Strategic destruction of the Western commercial aircraft sector: Implications of systems integration and international risk-sharing business models

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ABSTRACT

This paper offers a critical perspective on the changing organisational structure of the Western commercial aircraft industry. The role of systems integration based on risk-sharing partnerships for new aircraft programmes is explored. We find that build-to-print subcontracting relationships are being replaced by internationally devolved design and engineering tasks for airframe development, signaling a profound change in the geography of commercial aircraft production. While sensible from a financial standpoint, the international outsourcing of design-intensive production entails substantial amounts of technology transfer – including the delivery of proprietary knowledge to risk-sharing partners. For several of the advanced market economies, including Canada, France, Germany, the UK, and the US, the long-range strategic downside is that foreign risk-sharing partners could eventually become competitors. Systems integration on a risk-sharing basis also implies home-country job-losses among skilled workers with expertise in design, engineering, and R&D.

1.0 INTRODUCTION

The commercial aircraft industry has long been a powerful symbol of Western technological leadership in product-markets requiring high levels of design and engineering innovation. This industry has been an important North American and European export sector for more than 50 years, and many of the advanced manufacturing techniques developed by this sector have been successfully transferred to other industries (e.g. auto-production, machinery, metal fabricating). From now on, however, Western manufacturers of commercial aircraft (e.g. Boeing, Airbus and Bombardier) will likely embrace a systems integration mode of development and production. Under this system, key components and sub-assemblies will be designed and manufactured by external suppliers. While this represents a sensible strategy from a financial perspective, a potential downside is that foreign risk-sharing partners must receive infusions of tacit scientific and technical knowledge from Western manufacturers. Without these transfers, the systems integration strategy would not be effective because risk-sharing agreements usually

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entail much more than build-to-print relationships (discussed shortly). This raises an important question that ought to be of interest to Western trade policy analysts. Specifically, how can technology transfer to Japanese, Chinese, Russian, or other Asian companies have a positive long-term business impact on the Western commercial aircraft industry? Is this the next generation of creative destruction for this sector? Specifically, are we witnessing a process of industrial transformation based on radical innovation at the organisational level[25]? Or, is it the beginning of a new industrial stage based on what we call strategic destruction?

We define strategic destruction as a preference for short-term financial advantage at the cost of losing the knowledge-based value of the company over the long-term. The high-technology commercial aircraft industry is an example of trading away intellectual property to risk-sharing partners – intellectual property that took decades to mature with internal corporate investment and public support from government-funded research laboratories. Private capital markets have never been willing to finance the development of large civil aircraft, pushing most aircraft manufacturers toward global sourcing under risk-sharing partnerships and/or complex subsidy configurations involving both domestic and foreign public agencies. By transforming themselves from manufacturers to systems integrators, will Boeing, Airbus, and Bombardier be promoting innovation by transferring key technologies and core competencies to first-tier risk-sharing partners? Or, will it mean an end as we know them as 'commercial aircraft manufacturers' as they transition toward institutions that market and sell aircraft?

Our goal in this paper is to offer a critical perspective on the changing organisational structure of the Western commercial aircraft industry. Three main research questions are addressed. First, to what extent might risk-sharing under systems integration provide foreign suppliers with the technological capacity to become future competitors? Second, why has risk-sharing become so popular among the world's major commercial aircraft manufacturers? And third, what might the geography of commercial aircraft production look like over the next few decades? These are tough topics to address because the pace of change in this industry has accelerated dramatically in recent years. As little as five years ago, for example, it was inconceivable that Boeing would even consider devolving responsibility for wing design, development, and production to external suppliers (especially foreign ones). But this is exactly what happened in 2005 on the 787 programme. Only four years ago, we argued that Airbus differed from Boeing in that the former preferred to subcontract parts production for older models, keeping key technologies and processes for newer models in-house[22]. This has changed too, notably on the A350 programme. By the time this paper is published, no doubt other dramatic events will have taken place. Even so, a synopsis of recent corporate change within the commercial aircraft industry would seem appropriate at this point in time – especially in view of the escalating commercial tensions between the EU and the US regarding trade in large civil aircraft.

2.0 RESEARCH CONTEXT

The West has enjoyed a strong comparative advantage in commercial aircraft production for more than 50 years. However, this advantage is starting to weaken in light of growing international competition from lower-cost countries such as Brazil, Russia, and China[12,20]. Boeing has already opted for a systems integration mode of production for its new 787 model, whereby manufacturing and design processes are distributed across an international network of risk-sharing partners[22]. Airbus and Bombardier plan to use this business model for launching their latest aircraft programmes (A350XWB and C-Series), if only because this approach has clear financial advantages for the systems integrator. This approach allows aircraft companies to invest less capital into new launch programmes, as compared to the self-funded launch initiatives that have traditionally characterised this industry. Today's commercial aircraft industry is far different from the early days of jet production, when each aircraft company invented on its own. In the future, system integrators will lose ownership of intellectual property to an industry that is moving toward open architecture. Specifically, the knowledge from research will be made 'public' by the first and second-tier suppliers. Since the risk-sharing partners will not be allowed to pass along their non-recurring development costs, they will recoup their investment by amortising the cost of product development across several manufacturers' aircraft programmes.

