russian aerospace industry due to the country's system of government, which has developed (arguably) into a joint venture between kleptocratic elements (featuring a strong role for organized crime) and the neo-Soviet organs of state security. Russian aerospace firms are also a morass of inter-related companies, all of whom are involved in defense systems and all of whom have the backing of the state in some form. Together with a collapsing public sector mired in problems such as declining life expectancy, a highly polluted and often radioactive environment, and rampant alcoholism, any information released about successes of the SSJ-100 and MC-21 has been intentionally sketchy. Both aircraft, however, are twin-engine jets intended to compete with the A320 family and the Boeing 737, at least at the lower end of passenger capacity for the two mainliners.

Superjet International manufactures the SSJ-100. The firm is a joint venture between Alenia Aeronautica of Italy (51%, unspecified as to the meaning of the number) and Sukhoi Holding Company for the balance. Superjet is headquartered in Venice, undoubtedly presenting a much more pleasant impression than the location of the main assembly plant in Komsolmosk-on-Amur in Novosibirsk. Subsequently, the state carried out a consolidation of the Russian aerospace industry, with Sukhoi becoming part of the United Aircraft Corporation (Superjet International, 2010; Aerospace Technology, 2010; Sukhoi, 2010; ITAR-TASS, 2010).

Depending on the variant, the SSJ-100 seats between 78 and 105 passengers. The twin power plants are joint ventures of France's Snecma and Russia's Saturn Aerospace, designated as the Powerjet SaM146 turbofan. Maximum range of the aircraft (a SSJ-75LR variant) is 2,456 nautical miles. The prototype was rolled out in 2007, and the first flight was at an unspecified date in 2010 (RIA Novosti, 2010). ITAR-TASS assures that deliveries will begin before the end of 2010. Additionally, all aircraft will satisfy "Russian and international requirements" according to TASS, but the term "certification" is lacking in any Sukhoi or Russian material (ITAR-TASS, 2010; Sukhoi, 2010).

However, Sukhoi has obtained type certification for the engines from the European Aviation Safety Agency (EASA), although there is no forecast certification date for the aircraft itself. (Kingsley-Jones & Komarov, 2010) Jane's, in its typically cautious manner, can attest to only 122 orders (Jane's, 2010g; Sukhoi, 2010).

Aeroflot, forced by the Russian state into the position of launch customer, is expecting first deliveries at the end of 2010. However, the airline has declined to include the SSJ-100 in its timetables, citing repeated program delays. The aircraft is over two years late, due to development problems with the engine and a variety of unspecified challenges with the other parts of the aircraft (Kingsley-Jones, 2010).

In addition to Snecma (described as a partner to Sukhoi) and Boeing (described as a consultant), a quite representative range of Western suppliers are

participating in the Superjet project, including Thales (avionics), Messier Dowty (landing gear), BAE (interior), Honeywell (auxiliary power unit), Hamilton Sunstrand (electrical system), Goodrich (wheels and brakes) (Sukhoi, 2010; Jane's, 2010g). Whatever the failings of the Russian Federation, Western firms do not seem to perceive a risk in doing business with a country characterized by ambiguous politics and a military that is beginning to grow and modernize.

The second Russian aircraft that is in competition for the narrow-body market is the Irkut MS-21. Irkut has also become a component of United Aircraft Corporation (UAC). The MS-21's development is a few years behind the Superjet, with its first flight due in 2014 and service entry in 2016. Capacity, depending on variant, is 150 to 215 passengers, clearly matching the A320 and 737. The aircraft will replace the Soviet-era Tu-154, which is inefficient and arguably unsafe. Irkut plans MS-21 certification by the Federal Aviation Administration and EASA (Jane's, 2010f).

The MS-21 will feature the P&W Geared Turbofan engine and a composite wing. Irkut accepts the fact that there will be a requirement for after-sales support, a major weakness of Russian aircraft. Once again, Aeroflot will be the launch customer. The following article summarizes the project's status:

> The 150-210-seat, three-model MS-21 family is being developed by Irkut under the umbrella of United Aircraft Corp. (UAC). Development is expected to cost 190 billion rubles ($6.3 billion) through 2016 when it is due to enter service; 40% is being funded by the Russian federal budget, with the remainder coming from loans and UAC's investment.
>
> Total commitments for the twinjet stand at 190, and the most recent addition is a letter of intent for 50 from Russian state holding company Rostekhnologii. "These are due for delivery between 2016 and 2020, and we are fairly sure they will go to Aeroflot," Budaev says.
>
> Irkut is negotiating with airlines in Europe and North America about order, and is also looking to link up with a Western company to provide international support, Budaev adds.

