Commercial Aircraft Corporation of China (Comac) Attempts to Break the Airbus-Boeing Duopoly, Will It Succeed?: An Industry Analysis Framework Applied

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Abstract

Using an industry analysis framework, this thesis analyzes whether the recently established Commercial Aircraft Corporation of China (Comac) is likely to break the Boeing-Airbus duopoly in the industry of large commercial airplanes.

The selected framework for this thesis is comprised by the following two principles:

> 1) "The nature and degree of competition in an industry hinge on five forces, one of these being the Threat of New Entrants, which depends on the height of Entry Barriers." (Porter 1979, 1)
>
> 2) "In order to cope with the competitive forces in an industry, there are three potentially successful generic strategic approaches to outperforming other firms in the industry: overall cost leadership, differentiation, and focus." (Porter 1980, 35)

The results from the barriers of entry analysis suggest that Comac enjoys full unconditional support from the Chinese government as the development of an aerospace industry is deemed as national interest. However, the firm faces a high barrier of entry derived from the advantages the incumbent companies have in terms of their learning and experience curves, which allow them to effectively conduct research and development and innovate.

In the long run, as the companies seek sustained competitive advantage (Porter 1984, 34), I find that Comac will mainly rely on generic strategy 'cost', while the incumbents counteract by adopting mainly generic strategy 'differentiation' and 'focus'.

This thesis claims the chances of success for Comac largely depend not only on finding the right strategy for a proper balance between 'cost' and 'differentiation', but mainly on the Chinese government being able to maintain protectionist policies in place. In other words, the Chinese government must continue to decide for the domestic airlines what airplanes they should buy. This conclusion is reached by analyzing the history of all previous attempts by China to develop a national jet—which have all been unsuccessful— and the recent history of high-tech industries where China represented the world's largest market and there was a national interest for technology transfer.

Thesis Supervisor: James M. Utterback
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1. Introduction to Document Structure

1.1 Research Motivation

The commercial aircraft industry has been dominated by the duopoly of Airbus and Boeing for over five decades. Current dynamics in the industry suggest the entry of five companies could break the incumbent duopoly[1, 2] —the emergence of China in the industry as a potential serious contender makes it a thought-provoking topic.

1.2 Thesis Scope

The scope of this thesis is limited to commercial aircrafts in the single aisle market segment (that is, more than 90 passengers) and focused on the potential of the Chinese aircraft industry to enter this market. Mention to other market segments, other countries and other companies as possible entrants to the industry is used for reference only.

1.3 Thesis Objective

The objective of this thesis is to provide an answer to the question of whether the Chinese aircraft industry could break the Boeing-Airbus duopoly. By 'break' is meant to establish a company that can compete and gain market share in this segment in the long run, like Airbus did at the time. Therefore, the concept of 'break' is considered independent of the total number of airplanes sold in the domestic market or abroad.

1.4 Thesis Methodology

The methodology of this thesis consists of describing a framework to analyze barriers of entry to any industry and applying that framework to the case of China and the Chinese aircraft industry.

1.5 Thesis Structure

The thesis is developed in five chapters. The first chapter lays out the motivation and structure of the thesis. The second chapter introduces the evolution and outlook of the commercial aircraft industry. The third chapter formulates the theoretical framework. The fourth chapter applies the framework to the case of the Chinese aircraft industry as a potential entrant to the global commercial aircraft industry — for the sake of comparison the emergence and evolution of two high-tech industries in China are discussed. The last chapter draws the conclusions derived from the analysis in the previous chapter.

2. Introduction to the Commercial Aircraft Manufacturing Industry

2.1 Introduction to this Chapter

This chapter introduces the key aspects of the commercial aircraft manufacturing industry. It covers the evolution of the sector since its origins, an overview of manufacturers, production systems, and the current market outlook. The information is presented in chronological order in three subchapters: past, present and future.

2.2 Last Century: Milestones in Evolution of Airplane Models and Production Systems

The following milestones illustrate the evolution of the industry since its origin:

- 1935 (Douglas DC-3): First commercial airplane that made passenger operations economically viable without government subsidies (Westcott et al. 1985)

- 1940 (Boeing 307): First commercial transport with a pressurized cabin that allowed high altitude flights

- 1949 (de Havilland Comet): First jet aircraft for passenger transport that allowed high altitude subsonic flight

- 1995 (Boeing 777): First entirely computer-designed commercial airplane; multiple suppliers around the world

- 2009 (Boeing 787): first major airliner using composite materials for most of its structure. Advancement of the global production system where suppliers in different continents complete large subassemblies such as fuselage and wings. Target assembly time from start to finish is three days.[3] (Note: year is date of first flight).

Appendix A provides a report of the different airplane models produced since the industry origins in 1935—it includes for each model the quantity of airplanes built and the years that have been in production, which highlights the numbers that have made programs successful.

Appendix B provides an evolution of the production systems in the industry since 1935, which shows the development toward a more global production system and the role of large-scale system integrators.

2.3 Current State of The Industry

The industry has been dominated by the duopoly of Boeing and Airbus. Airbus, established in 1970 to challenge the dominance of the American companies at the time, has created a family of airplanes that mirrors the one of Boeing as shown in the table below. More recently, up to five regional aircraft companies have focused on trying to break the duopoly by entering the low end of their market—the single-aisle segment. The figure below provides a snapshot of the airplanes currently in production and under development.

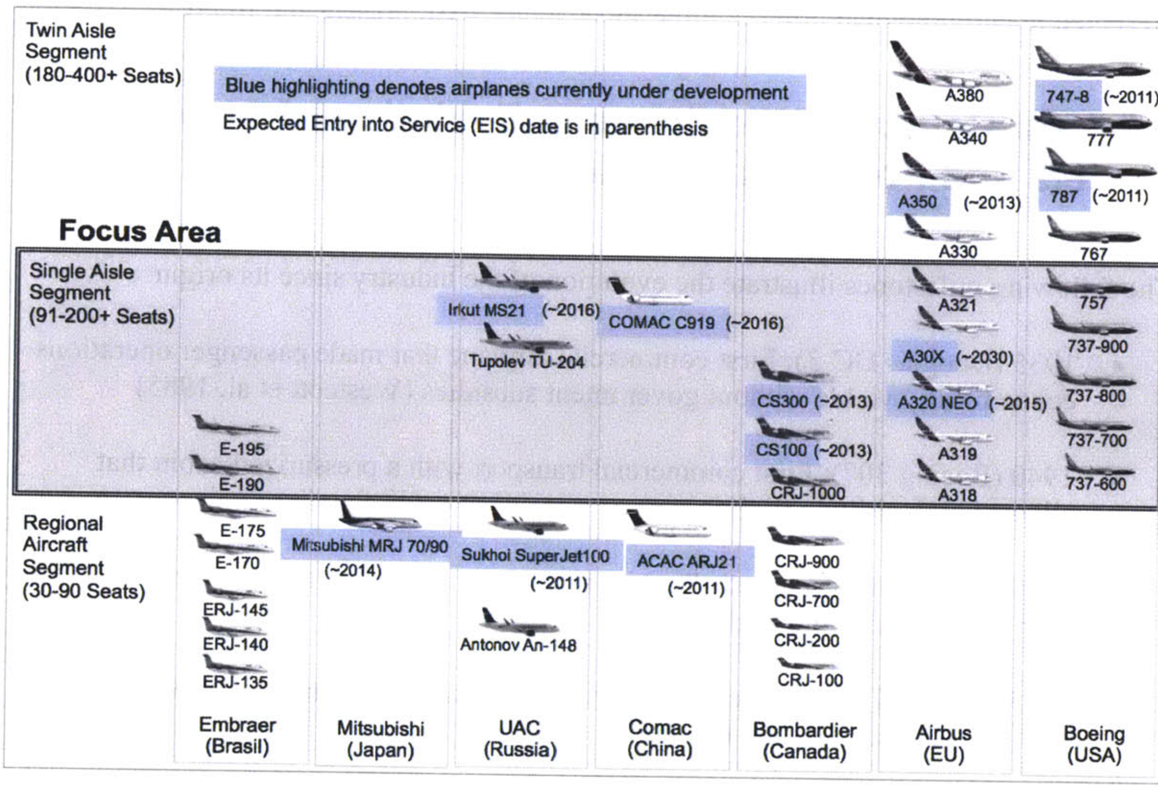


Figure 1 – Single Aisle Market – New Airplane Programs Under Development

Source: Market segments and airplanes models per Boeing Market Outlook 2010-2029[4], in Appendix D. Dates for Expected Entry into Service based on data in Appendix E.

Appendix C is an overview of aircraft manufacturers competing in the single aisle market, and their track record with new airplane programs.

Appendix D is a complete list of airplane models currently in production or launched, including all other manufacturers.

Appendix E is an overview of single aisle new airplane programs under development, in terms of program launch dates, max seating capacity and orders announced.

2.4 Market Outlook 2010-2029

Appendixes F to G present a market overview with a focus on the single-aisle market segment, the Asia Pacific region, and China, as follows:

Appendix F - Market outlook and demand, market segments and regions

Appendix G - Special report of China.

After the analysis of the market outlook, the two most important points to consider for the following chapters are:

1. The world fleet (airplanes that will be in service) is expected to double in the next twenty years.

2. The domestic demand in China for single-aisle airplanes represents 10% of the world demand for new airplanes (3,090 airplanes) in the next twenty years—large enough to set presence in the industry if China were to be its sole supplier.

2.5 Key Takeaways Before Framework's Analysis

It is worth noting two main takeaways from this chapter before describing the framework used for the analysis:

1. *History of the Chinese aircraft industry in launching new airplane programs shows the demonstrated capability required for establishing an industry for large commercial airplanes.*

This is confirmed by its history in research and development (developed the Shanghai Y-10 in 1980, although it only built and flew 3 airplanes) and in manufacturing (assembled under license 35 MD80s in the 1990's, and most recently in 2009 delivered the first Airbus A320 assembled outside of Europe).

Although China does not have a demonstrated capability in mass production of airplanes, development of platform systems for a family of airplanes (Simpson et al. 2006, 241), or with a global network for marketing, sales and service of large fleets, there is confidence in the executives at the incumbent companies that China will be a player. Jim Albaugh current CEO of Boeing Commercial Airplanes stated the following this year[5]:

> "They will at some point in time have a good airplane.
>
> "We know they will. They went to space. They can probably do anything they want to do. They have the resources. They have smart people,' said Albaugh, who is serving as the 2011 AIA chairman"

> "We are competing against the Europeans. In the years to come, it's going to be the Europeans, the Brazilians, the Canadians. It's going to be the Chinese COMAC [Commercial Aircraft Corporation of China]. It could be the Russians,"
>
> "I think from an export standpoint, we will be increasingly challenged as an aerospace industry because the Chinese are going to be players, too," he added.

2. China is in a unique position to enter the single-aisle market segment

The single aisle market is the largest market for the commercial aircraft industry in the next twenty years, in terms of market value, and in terms of number of airplanes required. The Asia Pacific region represents the largest demand for the single-aisle market segment (34% of the world demand), and China's domestic demand for this type of airplane is significant (10% of the world demand, representing 3,090 airplanes out of the 30,900 of the world demand in the next twenty years).

3. Framework Definition

3.1 Introduction: Selection of Framework

This chapter presents the theoretical framework used to analyze the potential of entry of the Chinese commercial aircraft industry as a global competitor. Detailed analysis and references to China, the Chinese aircraft industry and Comac will be covered in Chapter 4.