After losing ground to Airbus for much of the early 2000s, Boeing rebounded to a 50·3% share of the large commercial aircraft (LCA) market in 2006 (sales of $27bn) – leaving Airbus with a 49·7% share ($26·7bn). The regional jet (RJ) market is split between Bombardier (with a 48% market share in 2006) and Embraer (42%). ATR had a 10% share of the RJ market in 2006. Both the LCA and RJ markets can be described as duoplies, in that two players dominate each segment. In a previous paper[22], we argued that duopolistic competition in either market would be unlikely to prevail idenfinitely because the globalisation of the aircraft industry has been opening doors for new competitors. Some of the emerging market opportunities for new entrants (or re-entrants such as Russia) have been driven by industrial offset agreements, while others stem from recent developments in the regulatory environment for international trade.

From a commercial perspective, the current World Trade Organization (WTO) EU/US large aircraft dispute will likely alter the way all aircraft manufacturers finance the launch of new programmes. Boeing has chosen not to fully self-fund the Boeing 787 programme, although the company certainly has the cash reserves to do so. Instead, Boeing has elected to lower its programme costs by opting for domestic and foreign subsidies (along with outsourcing the bulk of the development and production costs to risk-sharing partners). Bombardier is at a crossroads for its regional jet product line with the ramping-down of its CRJ200 and 400 models, and has a backlog of less than 70 aircraft for the CRJ700 and 900 models. Bombardier is not in a financial position to self-fund the launch of the proposed C-Series aircraft, and plans to adopt the system integration business model as a matter of necessity. Bombardier has openly stated that the company will take funding from national and regional governments for the C-Series programme. Airbus also plans to employ a systems integration mode of production because of the possible loss of repayable launch investment for the A350XWB, and will utilise "domestic and foreign" government financial incentives that match the types of subsidies that Boeing has secured for its 787 programme. Only a few years ago, Airbus confined its industrial offset and subcontracting relationships to minor 'bits and pieces' – and usually for older models. This is no longer the case. Development and production delays for the A380, along with design and production uncertainties for the A350, have pressured Airbus to explore massive cost-containment initiatives (Power8). The commercial success of the yet-to-fly Boeing 787 has added to the competitive pressures facing Airbus, yet there is turbulence on the radar for all four of the major Western producers of passenger jets (i.e. Airbus, Boeing, Embraer and Bombardier).

The reluctance of companies to invest in their own aircraft programmes is symptomatic of this sector's growing reliance on risk-sharing contracts with external suppliers. The widespread acceptance of the system integrator approach, which relies heavily on outsourcing design and sub-assembly production, seems to be taking hold with all four major commercial aircraft manufacturers. We need to give credit to Embraer in fostering this business model on the ERJ series of regional jet aircraft, even though it was more out of necessity than reluctance to use its own financial resources. In any case, Boeing has taken the system integrator model to a new level by outsourcing close to 90% of the parts for the Boeing 787 twin aisle aircraft (the only significant part of the airframe that Boeing will produce is part of the vertical tailfin). This is in contrast

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to the launching of a commercial aircraft programme in the 1960s, which saw the major aircraft manufacturers launch a new aircraft by self-funding the design, development, tooling, and infrastructure – though often with indirect public subsidies. Beginning in the mid-1970s, companies would deploy offset programmes to sell aircraft and transfer production to foreign countries. This had two important implications. First, the manufacturer gained market access to sell aircraft abroad. For example, industrial offset agreements with China in the 1980s assured Boeing that Air China would buy large numbers of 747s (a successful strategy). Second, it reduced the level of self-funding needed to launch a new aircraft.

3.0 SUPPLY SOURCES MIGRATE TO THE EAST

The aircraft industry currently has several major programmes in development, including the recently certified Airbus A380 and the Eclipse 500 VLJ (very light jet). Other programmes are starting their final assembly phase, such as the Boeing 787, Sukhoi's Super Jet 100, China's ARJ-21 Regional Jet, and the A400M Airbus Military Transport. Along with the Airbus A350XWB, Embraer's Phenom VLJ, and the proposed Bombardier C-Series, there are plenty of new aircraft programmes in the works. Although all this sounds like good news for existing North American and European suppliers, the devil is in the details. All of these programmes have a common theme. Specifically, they all require the flight hardware/airframe suppliers to contribute to the programmes by various means such as non-reimbursable development costs or no-cost pre-production/test hardware, as well as the possibility of becoming risk-sharing partners.

The aircraft supplier base is a niche group of companies that vie for long-term fixed- price contracts or participate in risk-sharing programmes. Today, demands on the technical and financial resources of these suppliers are being strained to the point where many of these companies will not be able to meet production requirements (cash flow). Some of these companies might actually elect not to bid on programmes. As an example, Boeing has done an excellent job on the 787 programme by tying up most of the world's qualified first-tier composite structures suppliers, leaving Airbus to develop new suppliers that will take on a risk-sharing role in its A350XWB programme. Entering this market as a prime contractor in the composites domain will be both costly and risky for any new player, and may well require major public subsidies.