> The MS-21's key design points include Pratt & Whitney's PW1000G geared turbofan (GTF) as lead powerplant and a carbon-fiber wing. The MS-21's GTF would be similar to the version that would be developed for Airbus's proposed A320 New Engine Option upgrade, says Budaev.
>
> Current plans call for the MS-21's GTF to have a baseline thrust of 35,000 lb. and a fan diameter of roughly 80 in. Evolved from the lower-powered GTFs in development for Bombardier's CSeries and the Mitsubishi Regional Jet, the MS-21's engine may incorporate some material changes and different gear ratio. (Kingsley-Jones & Komarov, 2010)

UAC forecasts a global market for 1200 MS-21a over 25 years, of which 300 would be for the domestic market. This would correspond to 10% of the global demand for aircraft in the 150–220 seat range ("Russia's Aerospace Revival," 2010). Given the factors already cited with respect to the Superjet 100, the addition of a composite wing leads to some genuine skepticism, particularly at a time when Boeing, with outstanding engineering capabilities, finds itself grappling with implementation of a composite wing on the 787 (Mecham & Wall, 2010).

J. Perspectives on the Narrow-Body Market

1. Assessing the Threats

The aging A320 and Boeing 737 present an opportunity for market entry by new manufacturers into what has been an effective duopoly in the worldwide manufacture of mainline passenger jets since the absorption of McDonnell Douglas by Boeing in 1996.

All of the presumed new entrants—Bombardier, Comac, Embraer, Irkut, and Sukhoi— claim major advantages for their products over the two ubiquitous narrow-bodies that have sold over 7,000 shipsets. The new players consistently mention capital and operating costs, fuel efficiency, emissions, turnaround time, range, and commonality within variants as reasons to leave the duopoly and try out something new.

Boeing executives, in a predictable but legitimate view, consider the in-service dates of all the new entrants unrealistic. They point out that the final

evolution of the Boeing 737 fuselage, coupled with what may be the ultimate version of the CFM56, will save operators about $120,000 a year over current 737s. Finally, fleet commonality and technical support are not even issues when buying Boeing aircraft ("Boeing *S*keptical," 2010).

The naïveté of some of the new entrants is surprising, particularly given the billions involved in developing any new aircraft. China may represent the largest emerging aviation market the world has ever seen but cannot demonstrate adequate intellectual property protection. The People's Liberation Army stands at the center of the Chinese state and would certainly acquire any useful foreign technologies for its rapidly growing desire for global power projection.

The most surprising result of our research is the lack of disclosure, or simply the outright absence, of the worldwide distribution and technical support networks that are necessary to support both aircraft and engines. A recent survey of airlines by CFM International indicated that fuel efficiency ranked fifth, with reliability a clear number one, in the decision to purchase a new airliner (Cohen, 2010). Only Airbus, Boeing, Bombardier, and Embraer have established the global infrastructure that is required to complement a very high degree of in-flight reliability.

As we discussed, Embraer currently appears to be pursuing a cautious course toward possible cooperation with European firms such as EADS and Dassault and will not enter the above-100-seat market. Embraer's interests in technology sharing and collaborative marketing, particularly with respect to its KC-390 tanker, confirm this direction.

That leaves only Bombardier's CSeries as a viable new entrant that can compete directly with the lower end (in passenger capacity) of the A320 and Boeing 737 families. Bombardier's ambitious manufacturing plan and somewhat adventurous worldwide supply chain, highlighted by production of the main fuselage in China, point to a high-risk project. In the case of the Boeing 787, outsourcing of the main composite fuselage barrel pushed the capability of the supplier too far.

Boeing was able to recover, in part by purchasing the Vought Aircraft facility in Charleston, SC, where the aerospace giant is now opening a nearby second assembly plant for the 787 (Sanders, 2009).

Bombardier is a diversified and smaller firm that may not necessarily have the ability to either manage the CSeries project or recover from a major supply chain problem in its manufacturing process. The decision to outsource the manufacturing of the fuselage barrel outside North America may be a major success in supply chain management, or it could virtually shut down the Montreal-based firm. The prospect of increased Chinese sales, in our view, is far too theoretical and distant to warrant such a risky decision, whatever the merits.

In conclusion, the only viable competitor to Airbus and Boeing (with Embraer having opted out) may find itself pulling back from a very expensive experiment. Has Bombardier really absorbed the significant and expensive lessons learned from the initial manufacturing concept for the Boeing 787?

2. The Narrow-Body Airliner as a Contestable Market

What is going on with the Boeing/Airbus duopoly in narrow-body airliners is largely explainable using a branch of microeconomics called *contestable market theory*. The generally acknowledged seminal work in this area is Baumol's *Contestable Markets and the Theory of Industry Structure* (Baumol et al., 1982).

While the Baumol exposition is quite sophisticated, the central idea is pretty simple. Markets that appear to have few (or one) firms competing may have potential entrants lurking about. The effect is to make the current (incumbent) firms behave more like competitive firms than appearances would indicate. (An Internet site states this idea rather well: "a market in which there are only a few companies that, because of the threat of new entrants, behave in a competitive manner" [Investopedia, 2012].)