One of the main purposes of this thesis is to find the right framework to answer the question of whether the Chinese aircraft industry could break the duopoly of Airbus and Boeing—proper analysis of the situation could only unfold from the right framework. The framework needed in this case is one that provides a holistic view of the industry and dynamics among stakeholders, while allowing the independent analysis of new entrants (e.g., Comac) and the incumbents (Boeing and Airbus).

Professor Michael Porter of the Harvard Business School is widely recognized as a leading scholar in the field of business strategy and has formulated several frameworks for industry analysis around the principles of competitive strategy that are very applicable.

The book Competitive Strategy: Techniques for Analyzing Industries and Competitors (Porter 1980) discusses his Five Forces framework for structural analysis of industries. This framework is the work for which he is most recognized and was first introduced in the paper How Competitive Forces Shape Strategy (Porter 1979), which was recently revisited in the Harvard Business Review (Porter 2008).

The Five Forces framework is the core theoretical line of thought of this thesis, and more specifically the Threat of Entry Force, for which Porter provides specific literature on seven underlying elements or Barriers of Entry that comprises it. This thesis is centered then on exploring and assessing those barriers of entry for the case of China, the Chinese aircraft industry, and Comac.

Along with the Five Forces framework, the Porter's Value Chain model is another important framework that although not selected as the core theory is worth mentioning to take as reference as it introduces terminology that is used throughout this thesis. The Value Chain model is best used to analyze organizations in terms of the activities or steps in the value creation process. Porter categorizes these activities as "Primary (i.e., Inbound Logistics, Operations, Outbound logistics, Marketing and Sales, and Service) or Supporting (i.e., Firm Infrastructure, Human Resources Managements, Technology Development and Procurement)." (Porter 1998, 33)

Porter's model includes "the three Generic Strategies (i.e., cost leadership or low cost, product differentiation, and focus) to cope with the five forces and outperform other firms in the industry." (Porter 2008, 35) The Generic Strategies are also very applicable and pertains to the last chapter.

3.2 Porter's Threat of Entry Force

Porter's Five Forces framework states that "the nature and degree of competition in an industry hinge on five forces: the threat of new entrants, the bargaining power of consumers, the bargaining power of suppliers, the threat of substitute products or services (where applicable), and the jockeying among current constants." (Porter 1979, 1) Porter argues that "the strongest competitive force of forces determine the profitability of an industry." (Porter 1979, 2)

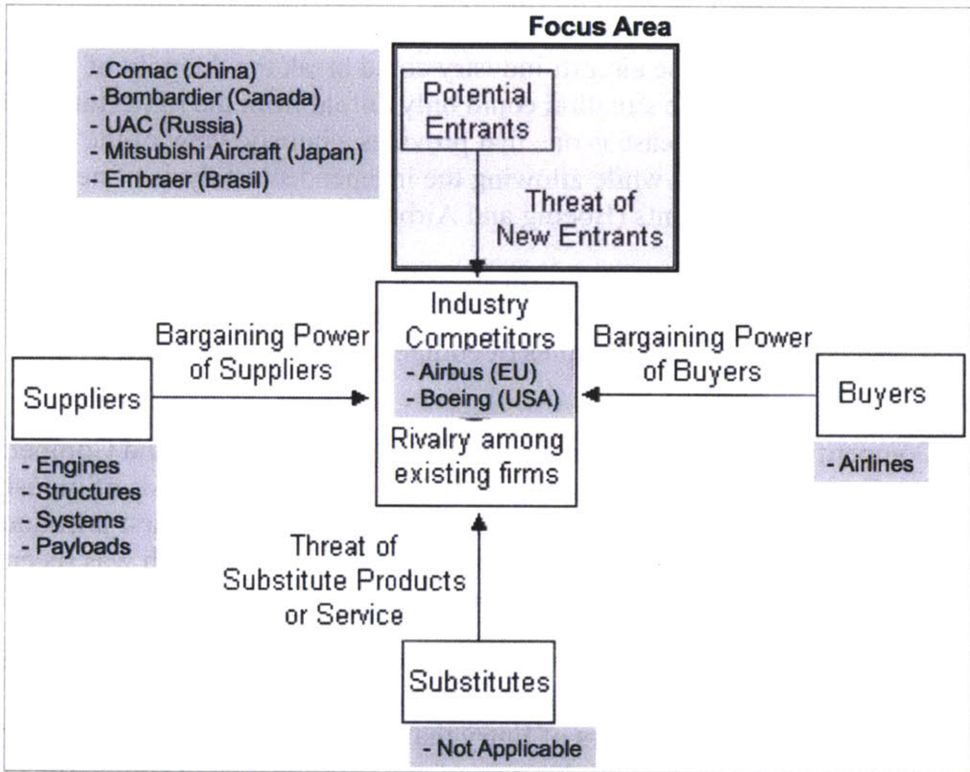


Figure 2 – Porter's Five Forces Framework in the Commercial Aircraft Industry

Source: Porter 1979, 2008. Adapted by author to the case of the large commercial airplanes industry

Porter states that, "the threat of entry in an industry depends on the height of entry barriers that are present and on the reaction entrants can expect from incumbents." (Porter 2008, 3) "It measures the level of difficulty for a new entrant to compete. If barriers are high and a new comer can expect sharp retaliation from the entrenched competitors, obviously he will not pose a serious threat of entry. Conversely, if the entry barriers are low and new comers expect little retaliation from entrenched competitors, the threat of entry is high and industry profitability is moderated." (Porter 1979, 3) He states that, "it is the 'threat' of entry, not whether entry actually occurs that holds down profitability. The threat of entry, therefore, puts a cap on the profit potential of an industry. When the threat is high, incumbents must hold down their prices or boost investments to deter new competitors." (Porter 2008, 3)

There are seven major sources of Barriers of Entry. (Porter 2008, 3)

1. Supply-side economies of scale
2. Demand-side benefits of scale
3. Customer switching costs
4. Capital requirements
5. Incumbent advantages independent of price (learning and experience curves)
6. Unequal access to distribution channels
7. Restrictive government policy

There are four main reasons why newcomers are likely to fear Expected Retaliation. (Porter 2008, 3)

1. Incumbents have previously responded vigorously to the new entrants
2. Incumbents possess substantial resources to fight back
3. Incumbents seem likely to cut prices
4. Industry growth is slow

Chapter 4 explores each of these elements in detail for the case of China and the Chinese aircraft industry, and the specific case of Comac.

3.3 Theory on Coalitions in Global Industries

Formation of coalitions is a topic not part of the framework but, since it will be important in the following chapters, it is pertinent to provide an overview of the theory to introduce the most important elements of Porter's work.

In the book 'Competition in Global Industries', Porter dedicates a chapter to the concept of Coalitions within the section Organizational Forms and Challenges.

Porter states that, "coalition formations seems particularly related to the process of industry globalization; ... in the commercial airframes and engines, coalitions involve virtually every significant industry participant." (Porter and Fuller 1986, 315)

"Coalitions are formal, long term-alliances between firms that link aspects of their businesses but fall short of a merger. Coalitions arise when performing an activity with a partner is superior to performing the activity internally." (Porter and Fuller 1986, 322)

A study to identify the motivations behind the coalitions analyzed seventy corporate agreements provided the following results:

Table 1 – Motivations for Coalitions in Global Industries

Motivation	%
Technology Transfer	29
Technology Complementary	41
Marketing Agreement	21
Economies of Scale	16
Risk Sharing	14

Source: Marity and Smiley; via Porter and Fuller (1986)

Porter and Fuller employ the Value Chain concept, introduced in Chapter 3.1, to analyze the different types of strategic alliances. They argue that coalitions can be formed at any point of the value chain.

Based on the value chain concept, they identify four types. (Porter and Fuller 1986, 330)

a. Technology Development
b. Operations and Logistics
c. Marketing, Sales and Service
d. Multiple Activity

They identify two distinct types of coalitions for any given activity: the X and Y types, which they describe as follows. (Porter and Fuller 1986, 336)

- X-type: coalitions across borders of activities. Firms divide the activities within an industry between themselves. For example, one partner manufactures while letting the others market the product.

- Y-type: coalitions within activities. Firms "share" the actual performance of one or more activities. For example, a joint marketing agreement. Y coalitions frequently take the form of joint ventures, but they also include technology sharing, cross-licensing, and other agreements. This is the type of coalition most frequently discussed in the following chapters.

They identify four Strategic Benefits in coalitions. (Porter and Fuller 1986, 322)

1. Gaining economies of scale
2. Access to the knowledge or ability to perform an activity
3. Reducing risk
4. Shaping competition

4. Framework Application to The Chinese Commercial Aircraft Industry

4.1 Introduction to this Chapter

This chapter provides an analysis of the Threat of Entry Force.

It assesses each of the seven underlying 'barriers of entry' that comprise this force against the following criteria:

a) Not a Barrier
b) Barrier – not Critical
c) Barrier – Critical

'Not critical' indicates China faces a barrier but collected data suggested it is expected to overcome it. 'Critical' indicates data is sufficient to expect China not to break the incumbent duopoly as it is in its current form.

The results of the assessment are summarized in a table at the end of the chapter, which in turn is used as reference for the Conclusions in the following chapter.

4.2 Assessment of Barriers of Entry

Each of the seven types of barriers of entry is assessed using the following methodology. First, key statements from Porter's theory are introduced indicating how they apply to the commercial aircraft industry and my assessment of whether this represents or not a critical barrier of entry for China, the Chinese aircraft industry, and Comac. Second, my arguments are provided in bullet form, summarizing the key point, followed by paragraphs with my rationale pointing to data and references.

4.2.1 Supply-side economies of scale

Porter states that, "supply-side scale economies deter entry by forcing the aspiring entrant either to come into the industry on a large scale, which requires dislodging entrenched competitors, or to accept a cost disadvantage." (Porter 2008, 3)

This type of barrier is significant in the commercial aircraft industry in that aircraft companies' upfront investments in R&D are very high to launch new programs and those investments can only break even through mass production volumes.

I argue this barrier is *not critical* in the case of China for the following reasons:

1. *China's emergence and economic growth are closely tied to its emergence as a manufacturing nation*

The current emergence and success of China as a key player in the global economy is not only measured by how much its economy has grown over the past two decades, but by how it has become a leading manufacturer in different industries. As seen in the tables below, China's share in global manufacturing has surpassed that of the US on a broad basis and mainly due to the rapid expansion in the segments of basic metals, textile industry and computer equipment[6].

Table 2 – Global Exports of Manufactures (Billion of US Dollars)

Year	1990	2000	2009
China	44	220	1125
US	290	649	800
World	2391	4702	8355

Source: World Trade Organization, 2010 [6]

Table 3 – China and US Exports of Manufactures (% of Global Manufacture)

Year	1990	2000	2009
China	1.8%	4.7%	13.5%
US	12.1%	13.8%	9.6%

Source: World Trade Organization, 2010 [6]

2. *China's manufacturing sector is anticipated to remain strong due to low labor costs*

China's surge in manufacturing is largely explained by the labor cost advantages that some manufacturing sectors have exploited by producing there. The table below shows the much lower labor costs in China compared to the developed world. The second table shows the rigidity of employment.

Table 4 – Average Salary in the Manufacturing Sector (US Dollars)

	Weekly Hours	Compulsory Deduction	Net Monthly Income
US	40.8	19%	$2,372
Germany	37.6	29%	$2,336
France	36.7	0%	$1,604
China	NA	8%	$134

Source: International Average Salary Income Database, 2011 [7]

The rigidity of employment index measures the degree of regulation of employment, specifically the hiring and firing of workers and the rigidity of working hours. This index is the average of three subindexes: a difficulty of hiring index, a rigidity of hours index, and a difficulty of firing index. The index ranges from 0 to 100, with higher values indicating more rigid regulations.