We will sidetrack for a moment to illustrate the changes in commercial aircraft launch funding over the past 40 years that have affected the supplier base. In the 1960s, Boeing would launch a new aircraft by self-funding the design, development, tooling, and infrastructure (albeit with indirect public subsidies from the military side of Boeing's operations). Boeing went so far as to donate production equipment to its US suppliers, as the company had an urgent need for accurately machined airframe components. From the mid 1970s, Boeing deployed offset programmes to sell aircraft and transferred production (build-to-print) to foreign countries. This had two important effects. First, Boeing gained market access to sell new aircraft. Second, this strategy reduced the level of Boeing's self-funding needed to launch a new aircraft. During this era, Airbus could rely on government repayable investment up to 100% for a new aircraft programme. Although the 1992 EU-US Large Aircraft Agreement limited such launch aid to 33%, the US abandoned the 1992 agreement in 2004 – cutting repayable launch investment to 0%. So, in a nutshell, Boeing learned to find government financial support mechanisms for its foreign suppliers to replace its own self-funding of aircraft launches, while simultaneously challenging the ability of Airbus to legally obtain EU government repayable launch investment for new aircraft programmes. The recently announced details of the Airbus's Power8 programme suggest that the European workforce will be cut by 10,000[1], which reinforces the Airbus strategy of moving away from European launch repayable aid for the A350XWB programme.

In late 2004, the US Trade Representative (USTR) gave notice of withdrawal from the 1992 EU–US Large Aircraft Agreement. The goal was to give Boeing a 'level playing field' by challenging the legitimacy of Airbus EU repayable launch investment. In effect, this forced Airbus to become a system integrator along the lines pioneered by Boeing on the 787 programme. The system integrator approach for Airbus and Boeing will have them totally committing their launch process to high levels of design and production outsourcing, seeking long-term contracts in dollars, and sourcing to low-cost regions (e.g. China, Russia, and India). This is all bad news for the traditional North American and European supplier. The new 'government supported' risk-sharing partners in the 'East' will require Western suppliers to participate by various means in host-country production through outsourcing or offshoring, in-country design offices to service the first-tier risk-sharing partners (tribal knowledge transfer and technology leakage will occur), and possibly the licensing of production. Airbus has informed its first-tier suppliers that outsourcing to Asia is a requirement, and that failure to comply will entail significant penalties. These requirements will no doubt be down-flowed to second and third-suppliers, which will enable the first-tier group to meet its requirements. How can the traditional North American and European suppliers compete with foreign government financed aerospace industries in the "East" unless they make outsourcing an integral part of their production strategies? Is this creative or strategic destruction?

4.0 THE BOEING 787 PROGRAMME

Boeing has outsourced close to 90% of parts production for the 787, even after the US government provided Boeing with $1·8bn in NASA money for the High Speed Civil Transport (HSCT) programme (which was specifically earmarked to enhance the US industrial base). Boeing gained knowledge and expertise from B-2 military composite technology development in the 1980s, when the company benefited from facility capitalisation which included engineering and manufacturing equipment to support large composites structure production which was a new endeavour[2]. The US taxpayers reward Boeing shareholders with billions of dollars by elimination of taxes, yet there is no accounting for domestic content in return. As far as we can tell, there are no significant clawbacks attached to any of these tax holidays or subsidies.

On the 787 programme, foreign risk-sharing partners will have full control over the selection of second-and-third-tier suppliers. This has never happened before, and represents a turning point in US commercial aviation history. The technology and process improvements required for the 787 go well beyond raw material requirements (composites). Boeing's partners in Japan and Italy will be building composite structures that include sophisticated sub-systems that are already certified, tested, and ready for final assembly. There will be minimum work content in the three-day final assembly (accounting for about 4% of the aircraft's value) for the fewer than 1,000 Boeing Everett workers on the 787 programme. Although Washington State gave a $3·2bn ($3·2m per production employee) subsidy package to Boeing to support the 787 programme (Pritchard, 2004), Boeing has continued to decrease the US content of its aircraft models as illustrated in Table 1. This downsizing can also be illustrated by the reduction of employment in Boeing's commercial division from pre-9/11 levels of around 90,000 to current levels of a little over 40,000. Employment has been slashed by selling major manufacturing sites to other aerospace companies, by closing production lines (e.g. 717 and 757 models), and by boosting foreign content.

An interesting feature of the 787 development process is that Japanese aerospace companies will build the all-composite wing. The diffusion of technology and innovation to Japan means that Japanese suppliers will soon be in position to build their own

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Table 1
Boeing's 727/777/787 foreign content

Airframe	727	777	787
Wing assembly	US	US	Japan
Centre wing	US	Japan	Japan
Front fuselage	US	Japan	Japan/US
Aft fuselage	US	Japan	Italy
Empennage	US	Foreign	Italy/US
Nose assembly	US	US	US

commercial aircraft as a direct result of decades of industrial offset arrangements between Boeing and the Japanese 'heavies'. It was recently reported that Japan will launch a large regional jet (72 to 92 seats) dubbed the MRJ Jet in 2008, with Japanese government subsidies of roughly $1bn. We find it curious that the US Department of Commerce did not probe the diffusion of US composite technology on the 787 programme with greater intensity.

5.0 AIRBUS A350XWB

The launch of the A350XWB in December 2006 is likely to change the way Airbus designs, manufacturers, outsources, and assembles aircraft. There are two contributing factors for this restructuring. First, there is a potential shortage of development funds because of legal uncertainties regarding the availability of European repayable launch investment. This is a direct result of the current WTO aircraft dispute between the US and Europe, which led the US to abrogate the 1992 Large Commercial Aircraft agreement in October 2004. Secondly, there is a need for Airbus to control its production costs by seeking risk-sharing partners in low-cost regions that will contract in dollars and have access to domestic government subsidies. Airbus ceo Louis Gallois recently noted that "50% of the aerostructure work on the A350 XWB will be outsourced to risk-sharing partners[9]". Airbus has not outsourced at this level in the past, suggesting a profound change in corporate philosophy that mirrors at least some of the cost-reduction initiatives that Boeing has been perfecting for several years. In some respects, Airbus is a late player in a game that was started by Embraer – but honed by Boeing.