Going a little bit deeper, a market is said to be “perfectly contestable” if the potential entrants could enter that market and exit without incurring any (non-recoverable) costs, or “costlessly reversible entry” (Bailey, 1982, p. xix). (It’s worth noting that entry and exit are both important.) More generally, markets can have degrees of contestability, which increases as costs of entry and exit decrease.

In that context, the regional jet companies (such as Bombardier) have observed that the narrow-body airliner market now dominated by Airbus and Boeing is very profitable. Furthermore, having the option to do that is sufficiently valuable that the potential entrants have developed variations of their regional jets that are much closer substitutes for the Boeing 737 and Airbus 320 families.

But, with the apparent exception of the Chinese Comac C919 (which is comparable in size to the A320), the potential entrants have trimmed their costs and hedged their bets by developing larger versions of their existing regional jets.

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IV. Concluding Remarks

This report has focused on the EADS-Boeing rivalry. We've considered one of its major manifestations in the defense market—the multiple KC-X source selection episodes. The KC-X is significant for a number of reasons. First, it is one of the major defense manifestations of a rather heated international rivalry in pursuit of both commercial and defense business. Another is the extensive interconnection between commercial and defense aerospace markets (for aerial tankers in this case).

At the same time, the Boeing (737) and Airbus (A320) narrow-body airliner families are (a) a key part of the overall Boeing-EADS competition and (b) major profit centers for both firms. As one would expect, prospects of profits have attracted a number of firms, who are actively working on market entry strategies. The approaches involved include upsizing regional jet designs (e.g., Bombardier of Canada) and new airframe designs (e.g., Comac of China) intended to compete directly with the incumbents (Airbus A320 and Boeing 737). In short, the narrow-body airliner market is becoming *contestable*.

Both Boeing and Airbus (as incumbents) have developed counters to their potential competitors: the A320neo (new engine option) and the B737 MAX (also with a new engine). Both aircraft are already commercial successes (each with more than 1,000 orders or commitments). However, their ultimate degree of success in keeping potential new competitors out of this lucrative market remains to be seen.

In any case, this situation has potential to affect the global aerospace market in major ways. If (despite the difficulties), one or more potential entrant becomes a major player, then the narrow-body airliner market will become more competitive – and less profitable. With lessened profits from the A320 and 737 product lines, wide-body developments (with their defense variants) could change substantially.

We've also offered explanatory models for the developments we've discussed. The microeconomic theory of contestable markets turns out to be highly useful in explaining developments in the market for narrow-body airliners. For the third (and presumably successful) attempt to select a new aerial tanker (KC-X) for the U.S. Air Force, the picture is more varied. We used Allison's three models as candidates for explanation. Model I (unitary rational actor) is highly useful in explaining Boeing's rather low final bid—particularly as operationalized in the form of business case analysis.

There is more variety in the useful perspectives regarding the Air Force's selection of the Boeing KC-46: changing circumstances, changing selection criteria, and politics. The "politics" hypothesis lays out pretty much within Allison's Model III (governmental politics). The "changing circumstances" hypothesis predicts a changed aerial tanker selection as a result of a changed airlift force structure (principally through increased numbers of C-17s available); this fits well with Model I (rational actor). Finally, the "changing selection criteria" hypothesis can originate from any one of Allison's models. Model I applies if the rule changes are related to changing circumstances (such as more C-17s). Model II (bureaucratic process) or a variant is useful in explaining the Air Force acquisition establishment's effort to develop protest-resistant source selection processes. Finally, the politics hypothesis relates closely to Model III (governmental politics)—primarily, the contending congressional factions.

List of References

Aerospace Technology. (2010). Sukhoi Superjet 100 Russian Regional Jet (RRJ), Russia. Retrieved from http://www.aerospace-technology.com

Agence France-Presse (AFP). (2011, 1 February 1). Boeing to revise bid for U.S. military tanker deal. *DefenseNews*. Retrieved from http://www.defensenews.com/story.php?i=5593186&c=AME

Agence France-Presse (AFP). (2011, 26 February). Tanker victory spells risks for Boeing. *DefenseNews*. Retrieved from http://www.defensenews.com/story.php?i=5812841&c=AME&s=AIR

Agence France-Presse (AFP). (2012, 29 February). Schwartz calls cancelled aircraft deal an embarrassment. *DefenseNews*. Retrieved from http://www.defensenews.com/article/20120229/DEFREG02/302290008/Schwartz-Calls-Cancelled-Aircraft-Deal-An-Embarrassment?odyssey=tab|topnews|text|FRONTPAGE

AFA (Air Force Association, 2012, 5 January), Light air support work placed on hold. Retrieved from http://www.airforce-magazine.com/DRArchive/Pages/2012/January%202012/January%2005%202012/LightAirSupportWorkPlacedonHold.aspx

Airbus. (2012a). A320 family. Retrieved from http://www.airbus.com

Airbus. (2012b). A380 family. Retrieved from http://www.airbus.com Airbus. 25 January..