Table 5 – Rigidity of Employment Index

China	24
France	56
Germany	44
US	39
Global Average	37.7

Source: The World Bank, 2011 [8]

However, lower labor costs do not lead yet to manufacturing developments to the scale and technology in the aircraft industry, quite the opposite, as shown in the table below, some of the largest segments in manufacturing remain dominated by infinite number of small and scattered enterprises—examples of that are the current dynamics in auto and textile industries.[9]

Table 6 – Number of Industrial Enterprises in China According to Size

Type of Enterprise	Total in 2009
Large enterprises	3254
Medium-sized enterprises	38,036
Small enterprises	393,074

Source: National Bureau of Statistics of China, 2010 [10]

3. *China's track record of building large infrastructure demonstrates the capability to build a large complex for aircraft manufacturing*

China's current developments in the energy sector shows how high-tech infrastructure developments of very large scale are being undertaken in China. The construction of indirect coal liquefaction project in the province of Ningdong (a plant for coal-to-oil and coal-to-energy conversion) with a "total investment of $8 billion represents the biggest Sino-foreign investment project to date in China—a joint venture between China Shenhua Energy Group and South Africa Sasol Synfuels International Limited."[11] To put this investment in perspective, the amount put behind this project is similar to the one required for a new airplane program. This investment in infrastructure in the industrial coal gasification has been followed by the announcement this year for another clean coal technology joint venture between General Electric and China Shenhua—in what is called integrated gasification combined cycle (IGCC), a technology that turns coal into gas that results in fewer emissions. GE was also expected to announce over $2 billion in rail, locomotives and other deals in China the same week, according to a report, pointing out that GE's sales to China are growing at 20% a year.[12] These examples and the table below show that the amounts being invested and the scale of infrastructure being developed is at par to what it is required to build a large complex for aircraft manufacturing.

Table 7 - China's Structure of Investment (in 100 million Yuan)

	Construction and Installation	Purchase of Equipment and Instruments	Others
1985	1,655	718	170
1990	3,009	1,166	343
1995	13,173	4,262	2,583
2000	20,536	7,786	4,596
2005	53,383	21,423	13,968
2006	66,776	25,564	17,658
2007	83,518	31,575	22,231
2008	104,959	40,594	27,275
2009	138,758	50,844	34,996

Source: National Bureau of Statistics of China, 2010

4.2.2 Demand-side benefits of scale

Porter states that, "demand-side benefits of scale, also known as network effects, arise in industries where a buyer's willingness to pay for a company's product increases with the number of other buyers who also patronize the company. Buyers may trust larger companies more for a crucial product. Recall the old saying that no one ever got fired for buying from IBM (when it was the dominant computer maker). Buyers may also value being in a 'network' with a larger number of fellow customers." (Porter 2008, 3) "Brand identification also creates a barrier by forcing entrants to spend heavily to overcome customer loyalty." (Porter 1979, 1)

This type of barrier does apply to the commercial aircraft industry in that buyers/airlines operate the aircraft in a global environment and do trust companies that provide global support. Brand identification is also important for airlines in their decision process as it translates to safety and reliability, and the potential for the product to hold its value if the time comes to resell it. Even so, I argue this barrier is *not critical* in the case of China for the following reason:

1. *China may face difficulty conquering the international market, but domestic demand is large enough to establish significant presence in the industry*

The world fleet (total number of airplanes that will be in service) will nearly double in the next 20 years—as explained in Chapter 2 in the overview of the market outlook. 30,900 new airplanes will be required in the next twenty years, of which 10,320 (34%) will go to the Asia-Pacific region and 4,330 (14%) to China specifically. Out of the 4,330 airplanes expected to go China, 3,090 (71%) are in the single-aisle market segment, the category of the airplane China is developing—called the Comac C919. A domestic demand of 3,090 single-aisles equals to 10% of the world demand, a significant portion of the market if China were to be the sole supplier of its own demand. Appendix E includes an excerpt from the published Boeing Current Market Outlook 2009-2029 with the specifics for the market outlook for China.

Taking a closer look at China's passenger traffic provides a better picture as to what has been the domestic strategy in the transportation sector. As the table below shows, highways are the primarily and fastest growing condition of transportation and explains the large investment in roadwork infrastructure in the country over the past three decades. Railways as an alternative of transportation is the second most preferred option, possibly explaining the keenness of the country in developing a high-speed train industry that enabled them to become global leaders in the sector.

Table 8 - China's Total Passenger Traffic (in 10,000 persons)

	2005	2006	2007	2008	2009	Growth Over the Past 5 years
Highways	1,697,381	1,860,487	2,050,680	2,682,114	2,779,081	63.7%
Railways	115,583	125,656	135,670	146,193	152,451	31.9%
Waterways	20,227	22,047	22,835	20,334	22,314	10.3%
Civil Aviation	13,827	15,968	18,576	19,251	23,052	66.7%

Source: National Bureau of Statistics of China, 2010

As it is discussed in Chapter 4.2.7, China developed its first high-speed train in 2007 and thanks to the government's strategy of developing a high-speed train industry (working both on the trains and train tracks in a unified fashion) and making this sector the largest recipient of R&D, the industry became a global leader in a matter of few years.

Of great importance is the speed at which civil aviation has grown over the past few years and one that is largely going to drive China's interest in developing a commercial aircraft industry in some way. Government policy is likely to leverage once again on the size of the economy and its low-cost advantage, as well as joint efforts with international partners to promote a commercial aircraft industry.

4.2.3 Customer switching costs

Porter states that, "switching costs are fixed costs that buyers face when they change suppliers. The larger the switching costs, the harder it will be for an entrant to gain customers." (Porter 2008, 4)

This type of barrier is significant in the commercial aircraft industry as buyers/airlines build significant infrastructure to support their fleets. If airlines decide to change their fleet significant switching costs arise such as high spending on training of personnel and flight crews. Costs will be high not only on the back of the elevated number of personnel in the staff but most importantly because the learning curve to operate the airplanes is a process that takes significant amount time.

Even so, I argue this barrier is *not critical* in the case of China for the following reason:

1. *Buyers in the aircraft industry have historically changed fleets driven by the economics of the new airplanes*

Airlines have historically operated fleets that combine Airbus, Boeing and other manufactures. Emirates Airlines at the 2007 Dubai Air Show, for instance, placed the single biggest airline order in history for a combination of 93 Airbus and Boeing airplanes in an order worth $34 billion. In air shows, "hefty discounts up to 30% are typical, which for a billion-dollar aircraft order translates into hundreds of millions of dollars."[13]

Economics are certainly a big driver in fleet and manufacture selection and seem to far offset the switching costs. This is even the case for major airlines in the low-cost business model that have adhered to operating only one type of airplane—such as Southwest Airlines, Ryanair and Easyjet. Easyjet already switched from Boeing to Airbus in 2002 and publicly disclosed that it was granted substantial price concessions by Airbus.[14] Ryanair, operator of almost 300 Boeing 737s, released a public statement in 2009 confirming it had terminated negations with Boeing in its growth plan and that it will not place new orders, arguing differences in price.[15] Since then it has hinted to switch to Airbus[16] and early this year publicly confirmed to be in talks with Russian and Chinese airplane markers.[17] Even Southwest airlines, the largest operator of Boeing 737s with over 500 airplanes, warned this year that it would consider switching to Airbus if Boeing chooses not to develop a more fuel-efficient version of the 737.[18] Airbus had announced almost a month earlier the launch of the A320 New Engine Option (NEO), which it claims to be 15% more fuel-efficient.[19]

4.2.4 Capital requirements

Porter states that, "the need to invest large financial resources in order to compete can deter new entrants. Capital may be necessary not only for fixed facilities but also to extend customer credit, build inventories, and fund start-up losses. The barrier is particularly great if the capital is required for unrecoverable and therefore harder-to-finance expenditures, such as up-front advertising or research and development." (Porter 2008, 4) Which is the case of the commercial aircraft industry.

Even so, I argue this barrier is *not critical* in the case of China for the following reason:

1. *R&D capital requirements for launching new airplanes is very high, but China's commitment in setting presence in the industry is very strong*

New airplane development costs are very high, and vary from an estimated $6 billion to $12 billion for the Boeing 777[20] and Airbus A380[21] respectively. For smaller airplanes in the single aisle market sector, Canadian Bombardier has reported an estimate of $3.5 billion for its C series airplane currently under development.[22] These figures are in line with the $8 billion coal gasification plant mentioned above in Ningdong, which underscores the fact that a new airplane program is the size of current programs being undertaken in China.

China has a strong commitment in being a player in the commercial aircraft industry. The aerospace industry is very particular, in the sense that "judged against almost any criteria of performance—growth in output, exports, productivity, or innovation—the civilian aircraft industry must be considered a star performer in the US economy."[23] From an international point of view, it is then an industry that reflects the technological progress and market dominance of both Europe and the US. In the US for instance, the aerospace industry accounts for about 7% of the total exports. From a domestic point of view is an industry that has made major contribution in the form of R&D development[24] with 1 -2% share of total US spending over the past decade, export growth (Boeing is the largest US exporter by value in 2010 according to the United States International Trade Commission), high-wage and high skilled jobs.

The fast-growth pace of civil aviation in China supports the country's interest to develop an aviation industry. Recent data on R&D spending in China as shown in the table below confirms that eagerness as the sector is the second to attract the largest R&D expenditure within the high-tech industry and by a large margin when compared to the electronics industry.

Table 9 – Top R&D Activities in High-Tech Industries in China in 2009

	R&D Institutions (unit)	R&D Projects (unit)	R&D Personn el (man - year)	Expenditure on R&D Project (10,000 Yuan)
Medical and Pharma Industry	849	8,272	58,117	831,642
Aviation and Aircrafts Manufacturing	111	5,273	26,790	546,142
Electronic and Communication Equipment	1,251	1,949	203,765	153,617
Electronic Computers and Office Equipment	217	577	39,823	82,365

Source: National Bureau of Statistics of China, 2010

4.2.5 Incumbent advantages independent of price (learning and experience curves)

Porter states that, "no matter what their size, incumbents may have cost or quality advantages not available to potential rivals." (Porter 2008, 4) "These advantages can stem from the effects of the learning curve (and its first cousin, the experience curve) and proprietary technology. Porter defines the Experience Curve as the efficiency achieved over time by workers through repetition." (Porter 1979, 4)

This type of barrier is very significant in the commercial aircraft industry. What Porter describes as the experience curve is a key element of the organization structure of the aircraft companies. The processes to design and build today's airplanes are the result of an experience curve that has taken decades to develop. These processes or know-how is something that cannot be created overnight and have taken the incumbent companies more than five decades of constant improvement to reach its current state.

I argue this barrier is high and *critical* in the case of China for the following reasons:

1. *China faces a high barrier of entry on the certification for product integrity and safety*

The certification process of the airplanes is a responsibility of the manufacturer that pertains completely to its engineering division, despite having a legal connotation. It is as much a legal issue as it is a technical one. It is highly engrained with the design and engineering of the airplane. Simply put, the same engineers designing the airplane to meet certain performance specifications are the ones involved in the certification process to demonstrate the plane complies with it after it is built.

The certification process is then part of the engineering integration role that incumbent companies such as Boeing and Airbus have been mastering over the past decades. This is often referred as the 'large-scale systems integrator' role that has become their core competence, almost like a 'secret sauce' to the incumbent aircraft companies when it comes to integration with suppliers.