This said, the A350XWB will have new technologies that will rival the Boeing 787. The wing and fuselage will make extensive use of carbon fibre reinforced plastic (CFRP) to improve operating costs. Airbus's A350XWB programme will have a technological advantage in composite wing development over the Boeing 787 because it will benefit from the already-built composite wing on the EADS A400M military transport programme. There are technological advantages to being a second-mover in the race for an all-composite commercial aircraft. Airbus has observed for the past two years the major engineering issues on producing composite barrels for the Boeing 787, and instead has chosen to create composite panels that will be fastened to an aluminum skeleton frame.

The Airbus A350XWB programme is going to cost $13·5bn in R&D, along with $2bn in capital expenditure[17]. The financing of the A350XWB will come from three sources, including Airbus cash flow generated from its Power8 programme, European government support (e.g. industrial bonds), and major suppliers who take a risk-sharing stake in the project. The risk-sharing partners will invest their own money in engineering, testing, and manufacturing. The Power8 vision addresses three major goals. The first goal is to speed up the A350XWB development time, so that the company can regain market leadership in the 250-350 seat category[8]. A second goal is to maximise cash flow for future aircraft launches (e.g. an A320 replacement). The third objective is to cut costs to secure competitiveness (contract in low-cost regions in US dollars). A major restructuring of how Airbus procures aircraft is at the center of the Power8 programme. The company plans to move from a decentralised to a centralised purchasing organisation, change its supplier base from a fragmented to a consolidated structure (first-tier suppliers will control lower tiers), and move sourcing from high-cost Western countries to lower-cost nations such as China, Russia, and South Korea. Airbus plans to eliminate its investment in parts inventory by forming four to eight logistics centers to co-ordinate supplier-owned stock parts, which will be delivered to Airbus factory sites on a JIT (just-in-time) basis. The Power8 path will take five years to maximise the full results by implementing the eight modules:

- Develop faster,
- Smart buying,
- Lean manufacturing,
- Reduce overhead,
- Maximise cash,
- Restructure industrial set up,
- Streamline final assembly lines, and
- Focus on core

Airbus will also be investigating the possibility of divesting major manufacturing sites, just as Boeing did in the immediate post-9/11 period. In November 2006, Goldman Sachs issued an EADS report that discussed the possibility of divesting seven of their 16 major manufacturing plants in an effort to reduce direct costs. The factories considered as non-core to Airbus's future requirements are Nantes and Meaulte in France, Stade, Buxtehude, Varel, and Nordenham in Germany, along with Illescas in Spain[11]. There are two common factors among these sites: they make lower level composite components or employ older 'metal bending' fuselage assembly technologies. Airbus is going to outsource over 50% of the airframe work on the A350, and is currently looking at ten potential risk-sharing partners from Europe, Asia, the US, and Latin America. The risk-sharing partners should expect to absorb $2·5bn of the A350 development costs. Memoranda of Agreement are already in place for China, South Korea, and Russia. The conditions for risk-sharing partners are that they need to pay for component development costs, as well as be competitive in terms of recurring costs (production) in dollar contracts. The critical aspect for risk-sharing partners to be successful is to ensure they have the financial and technical capabilities, along with the engineering workforce available to design and build composite structures. The allocations to the risk-sharing partners for the A350XWB work packages are expected to be accomplished by mid 2007.

In late February 2007, Airbus announced that it would sell or find partners for six factories as they cope with the burden of the decline of the dollar against the Euro (a 40% drop since December 2000), along with a $900m write-off as it transforms the current business model into a global network of partners. There has been significant give and take between the countries that house Airbus facilities, but there is partial victory for the UK. The most probably scenario is that Airbus/Filton (UK) will joint-venture with GKN, the UK engineering group, to manufacture the next generation of composite materials for the A350XWB[7]. Germany is not so lucky in this regard, as German factories are almost totally reliant on contracts for metal structures.

6.0 THE BOMBARDIER C-SERIES

Bombardier is at an inflexion point regarding its regional jet product line. In 1998, Bombardier was poised to launch the BRJ-X programme (Bombardier Regional Jet eXpansion: 80-120 seats), which would have been in direct competition with the very successful Embraer 170/190 series aircraft. In November 2000, however, Bombardier's management decided that the BRJ-X was a precarious venture, and instead opted to stretch the CRJ into 70 and

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90 seat platforms[5]. These CRJ stretch programmes have not been successful. By mid 2005, Bombardier's cash on the balance sheet stood at $2·3bn, while long term debt was $3bn as their regional jet backlog was dwindling. Bombardier is now asking for government subsidies from Canada and the UK, along with possible risk-sharing participation from China and Russia to launch the C-Series aircraft. Bombardier is slated to invest only about 25% of the total launch costs of $3·1bn for the C-Series regional jet, and will have final assembly and nose sub-assembly located in Canada. Bombardier is seeking $700m from the Canadian and UK governments. Funding will take place mainly via repayable launch investment and selective financial assistance. Bombardier recently changed the C-Series wing from the traditional metal to composite. This was driven by performance requirements from UK government agencies that instructed Bombardier to move up the technological ladder in exchange for government financial support. The programme is looking for another $700 million from non-engine risk-sharing suppliers, whereas Bombardier is expected to fund its $700m share of the development programme from cash flow. The engine manufacturers will have the largest investment in the C-Series programme, with $1bn slated for the development of new powerplants.