Airbus A320neo family. (2012). In *Wikipedia*. Retrieved March 2012 from http://en.wikipedia.org/wiki/Airbus_A320neo

Airbus A330. (2012). In *Wikipedia*. Retrieved March 2012 from http://en.wikipedia.org/wiki/Airbus_A330

Airbus Military, A330 MRTT. (n.d.). Retrieved from http://www.airbus.com/aircraftfamilies/military-aircraft/a330-mrtt/

Airbus v Boeing. (2010, 30 September). *The Economist*. Retrieved from http://economist.com

Allison, G. (1971), Essence of decision: Explaining the Cuban Missile Crisis, Boston, MA: Little Brown.

Allison, G., & Zelikow, P. (1999). *Essence of decision: Explaining the Cuban Missile Crisis* (2nd ed.). New York, NY: Addison Wesley Longman.

Amoult, S. (2001, May). Pardon our dust! *Air Transport World, 38*(5), 66–69.

ASC (Aeronautical Systems Command, 2010, 24 February), (KC-X) Request for Proposal, Wright-Patterson AFB, Ohio, FA8625-10-R-6600.

Bailey, E. (1982). Introduction. In W. J. Baumol, J. C. Panzar, & R. D. Willig, *Contestable markets and the theory of industry structure*. New York, NY: Harcourt, Brace, Jovanovich.

Baumol, W. J., J. C. Panzar, & R. D. Willig, *Contestable markets and the theory of industry structure*. New York, NY: Harcourt, Brace, Jovanovich.

Belote, R. (2008, 18 February). Northrop Grumman KC-30 tanker is 20 percent more capable according to US Air Force evaluation model. Retrieved from http://www.globalsecurity.org/military/library/news/2008/02/mil-080218-northrop-grumman03.htm

Bennett, J. T. (2011, 23 January). Air Force tanker decision likely delayed by Senate hearing. *The Hill*. Retrieved from http://thehill.com/news-by-subject/defense-homeland-security/139559-air-force-tanker-decision-likely-delayed-by-senate-hearing

Boeing. (n.d.a). 707 family. Retrieved from http://www.boeing.com/commercial/707family/index.html

Boeing. (n.d.b). *About the 737 family*. Retrieved from http://www.boeing.com/commercial/737family/background.html

Boeing. (n.d.c). DC-9 family. Retrieved from http://www.boeing.com/commercial/dc-9/index.html

Boeing. (n.d.d). Integrated fleet aerial refueling assessment White Paper [White paper]. Retrieved from http://www.scribd.com/doc/3665249/IFARA-Tanker-White-Paper

Boeing. (n.d.e.). Jet prices. Retrieved from http://www.boeing.com/commercial/prices/

Boeing. (2011, 24 February). Boeing receives US Air Force contract to build next-generation refueling tanker [Press release]. Retrieved from http://Boeing.Mediaroom.Com/Index.Php?S=43&Item=1638

Boeing. (2012, 12 February). Boeing to begin final phase of 737 MAX wind tunnel testing Media release]. Retrieved from http://boeing.mediaroom.com/index.php?s=43&item=2128

Boeing 737 MAX. (2012). In *Wikipedia*. Retrieved March 2012 from http://en.wikipedia.org/wiki/737_MAX

Boeing 767. (2012). In *Wikipedia*. Retrieved March 2012 from http://en.wikipedia.org/wiki/Boeing_767

Boeing skeptical of CSeries, C919, MS-21 EIS [Web log message]. (2010, October 28). *Leeham News and Comment*. Retrieved from http://leehamnews.wordpress.com__XXXX

Bombardier. (2010). CSeries family. Retrieved from http://cseries.com/en/

Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile. (2009, Juillet). *Rapport d'étape: Accident survenu le 1er juin 2009 à l'Airbus A330-203 immatriculé F-GZCP exploité par Air France: vol. AF 447 Rio de Janeiro – Paris*. Retrieved from http://www.bea.aero

Butler, A. (2011, 1 March). What the Boeing tanker win means. *Aviation Week*. Retrieved from http://www.aviationweek.com/aw/generic/story.jsp?id=news/awst/2011/02/28/AW_02_28_2011_p30-292581.xml&headline=What%20The%20Boeing%20Tanker%20Win%20Means&channel=awst

Butler, A. (2011, 7 March). EADS KC-X price exceeded Boeing by 10 percent. *Aviation Week*. Retrieved from http://www.aviationweek.com/aw/generic/story.jsp?id=news/awx/2011/03/04/awx_03_04_2011_p0-294097.xml&headline=Boeing%20KC-X%20Price%20Was%2010%20Percent%20Under%20EADS&channel=defense

Butler, A. (2011, 11 April). Pentagon gives first peek into KC-46A details. *Aviation Week*. Retrieved from http://www.aviationweek.com/aw/generic/story.jsp?id=news/asd/2011/04/08/01.xml&channel=defense

Butler, A. (2011, 29 June). Boeing liable for KC-46 overage. *Aviation Week*. Retrieved from http://www.aviationweek.com/aw/generic/story.jsp?id=news/asd/2011/06/29/01.xml&channel=defense

Butler, A. (2011, 19 September). USAF takes conservative approach to developing, buying future weapons. *Aviation Week*, p. 66.