I argue this is a high critical barrier for China, not only because of the relationship the incumbents have developed with their regulatory authorities in the US and Europe, but also because those authorities are the only two regulatory authorities that are recognized by international buyers. Local regulatory authorities in different countries often rather not create their own regulations but simply adopt the ones currently in practice by the authorities in the US and Europe—the Federal Aviation Administration (FAA), and the European Aviation Safety Agency (EASA). Further, the FAA has been working for several years now on the implementation of a process in which "delegation" is used to the maximum extent applicable with appropriate oversight safeguards as defined in the FAA's delegation guidelines.[25] Provided this delegation process has been implemented for years if not decades now, it has streamlined the certification process for incumbents like Boeing, that the Chinese aircraft industry is in disadvantage and facing an uphill battle with international buyers that value the certification of the airplanes for product integrity and safety, and because it hold its value if the time comes to resell it.

This kind of constraint suggests the future of a commercial aircraft industry in China is likely to be one that evolves along with international partners to maximize synergies—involving therefore some sort of coalition.

2. *China faces a high barrier of entry in an industry where new products are highly driven by technological innovation*

According to analysis of global trends in science by the Royal Society[26], China could overtake the United States as the world's dominant publisher of scientific research by 2013. However, in the aerospace sector the Chinese aircraft industry falls behind the American and European companies when measured by a set of metrics on technological innovation based on patent activity managed by The Patent Board, a company with over 40 years of history in patent analytics. The Patent Board, ranks corporate innovation by evaluating a series of patent portfolio metrics. It has built a highly accurate patent and patent portfolio database, which includes all patent grants and application data from the United States Patent and Trade Office (USPTO), the European Patent Office (EPO) and the World Intellectual Property Organization (WIPO).[27]

Appendix H provides The Patent Scorecard report for the Aerospace sector, ranking the top 50 companies based on metrics based on patent activity such as quantity and quality of patents, science focus, and speed of generating patents. In that report, incumbent companies rank very high. Boeing ranks as number 1 (for fifth consecutive year), and EADS, parent company of Airbus ranks seventh. Most companies in the ranking are based in the US, followed by Europe and a few companies in Japan. Not surprisingly, there is no Chinese company in the ranking yet. It is important to note that in order to be part of the ranking a company needs a minimum of 45 patents granted in the U.S. within a 5-year period, which highlights the low level of technological innovation of the Chinese aerospace companies so far when compared to Boeing and EADS, which were granted 697 and 355 patents respectively.

For purposes of this thesis, the relevant aspect of this survey is that the incumbent companies, Boeing and Airbus rank extremely high in the report highlighting the leverage they have in the aerospace industry and how high the entry barrier is for China to catch up in the technological innovation area. The previous section revealed the ongoing R&D expenditure in the sector in China—however the figures also show that China overall has a lot more investment to do when compared to what the US and Europe invest in R&D in the industry.

4.2.6 Unequal access to distribution channels

Porter states that, "a new entrant must, of course, secure distribution of its product or service. The more limited the wholesale or retail channels are and the more that existing competitors have tied them up, the tougher entry into an industry will be. Sometimes access to distribution posts an elevated barrier that new entrants must bypass distribution channels altogether or create their own." (Porter 2008, 5)

This type of barrier is significant in the commercial aircraft industry in that buyers/airlines are scattered around the globe so that a global network to support the airplanes is required after delivery—in areas such as maintenance, spare parts, airplane upgrades, and crew training.

Even so, I argue this barrier is *not critical* in the case of China for the following reason:

1. China lacks of track record in establishing a global network to market and service their products, but can go around it buy partnering with others in the industry

In terms of distribution channels China would have to establish a global network to market and sell their product, but most importantly to service the airplanes after delivery, an aspect China has no previous experience on. To go around this lack of capability, China could partner with others in the industry in trade for low cost manpower, which seems to be the path it is taking as per the recently announced partnerships with the Brazilian and Canadian aircraft companies.[28]

4.2.7 Restrictive government policy

Porter's view is that, "government policy can hinder or aid new entry directly, as well as amplify (or nullify) the other entry barriers. Of course, government policies may also make entry easier directly through subsidies, for instance, or indirectly by funding basic research and making it available to all firms, new and old, reducing scale economies." (Porter 2008, 5)

This type of barrier is significant in the commercial aircraft industry. Interests of the aerospace companies are sometimes as important to the governments as they are to the company themselves, as it is the case of the recent ongoing World Trade Organization dispute over aircraft subsidies.[29]

Even so, I argue that this barrier is *not critical* in the case of China, and it actually plays in favor of the Chinese aircraft industry for the following reasons:

1. *The current Chinese government policy towards the acquisition of new airplanes is protectionist*

Despite signed contracts with an aircraft maker, Chinese carriers cannot complete any airplane purchases without approval from the Civil Aviation Authority of China.[30]

2. *Other industries, such as Wind Power Generation, show how Chinese government policies can be the catalyst for local high-tech companies to become the leaders in their own market, grow, and position them to compete globally*

The Wind Power Industry is a great example to illustrate the impact protectionist government policies in China could have on an industry. This is an important illustration for the purposes of this thesis as it shows how such policies in the commercial aircraft industry could make Comac a global competitor in the long run. A similar situation happened to the Chinese wind turbine maker Sinovel, a company that was barely significant five years ago and is currently the market leader in China and competes globally.

Broadly speaking, the situation was described by a wind power industry expert as "an industrial arc traced in other businesses, like desktop computers and solar panels where Chinese companies acquire the latest Western technology by various means and then take advantage of government policies to become the world dominant, low-cost suppliers."[31]

The most significant policy in the wind power industry dates back to 2005, when the Chinese government issued a directive known as Notice 1204[32], "stipulating that Chinese wind farms had to buy equipment in which at least 70 % of the value was domestically manufactured"[31] and "farms not meeting the requirement of equipment localization rate shall not be allowed to be built", stated the directive.[31]

Government policies that set thresholds for local content are prohibited under World Trade Organization rules, but wind power leading companies attracted by the size of the market in China preferred to go and train local Chinese suppliers to meet the 70% threshold than fight.[31]

At the same time the local Chinese suppliers were being trained, the government provided them with several benefits such as free or subsidized land and grants that aimed to create incentives in the industry. The outcome is that companies that barely existed five years ago have grabbed more than 85% of the Chinese market share and controlled more than half of the global market.

Sinovel, China's biggest wind turbine maker, has said it now wants to become the world largest by 2015, "Sinovel is among the Chinese companies now opening sales offices across the United States in preparation for a big export push next year. They are backed by more than $13 billion in low-interest loans issued this past summer by Chinese government-owned banks; billions more are being raised in initial public offerings led mainly by Morgan Stanley this autumn in New York and Hong Kong."[31]

Multinationals are alarmed, including the longtime global leader Vestas of Denmark. "Vestas, for example, is closing four factories in Denmark and one in Sweden, and laying off one-eighth of its 24,000-person labor force this autumn, in an effort to push its costs down closer to Asian levels, its chief, Mr. Engel, said."[31]

The Chinese companies are now threatening to enter the global wind power market, in particular the US where General Electric is the leader supplier.

The U.S. government has now reacted and it claims China has broken the rules and therefore has filed a case against China with the World Trade Organization—known as Section 301 complaint under the Trade Act of 1974, "sliding with an American labor union, the United Steelworkers, in accusing Beijing of illegally subsidizing the production of wind power equipment."[33, 34]

China has responded and agreed to lift some of the barriers but others remain, "such as foreign developers being banned from offshore projects for what China describes as national security reasons, not allowing to borrow as much money as domestic developers and are prohibited from selling carbon credits from their wind farms.[33]

In hindsight, one would expect the leaders in the wind power industry to regret how the situation has unfolded in China, and more precisely how the Chinese manufacturers became the leaders of their own market and how they are posed to compete and potentially conquer the entire market. But the leaders of the industry would argue that there was not much they could have done given the government policies and incentives introduced.

Gamesa, for instance, a Spanish company and world's third-largest turbine maker—after Vestas and General Electric—which back in 2005 controlled more than a third of the Chinese market and now only about 3%, "insists that they have no regret about having trained more than 500 Chinese machinery companies as a cost of playing by Beijing rules". "If we would not have done it, someone else would have done it, said Jorge Calvet, Gamesa's Chairman and Chief Executive", "Gamesa has lost significant market share, but now sells twice as much as it did when it was the leader."[31] In other words, the cake of wind power is so big that every competitor has been able to get a slice of it.

Vestas, who also entered the Chinese market, does not seem to have much to regret either: "We strongly believe that for us to be competitive in China, it was very important to develop an Asia supplier base" said Ditlev Engel, its chief executive in an interview this year.[31]

The situation in the commercial aircraft industry could unfold differently. Aircraft components are in nature the same or more complex that those in wind turbines and outsourcing them to local Chinese suppliers is a path less likely to be followed. There is a difference in ceding production of *most* of its components (like the wind power industry companies did) and setting up an assembly plant (like Airbus assembling A320s in Tianjin, Embraer building ERJ 145s in Harbin, and Bombardier sources fuselages in Shenyang, or Chinese suppliers supplying from horizontal stabilizers and the aft tail section on Boeing 737s to the rudder for the Boeing 787.)[35] But there is an important lesson from the wind energy case — that government policies coupled with low cost resulted in 95% of local content in the case of Gamesa, far exceeding the initial 70% threshold it was trying to make, highlighting the capability of Chinese suppliers to produce complex components and how far multinationals could go when driven by low labor cost.

Appendix I provides the data and figures on the growth of the wind power industry in China. Figure I.1 shows how in the past fifteen years the industry grew at a rate of at least 20% per year, and Figure I.2 that China is currently the second largest country after the US with wind power capacity installed. Figure 1.3 and I.4 show that growth of installed capacity in China has accelerated in the past five years, making it the country with the most newly installed capacity in the world. As explained above, growth in wind power capacity has brought with it the emergence of Chinese brands, as shown in Figure I.5. Table I.1, I.2 and I.3 show that Chinese companies that now occupy the top three spots of suppliers for the Chinese market are now part of the top 10 wind power manufacturers in the world, and have emerged as true global competitors exporting to countries such as USA, India, Britain and Thailand.

In brief, the case of the wind energy industry and Sinovel highlights the impact Chinese government policies could have in leveraging the Chinese market size and the low cost factor to make their own companies leaders in a high tech industry, a scenario China could now try to replicate in its commercial aircraft industry in order to make Comac a global competitor.

3. *China's recent history in other industries like High-Speed Train manufacturing reinforce the case of the importance of Chinese government policy in enabling technology transfer to create Chinese companies that ultimately compete globally*

The case of high-speed rail in China is another example that follows the industrial arc where China represents the largest market in the world and Chinese government policy is set in place to allow technology transfer and enable Chinese manufacturers to develop their own products that can ultimately compete globally.

The importance of the case is that it mimics the experience of the wind turbine manufacturing industry discussed above and one that China and Comac will try to follow in the commercial aircraft industry.

The table below shows how China is by far the country with the largest rail system in operation and under construction. By 2012, China is expected to have 13,000 km high-speed rail, more than all the other countries in the world combined.