While Bombardier has yet to decide where the fuselage tubes will be manufactured, there have been discussions with Shenyang Aircraft (China) and Sukhoi Civil Aircraft (Russia) regarding production requirements for 232 fuselages per year. It is believed that neither of these two companies have the capability to produce the total yearly requirement, so it is conceivable that Bombardier will have co-production fuselage lines in China and Russia. Bombardier's proposed partners in China and Russia could be building structures that are stuffed with sub-systems that are already internationally approved, tested, and ready for final assembly. Under this scenario, there will be minimum work for Canadian employees on the C-Series programme, with only a three to seven day final assembly effort (fashioned like the Boeing 787 programme). If Bombardier allows its first-tier suppliers to select, contract, and oversee the second and third-tier suppliers, then the long-term survivability of Canadian suppliers could be in jeopardy. This, along with Bombardier's decision to invest $200m into Mexican manufacturing facilities that will produce wiring assemblies and major structural components, does not bode well for the Canadian workforce or its personnel in its Northern Ireland factory[15]. Although Bombardier enjoyed an almost 50% share of the world's regional jet market in 2006, it is clear that the company's senior management has fully endorsed the systems integration approach.

7.0 RUSSIA AS A PARTNER AND POTENTIAL COMPETITOR

The Russian commercial aerospace industry is starting to consolidate the control of its aircraft plants under the state-run Unified Aircraft Building Corporation (or UABC). The Russian government's ambition is to combine the aircraft companies Irkut, Mikoyan, Sukhoi, Ilyushin, Tupolev, and Yakovlev into a single company to raise the country's international competitiveness. The UABC was formed by presidential decree, and is seeking $12bn in public support to develop the country's aviation industry[18]. UABC will realise seven projects proposed by the Russian aircraft industry that will include the Sukhoi Superjet 100 (formerly the Russian Regional Jet), along with a medium-range (130-170 seats) MS-21 which will be designed and manufactured by Irkut, Ilyushin, and Tupolev. The funding structure is remarkably similar to the type Boeing receives from US government sources, and it will be interesting to see if the US or the EU draws Russia into the current EU/US WTO aircraft subsidy dispute. Sukhoi Civil Aircraft is partly financing the development of the Super Jet 100 programme with a 100m Euro loan from the European Bank for Reconstruction and Development[19], along with issuing a bond (ten-year maturity) for 5bn rubles[3].

Both Boeing and EADS/Airbus have vested interests in the Russian airline/aerospace industries, which span from the marketing strategy of selling aircraft in Russia to sourcing titanium components. EADS has a two-way relationship with Russia's state-owned Vneshtorgbank. The latter owns a 5% stake in EADS, whereas EADS owns 10% of Russia's Irktuk Aircraft Company. There have been discussions between Airbus and Russia regarding a production partnership for A320 and A330 freighter conversions. Airbus has held meetings with Alexei Fyodorov, chief executive officer of UABC, regarding Russian companies' risk-sharing partnerships for the design and production of the A350XWB. Richard Aboulafia, of the Teal Group, stated that "The Russians offer nothing unique technologically, but Airbus needs to spread costs, and because there's Russian government money available, the Russians can certainly do this"[23]. This could be said about every commercial aircraft industrial offset agreement because the prime contractor, in this case Airbus, is seeking low cost fixed-price contracts in US dollars.

While Airbus is currently making inroads in Russian industrial cooperation, Boeing has committed to developing a long-term relationship with Russia. This is evidenced by Boeing's investment of more than $1bn in co-operative programmes, including the development of the Boeing Moscow Design Center that supports 1,300 Russian engineers. Typical costs for Boeing's outsourced engineering work to Russia are about $15 an hour. In the past, this was done via contracting the Ilyushin Design Bureau at $15 per hour, with the Russian engineer receiving about $10 per hour. This has clear financial advantages for Boeing, in that a US engineer typically costs over $100k per year (salary, overtime, benefits and pension). The Boeing Moscow Design Center utilises the same engineering software platform as the Seattle offices. The level of complexity of work packages is lower, but in the long term there is still a leakage of Boeing tribal knowledge and intellectual property that could benefit the Russian aerospace industry in the future. Although recent political tensions between the US and Russia suggest that Airbus may start to gain a stronger foothold in this market over the next few years, Boeing has already made substantial investments in Russia that will be difficult to overlook by Russian politicians.

8.0 CHINA AS AN EMERGING REGION FOR COMMERCIAL AIRCRAFT PRODUCTION

China is committed to developing a family of aircraft that meet Western certification standards to support its domestic airlines. Decades of industrial co-operation with the main global airframers has helped China acquire basic production competence in several key areas (see Table 2). Currently, China is working with Boeing on 737 and 787 programmes that have an estimated contract value of $600m[10]. Airbus has a Memorandum of Understanding signed with China for a 5% risk-sharing partnership on the newly launched A350XWB. The Chinese government has a policy not to have competing production lines for the same single-aisle 'Western technology' aircraft. For example, China has the Embraer ERJ 145 co-production for the 45-55 seat aircraft, its own ARJ-21 for the

Table 2
China aircraft offset programmes

Assembly/part	Programme	Source/Offset
Vertical fin & tail	Boeing 737	Boeing USA
Empennage	Boeing 757	Vought USA
Final assembly	MD-82	McDonnell USA
Nose & wing	A320	Airbus Europe
Final assembly	A320	Airbus Europe

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60-105 seat range, and has recently announced a final assembly line for the Airbus A320 with 130-160 seats. The expected technology transfer from the Airbus joint-venture will assist China in its plans to develop its own trunk-line commercial aircraft with at least 150 seats, which is part of China's 11th Five Year Plan (2006-10)[13]. Preliminary discussions are underway between China and Russia to produce a wide body aircraft that would compete with Boeing's 787 and Airbus's A350XWB.