Butler, A. (2011, 22 September). Schedule is a risk in KC-46A work. *Aviation Week*. Retrieved from

http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=defense&id=news/awx/2011/09/21/awx_09_21_2011_p0-372900.xml

Butler, A., & Warwick, G. (2012, 5 March). Acquisition awry. *Aviation Week*, p. 35.

Capaccio, T. (2011, 28 November). Boeing's cost ceiling may go over $500 million for tankers. *Washington Post*, p. 13.

Censer, M. (2011, 13 March). Now 'good enough' wins the defense contract. *Washington Post*. Retrieved from http://www.washingtonpost.com/wp-dyn/content/article/2011/03/13/AR2011031304386.html

Cohen, A. (2010, 16 October). Boeing upgrades aim to cut 737 fuel use by 2 percent [Web log message]. Retrieved from http://blog.seattlepi.com/aerospace/archives/226223.asp

Credeur, M. J., & Schlangenstein, M. (2010, 13 September). Tiny regional jets fly toward the scrap heap. *Bloomberg Businessweek,* 26.

Cseries to be first for 'live black box.' (2010, 7 September). *Flight International*. Available from LexisNexis Academic database.

Defense Acquisition Management Information Retrieval (DAMIR). (2011, 30 September). *Selected acquisition report, KC-46,* RCS: DD-A&T(Q&A)823-387, Washington, DC: Department of Defense.

Defense Industry Daily (DID). (2011, 7 March). The USAF's KC-X aerial tanker RFP. Retrieved from http://www.defenseindustrydaily.com/the-usafs-kcx-aerial-tanker-rfp-03009/

Deveau, S. (2010, 17). Stakes are high for Bombardier's CSeries. *The Gazette* (Montreal). Retrieved from http://www.montrealgazette.com

Director of Operational Testing & Evaluation (DOT&E). (2011 December). KC-46A. In *FY11 annual report* (pp. 237–238). Retrieved from http://www.dote.osd.mil/pub/reports/FY2011/

Department of Defense (2010), *Mobility Capabilities and Requirements Study 2016* (unclassified Executive Summary), Washington, D.C., 26 February).

Drew, C. (2010, 1 December). Air Force acts to fix error in tanker bid. *New York Times*. Retrieved from http://www.nytimes.com/2010/12/01/business/advertisingemail/01tanker.html?src=busln&scp=5&sq=Christopher%20Drew&st=cse

Drew, C. (2011, 24 February 24). Boeing wins contract to build Air Force tankers. *New York Times*. Retrieved from

http://www.nytimes.com/2011/02/25/business/25tanker.html?nl=todaysheadlines&emc=tha25

Drew, C. (2011, 25 February). Air Force's shifting rules helped Boeing. *New York Times*. Retrieved from http://www.nytimes.com/2011/02/26/business/global/26tanker.html?ref=christopherdrew

Drew, C., & Mouawad, J. (2010, 16 November). Boeing and Airbus waver on reworking their smaller jets. *The New York Times*. Retrieved from http://www.nytimes.com

Embraer. (2010). The company. Retrieved from http://embraer.com

Eshel, N. (2010). IAI's B767-based multi-mission tanker transport demonstrates aerial refueling [Web log post]. *Aviation Week*. Retrieved from http://www.aviationweek.com/aw/blogs/defense/index.jsp?plckController=Blog&plckScript=blogScript&plckElementId=blogDest&plckBlogPage=BlogViewPost&plckPostId=Blog%3A27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post%3Ac2e93212-6028-4206-8ea9-7ae780ee4ca5

Flottau, J., & Wall, R. (2010, 14 June). Alliance revisited. *Aviation Week & Space Technology, 172*(23), 36.

Franck, R. (2012). Business case analysis in the defense sector [Unpublished manuscript]. Naval Postgraduate School, Monterey, CA.