Table 10 – High Speed Rail by Country

Country	In operation [Km]	Under Construction [Km]	Total [Km]
China	4,840	15,478	20,318
Japan	2,118	377	2,495
Spain	1,963	1,781	3,744
France	1,872	234	2,106
Germany	1,032	378	1,410
Italy	923	92	1,015
Republic of China (Taiwan)	345	0	345
South Korea	330	82	412
Turkey	235	510	745
Belgium	209	0	209
The Netherlands	120	0	120
United Kingdom	113	0	113
Switzerland	35	72	107

Source: International Union Railways, 2010

In terms of technology, high-speed trains are commonly classified for convenience according to the maximum operating speed. "1st generation trains are those with maximum speed of 250km/h. 2nd and 3rd generation are those with maximum speed of 300Km/h and 350Km/h respectively." (Zhou, L. and Zhiyun, S. 2011)

The first countries to developed high-speed trains were Japan, Germany and France. China came in sixth after Italy and Spain. As shown in the table below, Japan developed its first high-speed train in 1964 and only until 1988 was able to produce trains with speeds of 2nd generation.

Table 11 – Technology Development for High-Speed Trains Around the World

	Japan			France		Max	Germany			China		
Generation	Year	Train	Km/h	Year	Train	Km/h	Year	Train	Km/h	Year	Train	Km/h
1st	1964	S-0	210	1981	TGV-PSE	280	1991	ICE-1	250	2007	CRH1	200
	1975	S-100	270	1989	TGV-A	300	1996	ICE-2	280	2007	CRH2	200
	1997	E-2	275							2007	CRH5	200
											Imported	
2nd	1998	S-500	300	2001	TGV-Med	320	2002	ICE-3	300	2008	CRH2	300
				2007	TGV-EST	320				2008	CHR3	300
											Developed	
3rd	2011	E-5	320	2008	AGV360	300	2006	ICE350E	350	2010	CRH380-A	350-380
										2010	CRH380-B	350-380
											Created	

Source: Zhou, L. and Zhiyun, S. 2011

With that in mind, it is important to note that China developed its first high speed train in 2007 and it took only four years to produce a train of third generation. An important factor that contributed to this is that "China, unlike other countries whose train speeds are restricted by the existing conditions of the rail track, China's high-speed rail and train are manufactured and built in a unified way". "Up to present, only the China's CRH380 has succeeded in commercial operation with speed more than 350 km/h." (Zhou, L. and Zhiyun, S. 2011) But perhaps more remarkable for the purposes of this thesis is the fact that in such a short period of time China went from being begin a 'importer' of the technology and produce under license for the 1st generation; to 'develop' in joint venture for the 2nd generation, to 'create' their own for the third generation.

China's train manufacturers are comprised of two state-owned enterprises. China South Locomotive & Rolling Stock Corporation Limited (CSR), the world's largest manufacturer of electric locomotives; and China North Locomotive and Rolling Stock Corporation Limited (CNR). For the production of high-speed trains, CSR has established two subsidiaries that are separate joint ventures with Bombardier, the world leader in train manufacturing, (Bombardier Sifang Transportation Ltd), and with Kawasaki (Qingdao Sifang Kawasaki Rolling Stock Technology Co., Ltd).

Bombardier Sifang Transportation Ltd was the first of the two joint ventures—it started in 1998 and since 2007 it has worked on high-speed trains. It is China's largest research and development and manufacturing facility for electric locomotives.

Technical support was a factor in making Bombardier the first Chinese-foreign joint venture. As shown in the table below, the partnership with Bombardier has been instrumental for China to develop its own industry for manufacturing of high-speed trains.

Table 12 – Chinese High-Speed Trains Technology Origin

Generation	Train	Design Based on
1st	CRH1-A & B	Bombardier's Regina C2008
1st	CRH1-E	Bombardier's Zefiro 250.
1st	CRH2-A, B, C & E	Kawasaki Heavy Industries E2 Series Shinkansen
2nd	CRH5-A	Alstom's Pendolino, especially the New Pendolino
2nd	CRH3-C	Siemens' Velaro
3rd	CRH380-A & AL	Designed by CSR Sifang. *Own Design*
3rd	CRH380-B & BL	CRH3C
3rd	CRH380-D & DL	Bombardier's Zefiro 380.

Source: China Railway High Speed page in Wikipedia

From the table unfolds that Bombardier and China have proved that they can work together and manufacture an advanced transportation vehicle, and important point to consider for the partnership that just started between Bombardier and Comac in the commercial aircraft industry.

Chinese government policy has been a critical enabler of the high-speed train industry in similar fashion as explained above for the wind turbine industry. This is reflected in a statement from CSR in 2008 in a report for public offering of stocks where it stated it virtually had no competition. "The international rolling stock manufacturers that participate in China's rolling stock manufacturing market include Bombardier, Alstom, Siemens, GE and Kawasaki. Due to industry policy and certain technological barriers, overseas rolling stock manufacturers are currently unable to engage in manufacturing of complete units in China. Therefore, we currently do not compete directly with these international players in the PRC domestic market."

The history of China with Maglev (derived from magnetic levitation) trains illustrates China's ability to absorb advanced technology as well as the importance of technology transfer in China. "Maglev is a system of transportation that suspends, guides and propels vehicles, predominantly trains, using magnetic levitation from a very large number of magnets for lift and propulsion", Wikipedia. In 2004, the Shanghai Maglev Train became the world's first commercially-operated high-speed maglev, a turnkey system imported from Germany. Despite unmatched advantage in speed, the maglev has not gained widespread use in China's high-speed rail network due to high cost, concerns about safety, but most significantly due to German consortium refusal to share technology and source production in China.

4.2.8 Expected retaliation from incumbents

Porter states that, "industry newcomers are likely to fear expected retaliation if: incumbents have previously responded vigorously to the new entrants; incumbents possess substantial resources to fight back; incumbents seem likely to cut prices; or if industry growth is slow." (Porter 2008, 3)

I argue that in the short run the Expected Retaliation from incumbents is *not critical* due to the following reasons:

1. *Incumbents have previously responded vigorously to the new entrants, but have allowed competition as demonstrated by the case of the emergence of Airbus*

2. *Incumbents possess substantial resources but are not likely to dedicate them to fight back*

Boeing has had nearly four decades of commercial relationship with China and has stressed the need for continued collaboration.[36] It released a public statement, for instance, highlighting the relations with the Chinese suppliers, indicating it had more than $600 million in supplier agreements.[37]

Airbus is already further ahead in their partnership with China as it has built an assembly line for Airbus A320 in the province of Tinjian. The first airplane was delivered in 2009 to Beijing-based Dragon Aviation Leasing, which will lease it to Sichuan Airlines.[38]

3. Incumbents are not expected to cut prices dramatically

While the incumbent duopoly remains, the incumbent companies have high control of the market supply and prices, which they will not reduce dramatically for as long as the duopoly remains in its current form.

4. Industry growth is not slow

While the Global Gross Domestic Product (GPD) is expected to grow at an average of 3.2% per year for the next 20 years, and the public market outlook shows that the number of airplanes in the worldwide fleet will grow at an annual rate of 3.2%. Passenger traffic will average 5.3% growth and cargo traffic will average 5.9% growth over the forecast period. See Appendix D for more details on the market analysis.

4.2.9 Summary of Assessment

This chapter assessed independently the seven types of Barriers of Entry in Porter's theory. Summary of the results of the assessment are is in the table below.

Table 13 – Summary Assessment of Barriers of Entry

Barrier of Entry	Significant in the Commercial Aircraft Industry	Barrier Critical?
1. Supply-side economies of scale	Yes	No
2. Demand-side benefits of scale	Yes	No
3. Customer switching costs	Yes	No
4. Capital requirements	Yes	No
5. Incumbent advantages independent of price	Yes	Yes
6. Unequal access to distribution channels	Yes	No
7. Restrictive government policy	Yes	No
8. Expect Retaliation from Incumbents	Yes	No

This assessment confirms what has been intuitively known, that technological innovation is a critical barrier of entry for China to be a significant player in the aircraft industry in the long run.

4.3 Long-Run Assessment

4.3.1 Introduction: Sustained Competitive Advantage and The Three Generic Strategies

Porter states that the basis for above-average performance in an industry is Sustained Competitive Advantage.[39] He indicates that "in coping with the five forces, there are three potentially successful generic strategic approaches to outperforming other firms in the industry: ... i) overall cost leadership, ii) differentiation, and iii) focus." (Porter 1980, 35)

He describes Competitive Advantage "as taking offensive or defensive actions to create a defendable position in an industry to cope successfully with the five forces and thereby yield a superior above-average return on investment for the firm. Firms have discovered many different approaches to this end, and the best strategy for a given firm is ultimately a unique construction reflecting its particular circumstances." However, at the broadest level, he indicates that "the three internally consistent Generic Strategies can be used singly or in combination, and can be identified for creating such a defendable position in the long run and outperforming competitors in the industry." (Porter 1980, 34)

4.3.2 Adoption of Generic Strategy 'Cost'

A parallel to the wind power industry illustrated how the situation is likely to unfold for Comac in the long run.

As it has been the trend recently for other industries in China (as explained in 4.2.7), the expectation is that the generic strategy 'Cost' will be the strategy adopted by Comac.

The case of the wind power industry suggests that low 'cost' in combination with government policies could position the Chinese aircraft industry in a leadership role of its own market and to ultimately successfully compete globally—in similar fashion as it happened with Chinese company Sinovel (also explained in Chapter 4.2.7), the current leader in the wind power market—a company that barely had a footprint in the Chinese market five years ago.[31, 40]

In the case of Sinovel, Chinese government protectionist policies were such that the company became China's biggest wind turbine maker and has now stated it wants to become the world largest by 2015.[31] The chances of the company now conquering the global market are such that "Sinovel is among the Chinese companies now opening sales offices across the United States in preparation for a big export push next year. They are backed by more than $13 billion in low-interest loans issued this past summer by Chinese government-owned banks; billions more are being raised in initial public offerings led mainly by Morgan Stanley this autumn in New York and Hong Kong."[31]

In the commercial aircraft industry, Chinese government protectionist policies are also in place, as Chinese carriers cannot complete any airplane purchases without approval from the Civil Aviation Authority of China.[28] History in the wind power industry has shown that those policies are not always in line with the World Trade Organization rules, and as such, incumbent companies Boeing, Airbus, and Bombardier do cooperate with World Trade Organization to level the playing field but this is yet an area where there seems to be a long way to go before it reaches its desired state.[41]

Therefore, before that desired state is achieved, it is reasonable to assume that if the government of China maintains its protectionist policies in the aircraft industry there could be a way for Comac to follow the path of Sinovel, that by relying on generic strategy 'cost', it can become the global the leader in its domestic market and potentially become a player at a global scale.

4.3.3 Adoption of Generic Strategy 'Differentiation'

Taking as premise that Comac could become a leader in the Chinese local market and potentially a serious global contender as explained in the previous chapter, the expectation for incumbents is that they react increasing generic strategy 'focus' in the area where they are the strongest and China is the weakest, that is, adopting generic strategy 'differentiation'.

The barrier of entry "Incumbent advantages independent of price (such as learning and experience curve)" is as much a barrier for Comac as it is strength for incumbents Airbus and Boeing. The Patent Scorecard in the Aerospace Industry (as discussed in Chapter 4.2.5) highlights the significant gap between Comac and the incumbents in their ability to effectively conduct research and development, which is the key element to innovate and develop new airplane programs going forward.

A scenario that illustrates how incumbents differentiate through increased 'focus' is by introducing products with *disruptive technologies* (Bower, J. and Christensen, C. 1995) that respond to the needs of buyers in an unprecedented way, such as an airplane with dramatic improvement in areas like fuel efficiency, and environmentally friendly features such as noise reduction and lower carbon footprint.

The Boeing Blended Wing Body and the NASA N+3 Program are two examples that illustrate the incumbent's ability to effectively conduct research and development and innovate and how they could potentially increase generic strategy 'focus' while adopting generic strategy 'differentiation' in the long run.