The Western aircraft suppliers will have to foster a strategy to have close proximity to the Airbus factory in Tianjin (China), and take advantage of investment incentives ranging from tax holidays to capital grants that will significantly lower the cost of their new manufacturing facility. Transferring low-end engineering work packages will lower development costs and avoid the 23% import duty on their products to support the Airbus joint-venture. There is no doubt that suppliers are expected to transfer technology to their Chinese outsourcing partners or offshore facilities that will be utilised for China's mission to develop its own large commercial aircraft (twin-aisle).

It is often argued in the business press that China is decades away from developing large commercial aircraft, and that China lacks the technological capability to enter this market in the near future. We opt to challenge this perspective in light of the sheer volume of investment capital that the Chinese government can throw at its infant aircraft industry. At present, for example, China's official reserves stand at over $900bn and China has a recent GDP growth rate of close to 10% per annum. China is already producing advanced fighter aircraft under license agreements with Russia, and Chinese factories are equipped with the types of multi-axis machine tools and fastening devices that are needed to build commercial aircraft. China, of course, has full access to the design software that is currently used by engineers in Seattle, Toulouse, and Montreal (among other cities). More important, perhaps, is the fact that China has openly declared its intention to develop an indigenous commercial aircarft sector as part of a strategic economic plan to curb imports. This intention should be treated seriously by trade policy analysts, if only because the Chinese have already entered markets that were once viewed as exclusively Western (e.g. automobiles) or exclusively 'superpower' (e.g. space vehicles). In short, it would be unwise to dismiss China as a potential player in the LCA or RJ markets simply because it took other players a long time to establish a credible foothold in this industry.

9.0 JAPAN'S INDUSTRIAL CO-OPERATION

Japan's national policy for developing its aircraft industry goes back to 1958 with the Aircraft Industry Promotion Law (AIPL), which helped create Japan's International Aircraft Development Fund (IADF) that supports the Japanese Aircraft Development Corporation (JADC). The main partners of the JADC are the heavies Mitsubishi (MHI), Kawasaki (KHI), and Fuji (FHI). These government mandates created a platform to subsidise the Japanese suppliers on the Boeing 767, 777 and 787 programmes with grants and royalty-based formulas. These trade-distorting programmes allowed the Japanese aircraft industry to receive technology infusions in exchange for low-margin fixed dollar price contracts. The previous Japanese government international funding schemes for the Boeing 767 (1979) and 777 (1991) aircraft programmes would be ruled illegal under the 1994 WTO Agreement on Subsidies and Countervailing Measures.

The Japanese have invested in high-end technology in their industrial cooperation programmes with the West. Their first major co-operative programme dates back to the late 1970s with the Boeing 767 programme, when they produced fuselage airframes (build-to-print). Today, Japan is the first-tier partner for the Boeing 787 composite wing programme. Under this programme, Japan has design and development responsibility for the wing. These first-tier partners are also responsible for contracting/managing the second- and third-tier suppliers. Japan's technological leadership in composites is one reason that Boeing contracted 35% of the 787 to Japan. The technology and process improvements required for the 787 go far beyond raw material requirements (e.g. Toray for composites). Boeing's partners in Japan will be building composite structures that are ready for final assembly in Everett, Washington. Table 3 illustrates the subcontracting packages to Japan which requires technology diffusion from the aircraft manufacturers.

Table 3
Japan industrial co-operation programmes

Assembly/Part	Programme	Source/Offset
Fuselage panels	A321	Airbus Europe
Fuselage panels	CRJ700/900	Bombardier Canada
Fuselage tubes	767 & 777	Boeing USA
Wings (composite)	787	Boeing USA
Wings (metal)	Global Express	Bombardier Canada

In the past year Japan has been returning Western work packages to Airbus, Bombardier, and Embraer. KHI did not renew its Airbus contract for the A321 aft fuselage section, and gave back to Embraer the wing assembly for the 170/190 regional jet. MHI turned back the Q400 (regional turboprop) fuselage work to Bombardier, which then was subcontracted to China. One can surmise that Japan is starting to 'clear the deck' by giving back work packages to open up manufacturing capacity and alleviate any contractual conflicts with their domestic commercial aircraft programme.