Franck, R., Lewis, I., & Udis, B. (2008a). *Echoes across the pond: Understanding EU-US defense industrial relationships* (NPS-AM-08-001). Retrieved from http://www.acquisitionresearch.net/files/FY2008/NSP-AM-08-002.pdf

Franck, R, Lewis, I., & Udis, B. (2008b). *New patterns of collaboration and rivalry in the US and European defense and aerospace industries* (NPS-AM-08-131). . Retrieved from http://www.acquisitionresearch.net/files/FY2008/NPS-AM-08-131.pdf

Franck, R., Lewis, I., & Udis, B. (2010). *Global cooperation and competition in the defense and aerospace industries* (NPS-AM-10-005). . Retrieved from http://www.acquisitionresearch.net/files/FY2010/NPS-AM-10-005.pdf

Franck, R., Lewis, I., Matthews, D., & Udis, B. (2011). Emerging patterns in the global defense industry (NPS-AM-11-001). Monterey, CA: Naval Postgraduate School. Retrieved from http://www.acquisitionresearch.net/files/FY2011/NPS-AM-11-001.pdf.

Fulghum, D. A. (2010, 20 October). Additional fuel may pay off in tanker competition. *Aerospace Daily & Defense Report*, p. 1

Gates, D. (2010, 7 December). Analyst: Boeing's hopes fading for tanker win. *Seattle Times*. Retrieved from http://seattletimes.nwsource.com/html/businesstechnology/2013612153_tanker07.html

Gertler, J. (2010), Air Force KC-X tanker aircraft program: Background and issues for Congress (FL34398). Washington, DC: Congressional Research Service.

Government Accountability Office (GAO). (2011, 22 December). *Matter of: Hawker Beechcraft Defense Company, LLC, File: B-406170*. Retrieved from http://www.gao.gov/assets/590/587328.pdf

Haskin, T. (2004, 8 July). The might-have-beens: Convair 880 and 990. Retrieved from http://www.airliners.net

Hout, T. M., & Ghermawat, P. (2010). China vs. the world: Whose technology is it? *Harvard Business Review*. December, Retrieved from http://www.hbsp.harvard.edu

Hawker Beechcraft. (2011, 22 November). Hawker Beechcraft requests review of U.S. Air Force light air support contract bidding process after U.S. Air Force denies debriefing request [Press release]. Retrieved from http://www.prnewswire.com/news-releases/hawker-beechcraft-requests-review-of-us-air-force-light-air-support-contract-bidding-process-after-us-air-force-denies-debriefing-request-134322173.html

Hawker Beechcraft. (2011, 27 December). Hawker Beechcraft to file suit with Court of Federal Claims on U.S. Air Force light air support contract bidding process following GAO dismissal [Press release]. Retrieved from http://www.marketwatch.com/story/hawker-beechcraft-to-file-suit-with-court-of-federal-claims-on-us-air-force-light-air-support-contract-bidding-process-following-gao-dismissal-2011-12-27

Hegeman, R. (2012, 28 February). Air Force investigating disputed plane contract. *Boston Globe*. Retrieved from http://www.boston.com/news/nation/articles/2012/02/28/air_force_investigating_disputed_plane_contract/

Hepher, T., & Shalal-Esa, A. (2011, 25 February). Analysis: EADS unlikely to protest tanker defeat. Retrieved fromhttp://us.mobile.reuters.com/article/idUSTRE71O4XP20110225?ca=rdt

Hodge, N. (2012, 29 February). Air Force sets aside plane contract. *Wall Street Journal*. Retrieved from http://online.wsj.com/article/SB10001424052970204520204577251252874025704.html?mod=dist_smartbrief

Hotakainen, R. (2011, 25 February). How one lawmaker steered tanker contract to Boeing. *McClatchy*. Retrieved from http://www.mcclatchydc.com/2011/02/25/109469/how-one-lawmaker-steered-tanker.html

International Aero Engines. (2010). About us. Retrieved from http://www/i-a-e.com

Investopedia (2012), Contestable market theory, Retrieved 17 February 27 from http://www.investopedia.com/terms/c/contestablemarket.asp#ixzz1nbb3XpRr

ITAR-TASS. (2010, 27 October). Ivanov confirms first Superjet-100 plane supplies will begin before yearend [Newswire release]. Available from LexisNexis Academic database.

Jane's. (1991–1992). Boeing model 727 (United States). *Jane's All the World's Aircraft*. Retrieved from http://janes.com

Jane's. (2010a, March 2). Bombardier CSeries. *Jane's All the World's Aircraft*. Retrieved from http://www.janes.com

Jane's. (2010b). Embraer ERJ-145, 170, 190 and Lineage 1000. *Jane's All the World's Aircraft*. Retrieved from http://www.janes.com

Jane's. (2010c). Airbus A320. *Jane's All the World's Aircraft*. Retrieved from http://www.janes.com

Jane's. (2010d). Bombardier CRJ200 and CRJ700. *Jane's All the World's Aircraft*. Retrieved from http://www.janes.com

Jane's. (2010). Boeing 737. *Jane's All the World's Aircraft*. Retrieved from http://www.janes.com

Jane's. (2010f). IRKUT MS-21. *Jane's All the World's Aircraft*. Retrieved from http://www.janes.com

Jane's. (2010). Sukhoi Superjet 100 (SSJ-100). *Jane's All the World's Aircraft*. Retrieved from http://www.janes.com

JetBlue. (2010). Embraer E190. Retrieved from http://jetblue.com

Keenan, S. (2010, 2 October). A new machine. *The Globe and Mail* (Toronto), pp. B6–B9.