1. Boeing Blended Wing Body (BWB):

Although still viewed as an unconventional aircraft concept in part still due to cultural issues (Wood and Bauer 2001), a blended wind aircraft configuration has been studied since the 1940s (Begin 1983), being the most notable airplane the Northrop Grumman B-

2 bomber, a well-proven design introduced by in the late 1980's, with 21 airplanes built to date.

A Blended Wing configuration has been discussed for more than a decade for commercial transportation of passengers and cargo.

First reports on the Boeing BWB are from 1997. Significant technical challenges were present as well as performance advantages over conventional aircraft (i.e., 21%, increase in lift/draft ratio; 28% reduction in fuel burn per seat mile; and 27% reduction of trust required, among others) (Liebeck et al. 1997, 1) A similar report the year after highlights that "all of these benefits are due to the BWB configuration itself, rather than specific traditional technologies such as aero-dynamics or structures." (Liebeck, R et al. 1998)

Figure 3 below shows the BWB configuration illustrating a fundamental departure from the swept-wing configuration that has prevailed since first introduced in the Boeing B-47 jet bomber more than 60 years ago. (Liebeck, R et al. 1998, 2)

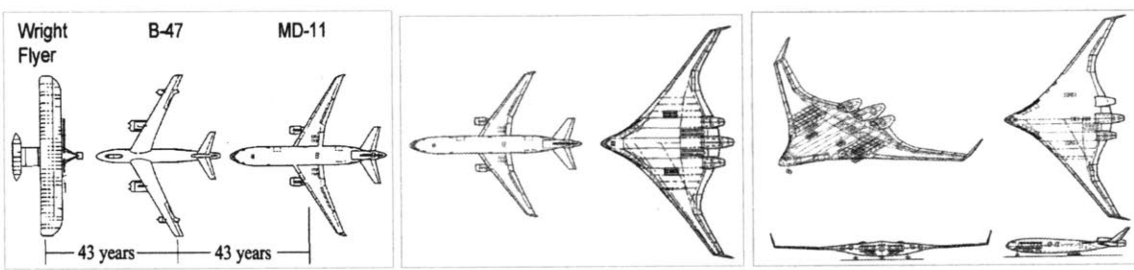


Figure 3 – Aircraft Design Evolution – First and Second 43 years; and MD-11, BWB Configuration Comparison (Liebeck, 1998)

Reports from 2000 onwards start to provide more positive prospects for the airplanes indicating, "development of the Blended-Wing-Body has progressed steadily over the past seven years. Once-apparent show-stoppers have been reduced to technical challenges, in most cases proper solutions." (Liebeck et al. 2005) Highlighting "the basic configuration of the BWB is similar to the Northrop Grumman B-2, a well-proven design." (Liebeck 2003) Positive prospects were also made in following reports indicating that, "subsequent in-house studies at Boeing have yielded the development of a family of BWB transports ranging from 200 to 600 passengers" and that, "the performance improvement of the latest Boeing BWBs over conventional subsonic transports based on equivalent technology has increased beyond the predictions of the early NASA-sponsored studies." (Liebeck 2004)

In 2011, an unconventional airplane configuration such as the Blended Wing Body is still not seen by the public as an obvious configuration for next generation commercial airplanes, but it is worth noting that current reports from the respected sources in the aerospace industry show it as a potential viable option. A reporter with Aviation Week and Space Technology provided an up to date perspective while reporting on Boeing getting closer to deciding on a replacement for the Boeing 737:

"Starting with the baseline aircraft layout, Boeing remains unwilling to stray from the conventional tube-and-wing configuration. Recent revelations about small dual-aisle "semi-widebody" designs are dismissed by some industry observers as "Sonic Cruiser-like smoke and mirrors." However, ongoing research at NASA indicates such alternate, highly integrated configurations hold great promise for more efficient designs in the 2030s and beyond."[42]

2. *NASA Research and Development N+3 Program*

The N+3 program (N+3 denotes three generations beyond the current transport fleet) is another example that shows how in the long run incumbents could increase generic strategy 'focus' while adopting generic strategy 'differentiation'.

The N+3 highlights the significant strength incumbents have in their ability to perform research and development by working collectively with other industry stakeholders in their respective nations.

This program kicked-off in 2008 "to study advanced concepts for subsonic and supersonic commercial transport aircraft that could enter service in 25 to 30 years."[43]

Participants in this program include commercial aircraft governmental organization awarding the contracts (i.e., NASA), aircraft manufacturers (e.g., Boeing, Lockheed Martin and Northrop Grumman), engine suppliers (e.g. General Electric, Pratt & Whitney, Rolls Royce), and academia (e.g., Georgia Tech and MIT), among others.

Phase I of the program concluded last year with 18 months of studies where multiple concepts were explored, notably the Sugar (Subsonic Ultra Green Aircraft Research) Vault concept, which includes "an electric battery gas turbine hybrid propulsion system that can reduce fuel burn by greater than 70%". Supersonic concepts were also evaluated and found "viable, economically and environmentally"[43], however further study in this areas was not provisioned for Phase II.

Phase II studies started toward the end of 2010. A contract worth noting is the three-year program awarded to Boeing and MIT "to build computer and wind-tunnel models of advanced airliner designs under NASA contracts to further research into unconventional configurations that could significantly reduce the noise and emissions of commercial aircraft entering service between 2030 and 2035."[43]

The possibility that a company, other than the incumbents Airbus and Boeing, ventures on an unconventional configuration such as the Blended Wing Body is unrealistic considering previous history of those that have attempted to enter the industry.

One could think that a new entrant in the industry in order to differentiate could try to launch its first airplane in a revolutionary new configuration like the Blended Wing Body. Not only the risks are already high for incumbents that have been through the learning and experience curves, but history of the industry shows how hard it is to position the first products. There is the case of Airbus that succeeded. The case of Great Britain and Japan that attempted and failed, and found that collaboration was a way to succeed. And there is the case of China, that has attempted, failed, and is yet to find a way to succeed in the industry.

Airbus had a very difficult start in its origins when it had only one product. "Airlines were not willing to commit themselves to a new aircraft designed and manufactured by a fledging consortium". "It is indeed remarkable that Airbus was able to overcome the high entry barriers and become a major player in the industry when for more than ten years it only had one product, the A-300." (Yoshiro 1986)

Yoshiro goes further and states that Airbus succeeded in establishing as a manufacturer of commercial airplanes because it was able to differentiate with a product capable of conquering the global market. "Airbus succeeded in the international market because the A300, its first airplane, won wide acclaim for its technical excellence and operating efficiency." (Yoshiro 1986)

For those that have attempted but failed, as it is the case of Great Britain or Japan, Yoshiro highlights that collaboration is a viable option if properly executed. "They realize that collaboration is the only way to overcome the enormous entry barriers erected by the U.S. rivals, in particular Boeing." (Yoshiro 1986)

The case of Japan is a successful story of those that have failed and have found collaboration as a way to succeed. By the mid 1950's, Japan, which at the time had built military airplanes (same as China today), turned its attention to manufacturing its first commercial airplane. A regional turbo prop aircraft called the YX-11. It sold 182 units over its entire life. It was a commercial disaster. The Japanese government chartered a study to understand the root of its failure. "The report indicated that the failure was attributable to the lack of basic knowledge and experience in design, production and marketing of the aircraft." (Yoshiro 1986) Since then, "the government and industry participants began to recognize that the only realistic option for Japan was to join a consortium". In the mid 1980's Japan agreed to collaborate with Boeing on the 7J7, a 150-passanger airplane that was meant to revolutionize the industry with significant fuel efficiency improvements. The airplane was meant to possibly use unducted fan (propfan) engines and introduce other advanced technologies. "The Japanese would provide roughly one-quarter of the total funding, in return, this time they would be allowed to participate not only in manufacturing, but in design and marketing, and product support". This program would have been what Porter calls a Y-type coalition (explained in Chapter 3.3). In the 1980's oil prices dropped and the program was eventually cancelled. The program however has marked the beginning of a new era of collaboration between Boeing and Japanese suppliers, which has had a significant role on the Boeing programs, most notably recently on the Boeing 777 and 787.

And there is the case of China that has attempted new airplane programs, has failed, and is yet to find a way to succeed in the industry. "China has attempted to build a national jet for decades, without success. The closest it got for 40 years was the Shanghai Y-10, a program that in 1980 was squashed after two prototypes were built." (Aboulafia 2010) Considering the long list of new airplane programs it has attempted, uncessfully, such as the "MD95, Fairchild Dornier's 728JET, DASA's MPC 75, Airbus/DASA's A31X, and Airbus's AE-100,"[44, 45] It appears then that in the civil aircraft industry China's has been far from replicating the successful cases in other industries where it has been able to launch its own programs after successfully transferring the technology from leading companies.

5. Conclusions

Using as baseline framework the theoretical work from Professor Michael Porter (particularly the areas of Competitive Advantage, The Five Competitive Forces for industry analysis and The Threat of Entry Force, Barriers of Entry, and Theory on Coalitions), this thesis analyzed the case of China as a global player in the commercial aircraft industry—in particular, this thesis looked into whether Comac would be able to break the duopoly of Boeing and Airbus, and if that threat materializes under what circumstances would it be.

Two major conclusions surfaced:

1. *The Chinese commercial aircraft manufacturing industry faces a high barrier of entry derived from the advantages the incumbent companies enjoy independent of price, one that is unlikely to be overcome in the near future*

This thesis concludes that the Chinese commercial aircraft manufacturing industry faces a high barrier of entry that has prevailed for decades and one that is unlikely to be overcome in the near future. The results of the barriers of entry analysis summarized in Table 13 above suggest that the Chinese aircraft industry faces a high barrier derived from advantages the incumbents companies enjoy independent of price—such as learning and experience curves. Chapter 4.2.5 reviewed in detail why China is unlikely to overcome that barrier.

A snapshot of the traffic in China suggests the country has adopted a strategy towards the transportation sector as a whole. China has developed highway infrastructure over the past three decades, as it is the preferred condition of transportation. The country has developed and turned the high-speed train industry into a global leader over the past decade—a very successful example of industrial and infrastructure investment. Railways are the second most preferred condition of transportation in China. The step-by-step development of the transportation sector along with the fast-growth civil aviation subsector suggest the country is ready to focus on developing a commercial aircraft industry.

The experience of the wind power industry in China showed the strong motivation to develop a leading industry in the country while foreign companies could still profit from having opened up their technology to the domestic market. The demand in China for certain industries is so large that allows for everyone to be profitable, which in turn, should be conducive of partnerships with competitors going forward.

Over the medium term, government policy is likely to leverage on the size of the economy and its low-cost advantage, as well as joint efforts with international partners to promote a commercial aircraft industry.

Porter states that, "in coping with the five forces, there are three potentially successful generic strategic approaches to outperforming other firms in the industry: ... i) overall cost leadership, ii) differentiation, and iii) focus." (Porter 1980, 35)

In the long run, it is expected that the aircraft industry in China will increasingly seek Sustained Competitive Advantage (Porter 1980, 34) through Porter's generic strategy 'Cost', a common pattern for Chinese companies as explained in Chapter 4.2.7. To counteract, incumbents will continue to rely on generic strategy 'Differentiation'. In the event that Chinese companies gain significant ground in the local market, and potentially a share of the global market, incumbents will have to work on the third generic strategy 'focus' by introducing more radical advanced designs, to effectively adopt generic strategy 'differentiation'.