Japan is poised to become a future player in the regional jet market, notably with respect to the MHI announcement on the possible launching of the 72-92 seat MJ Jet[4]. The project to build Japan's first passenger jet will require about $1bn in funding, up to 30% of which will come from government subsidies[24]. This composite regional jet will be made possible in part by Boeing transferring the key technologies of the wing and fuselage on the Boeing 787 composite airframe structures. But this should come to as no surprise based on Mitsubishi Heavy Industries' vision on where the new aircraft composite technology for the 787 can lead the nation in the future. Junichi Maezawa, Executive Director of MHI, said that the "7e7 (now the 787) is a cornerstone for Japan to become a stand-alone aircraft manufacturer in producing a 30 to 50 seater aircraft in a few years." As of February 2007, the Mitsubishi Regional Jet programme has the timeline of spring 2007 for basic configuration, a decision gate of autumn 2007 for authorisation to offer the aircraft for sale, final Go/No-Go to proceed in the spring of 2008, and an entry into service date of 2012. The main determining factor for the success of this programme will be the risk sharing partners signing on to a programme that could be deemed the fourth player behind Embraer, Bombardier and Sukhoi. Boeing is currently looking at an all-composite replacement for the 737 (dubbed the 797), with a seating range from 90-200. It could be envisioned that Japan would produce the composite wings for all 797 versions, along with having the final assembly line for the 'regional jet size' version with 90-110 seats. One could easily link this project with Boeing's announcement that the company is looking to have two separate aircraft to replace the existing 737[26].

10.0 SUMMARY AND CONCLUSIONS

The introduction of Boeing's 787 systems integration approach, together with the current WTO EU/US aircraft dispute, has the potential to change the way all aircraft manufacturers will finance the launch of new programmes in the future. The complex web of global subsidies supporting the design, infrastructure, and production of commercial aircraft will transcend national borders. For Boeing, Airbus, and Bombardier, the launches of their aircraft programmes based on system integration makes good sense in terms of risk

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reduction, market penetration, the containment of launch costs, and the use of foreign risk-sharing partners to court foreign government funding. But the financial benefits need to be balanced against broader economic and strategic concerns, including the erosion of the Western commercial aircraft industry in terms of production activity – as well as the fact that rising levels of foreign content ultimately contravene the interests of Western workers in skilled occupations.

Boeing, Airbus, and Bombardier are poised to play an increasingly pivotal role in the globalisation of commercial aircraft manufacturing. These large multinational companies will cross-over the world to bring together the emerging markets of China, India, and Russia. In so doing, such companies will spread Western aircraft technologies, innovation and tribal knowledge to new players (and potential competitors). To survive, Western suppliers will have to lower their costs by outsourcing/offshoring design and production to emerging countries such as China.

For the first time in Western commercial aviation history, the system integration launch process has been structured in a fashion that gives foreign partners the control over design, manufacturing, and sub-tier supplier selection. Ultimately, these risk-sharing partners are acquiring the financial and technological capability to undermine the Western commercial aircraft industry. Will there be any corporate social responsibility from Boeing, Airbus, or Bombardier to their home countries that have spent billions of dollars in supporting and developing the technologies which they possess today? Instead, will they take short-term financial gains for their current shareholders at the cost of losing the long-term strategic value of their proprietary assets? There seems to be no turning back for these aircraft manufacturers. The cost of launching a new aircraft can run into the tens of billions dollars, and with the reluctance of the two who can self-fund their programmes compared to the one that is financially unable, the new system integration business model is here to stay.

From a policy perspective, there is probably little room for corrective action in terms of regional employment protection or the maximisation of value-added at the local scale – at least not for those localities that house systems integrators such as Boeing or Airbus. Subsidies granted to these major corporations appear to be void of significant clawbacks, if only because affected regions are invariably desperate to retain as many aerospace-related jobs as they can. The political backlash from the Airbus Power8 programme has already started to gain momentum in Germany, France, and the UK, where close to 10,000 jobs will be slashed over the next year or so. It would appear that Airbus has no choice but to replicate Boeing's approach toward cost containment.

A curious twist in this complex and rapidly unfolding story is that outsourcing under systems integration is not driven by a strategic interest in the minimisation of total costs for any given aircraft launch. Rather, a more important goal is to cut unit costs for the systems integrator and spread financial risk across the supply chain. Hickie (2006)[14] shows that systems integration in the aircraft industry tends to inflate total costs for a new product launch. Airlines and passengers do not absorb these extra costs, at least not directly. Instead, large chunks of these extra costs are paid by public agencies that fund their subsidy programmes from tax dollars. From a global welfare perspective, what might look like a free meal is anything but. Somebody has to pay, right? The 'free meal' is ultimately paid by taxpayers who have no direct control over the allocation of their tax dollars.

To rejoin the introductory thrust of our paper, it would seem that most of the world's major commercial aircraft manufacturers are heading down a path of strategic destruction. Short-term financial imperatives are driving a technology diffusion trend that will be hard to decelerate, stop, or reverse via public or shareholder intervention. The 787 programme provides a near perfect example of international technology diffusion, in that one of the most innovative aspects of this new aircraft is its all-composite wing (to be designed, developed, and manufactured in Japan). It is no coincidence that the US Census Bureau forecasts a 23% drop in design-related employment in the US commercial aerospace sector by 2020. By now, there is a substantial academic literature that warns of the strategic dangers of corporate hollowing-out (for a recent overview, see Dankbaar, 2007[6]). Specifically, outsourcers often lose their ability to innovate independently as a result of internal skills erosion. This does not mean that companies such as Airbus or Boeing will be financially unsuccessful in the future – far from it. Instead, our argument is simply that these companies are on-track to become assembly centres that build kits (albeit very expensive ones), and then sell them via their elaborate marketing and financing channels. The long-run employment implications for aerospace engineers in cities such as Montreal, Seattle, or Toulouse are presumably not good. In contrast, skilled workers in nations such as China, Japan, or Russia stand to gain quite a lot from global restructuring. Most economists would argue that this is a market-powered thrust that will eventually maximise global welfare in much the same way as 'outsourcing' in general. We disagree, but cannot see how any of this can be stopped.