Kingsley-Jones, M., Compart, A., & Flottau, J. (2010, October 4). Re-engining decision time. *Aviation Week & Space Technology, 172*(36), 45. Available from LexisNexis Academic database.

Kingsley-Jones, M., & Komarov, A. (2010, 6 September). Russian revival. *Aerospace Week & Space Technology, 172*(33), 40.

Larocque, S. (2010, 29 Octobre). Bombardier: La CSeries sera-t-elle prête à temps? *La Presse* (Montreal). Retrieved from http://lapresseaffaires.cyberpresse.ca

Lynn, W. J., Carter, A. B., & Donley, M. (2009, September 24). *Moving forward*. Retrieved from http://www.defenselink.mil/briefingslide.asx?briefingslideid=340

Mecham, M., & Wall, R. (2010, 22 November). Boeing 787 ice protection may pave way for new structural applications. *Aviation Week & Space Technology*., 45.

Mecham, M., & Norris, G. (2012, 13 February). A shim in time. *Aviation Week*, p. 32.

M.J.S. (2011, 25 February). Home-team advantage pays off for Boeing [Web log post]. *The Economist.* Retrieved from http://www.economist.com/blogs/clausewitz/2011/02/americas_air-tanker_order?fsrc=nwl

Majumdar, D. (2011, 24 February). DoD: Tanker decision protest-proof. *Aviation Week*. Retrieved from http://www.defensenews.com/story.php?i=5800133&c=AME&s=TOP

Majumdar, D. (2011, 17 March). USAF to tightly control tanker requirements changes. *DefenseNews*. Retrieved from http://www.defensenews.com/story.php?i=5989328&c=AME&s=AIR

Majumdar, D. (2011c, 13 October). KC-46: Model program, yet potential delays exist. *DefenseNews*. Retrieved from http://www.defensenews.com/story.php?i=7947746&c=AME&s=AIR

Majumdar, D., & Weisgerber, M. (2012, 19 January). U.S. Air Force disputes testers on KC-46 tanker. *DefenseNews*. Retrieved fromhttp://www.defensenews.com/article/20120119/DEFREG02/301190017

Maxon, T. (2010) Quick resolutions expected to hurdles in Southwest Airlines-AirTran deal, The Dallas Morning News, 29 September, retrieved from http://222.dallasnews.com.

Molnar, M. (2011, November). Boeing 737 MAX will feature larger engines, longer landing gear, fly-by-wire spoilers. Retrieved from http://www.nycaviation.com/2011/11/boeing-announces-new-737-max-engine-and-order-details/

Muradian, V. (2010, 19 November). USAF gaffe roils tanker contest. *DefenseNews*. Retrieved from http://www.defensenews.com/story.php?i=5079218

Muradian, V., & Reed, J. (2010, 16 May). Boeing source: We may not bid for KC-X.*Air Force Times*. Retrieved from http://www.airforcetimes.comNorris, G., Wall, R., & Anselmo, J. C. (2010, August 26). Airbus and Boeing poised for potential divide over reengining. *Aviation Week & Space Technology, 172*(32), 32–33, 35.

Office of the Assistant Secretary of Defense (Public Affairs; OASD[PA]). (2011, 24 February). DOD news briefing with Deputy Secretary Lynn and DOD senior leaders to announce the Air Force KC-46A tanker contract award [News transcript]. Retrieved from http://www.defense.gov/Transcripts/Transcript.aspx?TranscriptID=4776

Office of Assistant Secretary of Defense (Public Affairs; OASD[PA]). (2011, 30 December). Contracts: Missile Defense Agency [Contract]. Retrieved from http://www.defense.gov/Contracts/Contract.aspx?ContractID=4695

Page, J. (2010, 15 November). China wins jet orders in bid to battle big rivals. *Wall Street Journal*. Retrieved from http://online.wsj.com

Perrett, B. (2010, 13 September). C919 will be designed for prolonged competitiveness, says Avic. *Aviation Week & Space Technology*. Retrieved from http://aviationweek.com

Perrett, B. (2010, 22 November). Few orders, weight problems hampering C919. *Aviation Week & Space Technology*. Retrieved from http://aviationweek.com

Pierson, D. (2010, 13 November). China to unveil its own large jetliner. *Los Angeles Times*. Retrieved from http://latimes.com

Pratt & Whitney. (2010). Classic engines: JT3D (TF33). Retrieved from http://www.pratt-whitney.com

Ray, S. (2010). Boeing may win in 2010 orders on 737 as Airbus waffles on A320. Retrieved from http://www.bloomberg.com

Reed, J. (2009, 15 December). Sessions: Northrop threat has Congress uncertain. *DefenseNews*. Retrieved from http://www.defensenews.com/story.php?i=4421294&c=AME

Re-engine no-go? (2010, 6 September). *Aviation Week & Space Technology, 172*(33). Retrieved from http://www.aviationweek.com

RIA Novosti. (2010, 4 November). First commercial Sukhoi Superjet 100 makes maiden flight [Newswire release]. Available from LexisNexis Academic database.