2. *After 40 years of China attempting to build a national jet without success, newly formed Comac has established new partnerships in the industry, trying to replicate a model that has recently proven to be successful for other high-tech industries in China*

Chinese government policies if maintained towards protectionism can play a critical role in making Comac a leader of the local market and a potential global contender, in similar fashion as it happened in other manufacturing industries, as explained in Chapter 4.2.7. However, supportive government policies and low cost advantages will not be sufficient to compete globally in an industry where airlines at the time to buy their product place significant weight on advance technology and performance. China needs to find a way to offset its lack ability to differentiate.

With that in mind, China appears to be headed in the right direction considering the partnerships it has already established in the industry. A report in Aviation Week and Space Technology this month titled "Boeing and Airbus views of China are far apart"[35] underscores the differences in their strategies but highlights how both companies—and Bombardier and Embraer—have already established close partnerships with China.

Of all these partnerships, the most significant is perhaps this year's announcement between Comac and Canadian Bombardier and Brazilian Embraer "to cross-market their new, separate, single-aisle narrow-body jets in emerging and mature markets." As Bombardier spokesperson puts it, "it's the first step to subsequent agreements."[46] Chapter 4.2.7 illustrated how in other industries like the hi-speed train, Bombardier and China are an example of a successful partnership in the transportation and manufacturing industries. In that industry, Bombardier is the leader company and a joint venture with China was established in 1998. Today, more than ten years later, China is designing and developing their advanced trains that are competing globally.

The partnership of Bombardier and Comac is certainly important, but should be noted that differentiation (innovation) in the aircraft industry really happens one level below of the manufacturers. "Almost all of the technological innovation in the business today happens at the propulsion, subsystems and material levels". "Innovation mostly happens at the subsystems level". "Embraer is the only new company to successfully enter the industry since World War Two and it is because they survey the world for the best suppliers and build very little in house." (Aboulafia 2010)

China is trying to do what Embraer did but taking it one step further by also creating a domestic aviation component industry. Wu Guanghui, the C919's chief designer, said

"COMAC will choose international suppliers through bidding, but priority will go to foreign suppliers that design and manufacture products with domestic companies." (Aboulafia 2010)

Creating such an indigenous supplier base is an understandable move that mimics China's recently successful history in other industries as explained in Chapter 4.2.7, but one very risky in the case of Comac. "There is the very serious risk that by the time the C919 enters service (we think three years late is a good estimate) Airbus and Boeing product offerings would make the plane look obsolete. In which case, the government of China will need to decide whether it wants healthy airlines that are free to buy what is on the world market, or a healthy national jetliner champion, prospering because the luckless local carriers are forced to buy an inferior jet." (Aboulafia 2010)

Comac was just established in 2008 and its first airplane the C919 is still pending its first flight. As defined by Porter "Strategy is not a single step but a combination of steps to achieve a unique position." (Porter 2009) So, it is yet to be seen what other steps China takes beyond the partnerships with Bombardier and the suppliers, what type of coalition it evolves into (as explained in Chapter 3.3), and if it unfolds under a scenario where Comac achieves the right balance of the two generic strategies 'differentiation' and 'cost' over time, which will dictate its success in the long run.

Appendixes

Appendix A Commercial Airplanes; Units Built and Years in Production: 1935-Present

Tables below underscore the difference in production volumes before and after 1954, year when the commercial jet airliner is introduced. After 1954, successful programs normally exceed the 1,000 units built and 20 years in production.

Table A.1 – Commercial Airplanes Models (before 1954)

Model	Units Built
Ford Trimotor	199
Lockheed Electra 10	149
Douglas DC-2	200
Douglas DC-3 *	455
Fokker F27	586
Boeing 307	10
Boeing 377	56

* Additional 10,174 military transports

Table A.2 – Commercial Airplanes Models (1954 - Present)

Model	Units Built	Years in Production	
de Havilland Comet	114	10	
Boeing 707	1,010	21	
Boeing 727	1,831	21	
Boeing 737	6,687	44	Still in Production
Boeing 747	1,418	41	Still in Production
Boeing 757	1,050	22	
Boeing 767	1,000	29	Still in Production
Boeing 777	919	16	Still in Production
Boeing 717	156	8	
Douglas DC-9	976	17	
Douglas DC-10	386	20	
McDonnell-Douglas MD-80	1,119	20	
McDonnell-Douglas MD-11	200	12	
Airbus A320	4,582	23	Still in Production
Airbus A340	375	20	Still in Production
Airbus A330	765	18	Still in Production
Airbus A380	63	7	Still in Production

Source: both tables compiled by author from Wikipedia.com and Airliners.net

Appendix B Commercial Airplanes; Evolution of Production Systems: 1935-Present

The table below presents a comparison of key aspects of the production systems before and after the introduction of the commercial jet airliner in 1954.

Table B.1 – Commercial Airplanes, Evolution of Production Systems

	1935-1954	1954 -Present
Time Span	Beginning: Douglas DC-3 (First commercial airplane that made passenger operations economically viable without government subsidies (Wescott et al. 1985)). End: Boeing 307, and its successor the Boeing 377 (first commercial transport with a pressurized cabin that allowed high altitude flights).	Beginning: de Havilland Comet (first jet aircraft for passenger transport that allowed high altitude subsonic flight). Ongoing. Current models such as the Boeing 777 (first entirely computer-designed commercial airplane: (Sabbagh and Davis 2000) and the Boeing 787 (first major airliner using composite materials for most of its structure).
Typical Production Volume per Airplane Model	Total quantity of airplanes built per model in the order of hundreds. Peak is 587 units built for the Fokker F27. The Douglas DC-3 closely followed. More than 10,000 units were built, although most of them were for military use during WWII. See Appendix A for production volumes of other models.	Total quantity of airplanes built per model in the order of thousands. Peak is 6,687 built for the Boeing 737 (2,213 in backlog for a total of 8,800 orders to date). See Appendix A for production volumes of other models.
Business Model for Development of New Programs	Launch airline contracts with aircraft company, which in turn contracts with suppliers.	Launch airline contracts with aircraft company, which in turn contracts with supplier. Strategic suppliers for major subassemblies and subsystems are also brought in to invest and share development risk.
Production System	High level of vertical integration. Aircraft companies heavily involved in production and design of subassemblies and subsystems. The engines are the only main component of the aircraft that is sourced from suppliers.	Global Production Systems. Final assembly completed in house in a process that is targeted to three days from start to finish in the case of the Boeing 787[3]. Major subassemblies including large sections of the fuselage and wings are sourced from strategic partner suppliers in different countries.
Research and Development Focus	Advancement of technology in four general areas: structures, engines, instruments and aerodynamics (Wescott et al, 1985).	Advancement of technology on engines (more fuel-efficient and environmentally friendly); structures (based on composite materials); and instruments and avionics that are more globally interconnected and network-centric.

		In addition, aircraft companies are increasingly investing in strengthening their role of large-scale system integrator by advancing their internal processes for engineering integration and supply chain management, by adopting constant improvement best practices such as Lean manufacturing techniques pioneered in the auto-industry.

Source: table created by author

Appendix C Manufacturers in the Single-Aisle Segment: History with New Airplane Programs

Table below presents a comparison of current commercial aircraft manufacturers competing in the single-aisle market segment in the context of new airplane program development.

Table C.1 – Commercial Airplanes Manufacturers Competing in the Single-Aisle Segment

Company	Year Founded and Type of Company	Track Record with New Airplane Programs	Current Main Development Program in the Single-Aisle Market Segment
Boeing (USA)	1916, Public	Has successfully developed a family of commercial airplanes since the 1950's. Eight major model with variants.	None. Announcement expected in 2011. Current new airplane program developments are the Boeing 787 and the 747-8, both completed first flight and are pending first delivery.
Airbus (EU)	1970, Public	Has successfully developed a family of airplanes that mirrors the one from Boeing. Eight major models with variants.	Airbus A320 NEO (New Engine Option). Expected Entry into Service (EIS): 2015. Airbus has also announced an all-new model A30X to replace the A320, planned for 2030.[50]
Comac - Commercial Aircraft Corporation of China (China):	2008, Public, Government-owned	Has successfully developed aircraft through China Aviation Industry Corporation I (AVIC I), such as the Xian H-6 Bomber and the Xian JH-7 fighter jet; and smaller planes and helicopters by AVIC II. Shanghai Aviation Industrial Company (SAIC) is the third shareholder in Comac, along with AVIC I and AVIC II. SAIC developed the Shanghai Y-10, a four-engine commercial passenger jet that first flew in 1980. 3 units were built but the project was cancelled to shift efforts towards the production by license of McDonnell Douglas MD-80s/-90s. 35 units for the domestic market were assembled in China until the program was halted in 1994.[47] SAIC currently	Comac C9191 Expected EIS: 2016

		produces subassemblies for Boeing 737 (tail section) and the Boeing 777 (vertical stabilizer). Airbus built an A320 line in Tianjin, first delivery occurred in 2009.[38] In early 2011 unveiled its stealth fighter jet, the J-20.[5] In addition, Embraer builds ERJ 145s in Harbin, and Bombardier sources fuselages in Shenyang.[35] See Appendix J and K, section History for an expanded overview of commercial aircraft industry in China.	
Bombardier (Canada)	1942, Public	Has successfully developed a family of commercial regional aircrafts. Eight major models with variants.	Bombardier CS100/CS300 Expected EIS: 2013
United Aircraft Corporation (Russia)	2006, Public, Government owns major stake	Has successfully developed aircrafts through Irkut, Ilyushin, Tupolev and the other six subsidiaries that form UAC. Tuvolev developed the Tupolev Tu-154 and Tupolev Tu-204/214, airplanes that Irkut MS-21 is meant to replace.	Irkut MS21 Expected EIS: 2016
Mitsubishi Aircraft Corporation (Japan)	2008, Subsidiary of Public companies	Has successfully produced commercial airplanes but experience with new airplane programs is limited. In 1962 introduced its first regional turbo prop aircraft, the YX-11. 182 units were sold. Majority owner Mitsubishi Heavy Industries (MHI) has experience in the production of aircraft under license, such as jet fighters such as the Mitsubishi F-15, and helicopters such as the Sikorsky S-70 and the Mitsubishi H-60. MHI currently produces major structure subassemblies for the Boeing 777 and 787. Toyota Motor Corporation is minority owner with 10% with experience in general aviation.	Mitsubishi MRJ Expected EIS: 2014
Embraer (Brasil)	1969, Public	Has successfully developed a family of commercial regional aircraft. Eight major models with variants.	None announced.

Source: created by author. Dates for Entry into Service are from Appendix E

Appendix D Commercial Airplanes: Models in Production or Launched

Table D.1 – Commercial Airplanes Models in Production of Launched

Boeing Current Market Outlook 2010 to 2029

AIRPLANE MARKET SECTOR DEFINITIONS

Bold: Airplanes in production or launched.