REFERENCES

1. Power8 prepares way for 'New Airbus', 28 February 2007, Airbus. http://www.airbus.com/en/presscentre/pressreleases/pressreleases_items/07_02_28_Power8_Press_Conference_EN.html
2. B-2 systems engineering case study, 2003, Air Force Center Systems Engineering, . Wright-Patterson. http://www.afit.edu/cse/docs/AF%20SE%20B2%20Case%20Study.pdf
3. Sukhoi Civil Aircraft to place a debut bond issue worth RUB 5bn, 26 December 2006, AK&M Information Agency, http://www.akm.ru/eng/news/2006/december/26/ns1839767.htm
4. MHI scrambles to save jet dream, *Daily Yomiure Online*, 22 November 2006. http://www.yomiuri.co.jp/dy/business/20061122TDY08006.htm
5. Bombardier shelves 100-seat-plus jet plans indefinitely, *CBC News*, 30 November 2000. http://www.cbc.ca/money/story/2000/11/30/bombard001130.html
6. DANKBAAR, B. Global sourcing and innovation: the consequences of losing both organizational and geographical proximity, *European Planning Studies*, 2007, **15**, pp 21-38.
7. DONE, K. Airbus to unveil plan for new factory at Filton, *Financial Times*, 28 February 2007.
8. Power8 update, EADS, 2006, Global Investor Forum, 19-20 October 2006. http://www.eads.net/xml/content/OF00000000400004/2/74/41485742.pdf
9. Suppliers 'to fund €1·8bn Euro costs', *Flight International*, 6 December 2006. http://www.flightglobal.com/Articles/2006/12/12/211029/suppliers-to-fund-1.8bn-of-costs.html
10. FRANCIS, L. Opening doors, *Flight International*, 24 October 2006. http://www.flightglobal.com/Articles/2006/10/24/Navigation/318/210063/China+special+Opening+doors+-China's+growing+market+for+aircraft.html
11. EADS report, 21 November 2006, Goldman Sachs, http://www.leeham.net/filelib/EADS_22Nov06_GoldmanSachs.pdf
12. HARRIGAN, F. Integrating theories of boundary choice: a case of the global aircraft industry, 2006, UCD School of Business, University College Dublin: http://www.eaa2006.com/pdf/EAA2006_0794_paper.pdf (last accessed 10 October, 2006).
13. HAOTING, H. Chinese partner of A320 details shareholding, *China Daily*, 21 November 2006. http://www.chinadaily.com.cn/china/2006-11/21/content_738224.htm
14. HICKIE, D. Knowledge and competitiveness in the aerospace industry: the cases of Toulouse, Seattle, and North-west England, 2006, *European Planning Studies*, **14**, pp 697-716.
15. MACDONALD, D. Bombardier's Mexico plant a go, *Canada.Com*, 2005, 27 October 2005. http://www.canada.com/montreal/montrealgazette/news/business/story.html?id=d0943c56-6c68-4a8d-8dd6-fce003e7578f
16. MACPHERSON, A and PRITCHARD, D. The international decentralization of US commercial aircraft production: implications for US employment and trade, *Futures*, 2003, **35**, pp 221-238. http://www.custac.buffalo.edu/docs/UBfuturesarticle.pdf
17. MATLACK, C, Can Airbus afford the A350?, *Business Week*, 4 December 2006. http://www.businessweek.com/globalbiz/content/dec2006/gb20061204_704055.htm?chan=rss_topStories_ssi_5

https://doi.org/10.1017/S0001924000004577 Published online by Cambridge University Press

18. Aircraft maker asks state for $12bn, *Moscow Times*, 27 December 2006. http://www.themoscowtimes.com/stories/2006/12/27/043.html
19. EBRD Offers €100m credit for Russia's Sukhoi SuperJet project, *Mosnews*, 14 December 2006. http://www.mosnews.com/money/2006/12/14/ebrdloanjet.shtml
20. NIOSI, J. and ZHEGU, M. Aerospace clusters: local or global knowledge spillovers?, *Industry and Innovation*, 2005, 12, pp 5-29.
21. PRITCHARD, D. The Global Decentralization of Commercial Aircraft Production: Implications for US based Manufacturing Activity, 2001, University at Buffalo, State University of New York. http://www.pravco.com/PDF/dissert.pdf
22. PRITCHARD, D. and MACPHERSON, A. Industrial subsidies and the politics of world trade: the case of the Boeing 7e7, *The Industrial Geographer*, 2004, **1**, pp 57-73.
23. ROTHMAN, A. Airbus wants Russians to build more of A350 after cost rises, *Bloomberg*, 8 December 2006, London. http://www.bloomberg.com/apps/news?pid=20601087&sid=aTiqfN3RUEMQ&refer=home
24. Japan jet project to start with $1bn funds, 6 September 2006, *Airwise*, Reuters. http://news.airwise.com/story/view/1157546612.html
25. SCHUMPETER, J. *Capitalism, Socialism and Democracy*, 1942, Harper & Row, New York.
26. Boeing studies idea of two planes to replace 737, *USA Today*, 18 September 2006. http://www.usatoday.com/travel/flights/2006-09-18-boeing-737_x.htm

https://doi.org/10.1017/S0001924000004577 Published online by Cambridge University Press