Rothman, A. (2010, 12 October). Jet-leasing 'godfather' Udvar-Hazy clashes with Airbus on A320. Retrieved from http://www.bloomberg.com

Rothman, A. (2010, 21 October). Boeing favors all-new 737 with more seats to reduce emissions. Retrieved from http://www.bloomberg.com

Rothman, A. (2010, 17 December). Airbus works on final U.S. Air Force tanker bid, claiming edge on Boeing. Retrieved from http://www.bloomberg.com/news/2010-12-17/airbus-works-on-tanker-bid-with-plane-boeing-says-is-oversized-.html

Russia's aerospace revival [Blog post]. (2010, 1 November). Retrieved from http://www.asianaviation.com

Sanders, P. (2009, 8 July). Boeing sets deal to buy a Dreamliner plant—Company to pay Vought Aircraft $580 million, forgive cash advances for work on 787. *The Wall Street Journal*. Retrieved from http://www.wsj.com

Sanders, P. (2010, 9 September). Embraer to decide future of commercial jet program. *The Wall Street Journal*. Retrieved from http://www.wsj.com

Sanders, P. (2010, 29 October). Boeing's 737 gets new look. *The Wall Street Journal*. Retrieved from http://wsj.com

Schwartz, N. (2011, 2 March). *Remarks for Defense Programs Conference* [Media release]. Retrieved from http://www.af.mil/shared/media/document/AFD-110302-044.pdf

Scully, M. (2010, 22 November). EADS: Mistaken data release won't scuttle tanker contest. Retrieved from http://www.govexec.com/story_page.cfm?articleid=46575&dcn=e_gvet

Siebold, S. (2011, 5 February). EADS will not improve U.S. tanker. Retrieved from https://www.reuters.com/article/2011/02/05/us-airbus-interview-idUSTRE714O32011205

Sirak, M. C. (2011, 17 October). New tanker update. Retrieved from http://www.airforce-magazine.com/Features/modernization/Pages/box101711tanker.aspx

Smith, R. (1998). *75 years of inflight refueling*. Washington, DC: U.S. Government Printing Office.

Smith, V. (2011, 16 February). EADS cuts price on US tanker bid. *Agence France-Presse*. Retrieved from http://www.google.com/hostednews/afp/article/ALeqM5hC8bM-Cdq-

VJ4hJT6FrqFl1eFg6Q?docId=CNG.45cca10ebab65a1024a443b2db02b658.181

Sukhoi. (2010). *Sukhoi Superjet 100*. Retrieved from http://www.sukhoi.org

Superjet International. (2010). *Profile*. Retrieved from http://www.superjetinternational.com

Thompson, L. B. (2011, 28 February). Tanker wars: Why Boeing won. *Industry Week*. Retrieved from http://www.industryweek.com/articles/tanker_wars_why_boeing_won_23997.aspx?Page=2

Tiron, R. (2010, 12 October). Air Force chief: Tanker process won't be rushed. *The Hill*. Retrieved from http://thehill.com/business-a-lobbying/123895-air-force-chief-tanker-process-wont-be-rushed

Trimble, S. (2010, 2 February). Singapore 2010: IAI unveils plans to convert used 767s into tanker-transports. *FlightGlobal*. Retrieved from http://www.flightglobal.com/news/articles/singapore-2010-iai-unveils-plans-to-convert-used-767s-into-337941/

Wall, R. (2010, 19 July). Game changer. *Aviation Week & Space Technology, 172*(27), 121.

Wall, R., Norris, G., & Flottau, J. (2010, 26 July). Leasing companies give Airbus, Boeing reason to increase output. *Aviation Week & Space Technology, 172*(28), 32–33.

Warwick, G. (2010, 7 September). France and Brazil in Rafale for KC-390 deal? [Web log post]. *Aviation Week*. Retrieved from http://www.aviationweek.com/aw/blogs/

Weisgerber, M. (2011, 4 March). EADS won't protest USAF tanker pick. *Defense News*. Retrieved from http://www.defensenews.com/story.php?i=5868798&c=EUR

Weisgerber, M. (2012, 27 February). USAF vows to minimize acquisition 'Hiccups.' *Defense News*, p. 20.

Wilhelm, S. (2011, 28 November). Boeing spokesman insists Air Force tanker will turn profit. *Puget Sound Business Journal*. Retrieved from http://www.bizjournals.com/seattle/news/2011/11/28/boeing-spokesman-insists-air-force.html

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