Region summary
Airplane demand summary

SINGLE-AISLE PASSENGER AIRPLANES

More than 175 seats	**90 to 175 Seats**	**Regional Jets**
Boeing 707, 757	Boeing 717, 727	**Antonov An-148**
Boeing 737-900ER	Boeing 737-100 through -500	**AVIC ARJ-700**
Airbus A321	**Boeing 737-600, -700, -800**	Avro RJ70, RJ85
Tupolev TU-204, TU-214	**Airbus A318, A319, A320**	BAe 146-100, -200
	Boeing/MDC DC-9, MD-80, -90	**Bombardier CRJ**
	AVIC ARJ-900	Dornier 328JET
	BAe 146-300, Avro RJ100	**Embraer 170, 175**
	Bombardier CRJ-1000	**Embraer ERJ-135/140/145**
	Bombardier CS100, CS300	Fokker 70, F28
	Embraer 190, 195	**Mitsubishi MRJ**
	Fokker 100	**Sukhoi Superjet 100**
	Illyushin IL-62	Yakovlev Yak-40
	Tupolev TU-154	
	Yakovlev Yak-42	

TWIN-AISLE PASSENGER AIRPLANES

Large Three class: more than 400 seats	**Medium** Two class: 340 to 450 seats Three class: 260 to 370 seats	**Small** Two class: 230 to 340 seats Three class: 180 to 260 seats
Boeing 747-8	**Boeing 777**	**Boeing 767, 787**
Airbus A380	Boeing/MDC MD-11	Boeing/MDC DC-10
	Airbus A330-300, A340	Airbus A300, A310, **A330-200**
	Airbus A350-900, -1000	**Airbus A350-800**
	Illyushin IL-86	Lockheed L-1011
		Illyushin IL-96

FREIGHT AIRPLANES

Large freighter More than 80 tonnes	**Medium widebody** 40 to 80 tonnes	**Standard-body** Less than 45 tonnes
Boeing/ MDC MD-11	Boeing 767	BAe 146
Boeing 747	Lockheed L-1011SF	Boeing/MDC DC-8/9
Boeing 777	Boeing /MDC DC-10	Boeing 737
Airbus A340-600 SF	Boeing 787	Boeing 727
Airbus A350	Airbus A330	Tupolev Tu-204
Illyushin IL-96T	Boeing 777-A SF	Boeing 707
Antonov An-124	Illyushin IL-76TD	Boeing/MDC MD-80
		Boeing 757-200
		Airbus A318, A319, A320, A321

Production (Passanger and Freighters) and conversion (Special Freighters) models assumed for each type unless otherwise specified

Source: Boeing Current Market Outlook 2010-2029. Retrieved March 31, 2011 from http://www.boeing.com/commercial/cmo/

Appendix E Commercial Airplanes: Single Aisle Market, Launch Dates and Orders

Table E.1 – Single Aisles Market Segment, Launch Dates and Orders

	Program Dates			Orders *		Capacity
	Launched	First Flight	Entry into Service	Announced	Backlog	Max. Seats
Single Aisle (More than 175 seats)						
Boeing 737-900ER	1997	2000	2001	296	177	189
Airbus A321	1989	1993	1993	883	249	220
Tupolev TU-204/-214	1987	1989	1994	115	49	212
Irkut MS21-200	2008	Expected 2014	Expected 2016	146	146	212
COMAC C919	2008	Expected 2014	Expected 2016	100'	100'	190
Single Aisle (90-175 seats)						
Boeing 737-800	1994	1997	1998	3033	1241	189
Boeing 737-700	1993	1997	1997	1487	466	149
Boeing 737-600	1995	1998	1998	69	-	149
Airbus A320 NEO	2010	Expected 2015	Expected 2015	180'	180'	180
Airbus A320	1982	1987	1988	4484	1886	180
Airbus A319	1993	1995	1996	1489	213	156
Airbus A318	1999	2002	2002	83	9	132
Bombardier CRJ-1000	2007	2008	2010	49	40	100
Embraer 190	1999	2004	2004	478	157	114
Embraer 195	1999	2004	2005	105	41	122
Bombardier CS300	2008	Expected 2012	Expected 2013	57	57	145
Bombardier CS100	2008	Expected 2012	Expected 2013	33	33	125
Mitsubishi MRJ	2007	Expected 2012	Expected 2014	65	65	96
Regional (<90 seats)						
Antonov An-148	2001	2004	2009	237	229	80
Bombardier CRJ-900	1998	1999	2001	262	18	90
Bombardier CRJ-700	1997	1999	2001	340	19	78
Bombardier CRJ-200	1994	1995	1995	709	0	50
Bombardier CRJ-100	1989	1991	1992	226	0	50
Sukhoi SuperJet 100	2005	2008	2011	194	193	95
Embraer 170	1999	2001	2004	191	10	80
Embraer 175	2003	2003	2005	173	40	88
Embraer ERJ-135	1997	1998	1999	108	-	37
Embraer ERJ-140	1999	2000	2001	74	-	44
Embraer ERJ-145	1989	1995	1996	708	2	50
ACAC ARJ21	2002	2008	Expected 2011	237	237	90

* Excludes derivatives for military and business jets

Airplanes under development are highlighted in gray

Source: compiled by author from Airliners.net and Wikipedia.com

Appendix F Market Outlook 2010-2029: Demand, Market Segments and Regions

An analysis of the Boeing Market Outlook 2010-2029[4] underscores the significance of the single-aisle market segment and the market in China. Other highlights and key takeaways are as follows.

1. Highlights

Demand for new airplanes

The world fleet (total number of airplanes that will be in service) will nearly double in the next 20 years (will go from 18,890 airplanes in 2009 to 36,300 in 2029). Only 15% of the world fleet by 2029 will be airplanes that were in service by 2009. Of the new airplanes to be delivered, 44% are to replace existing fleets and 56% is for fleet growth.

Largest market segments in terms of fleet size

The single-aisle market segment will be the predominant fleet, even more than it is today, and will represent almost 70% of the demand in the next twenty years (21,321 new single-aisle airplane are expected to be delivered in the next twenty years).

Largest market segments in terms of market value

The commercial aircraft industry is a $3.6 billion market for the next twenty years. The single-aisle and twin-aisle market represent 92% of that value. Regional jets and large aircraft segments are the rest of the market. The single-aisle and twin-aisle segments are expected to have about the same market value by 2029 ($1.7billion and $1.6 billion respectively).

Largest market region

The Asia-pacific region represents the highest demand for new airplanes. 34% of the new airplanes to be delivered in the next twenty years will go to this region representing a $1.3 billion market. 64% of the new airplanes to be delivered will be single-aisle (6,604 airplanes, representing 31% of the world demand in the next twenty years for this market segment). It is also important to note that the market for regional jets represents only 5% of the new airplanes needed in the next twenty years in the Asia Pacific region.

2. Detail Charts Analysis

Market Size (in terms of new airplanes):

Figure below shows how world fleet (total number of airplanes that will be in service) will nearly double.

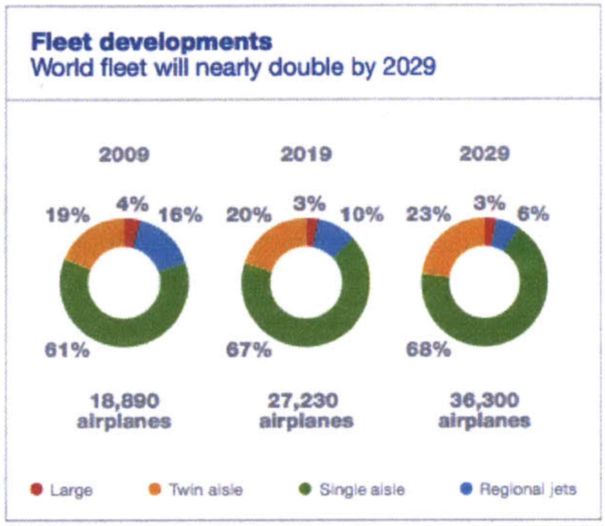


Figure F.1 – Market Outlook – World Fleet

Source: Boeing Market Outlook 2010-2029 [4]

Figure below shows that only 15% of the world fleet by 2029 are airplanes that are in service today.

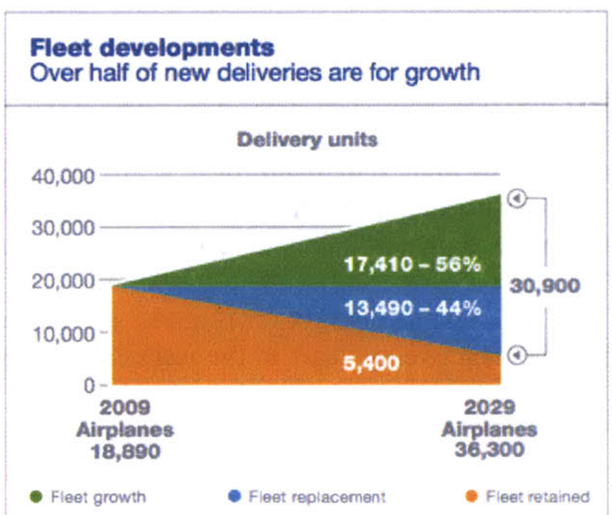


Figure F.2 – Market Outlook – Fleet Developments

Source: Boeing Market Outlook 2010-2029

Market Size (in terms of market value):

In terms of market value, market segments 'single aisle' and 'twin aisle' are about the same by 2029.

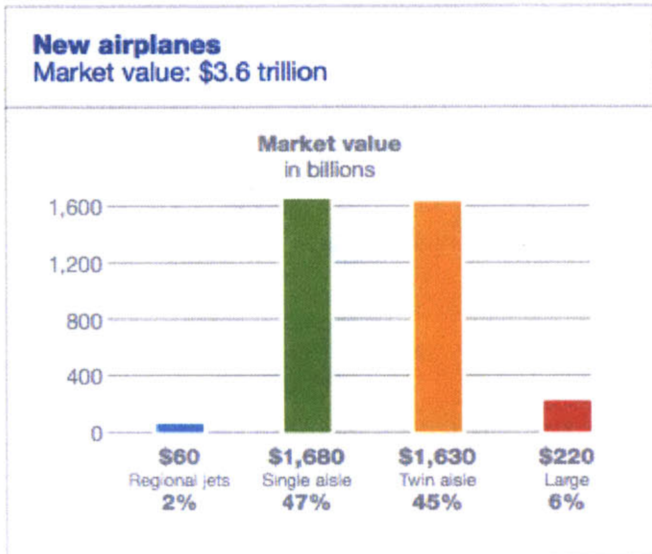


Figure F.3 – Market Outlook – Market Value of New Airplanes by Fleet Type

Source: Boeing Market Outlook 2010-2029

In terms of predominant fleet type by 2029, the single-aisle market segment is expected to be 70% of the world fleet.

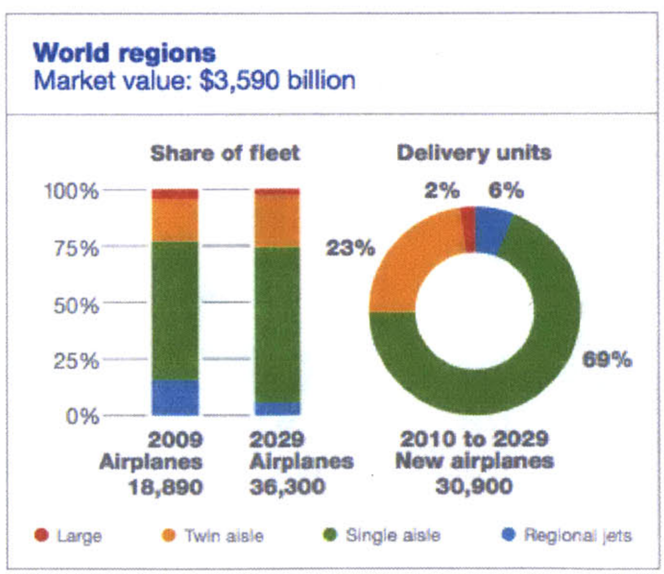


Figure F.4 – Market Outlook – Market Value of New Airplanes by Region

Source: Boeing Market Outlook 2010-2029

Market Regions:

In terms of number of new deliveries, 34% of the new airplanes are for Asia Pacific region.

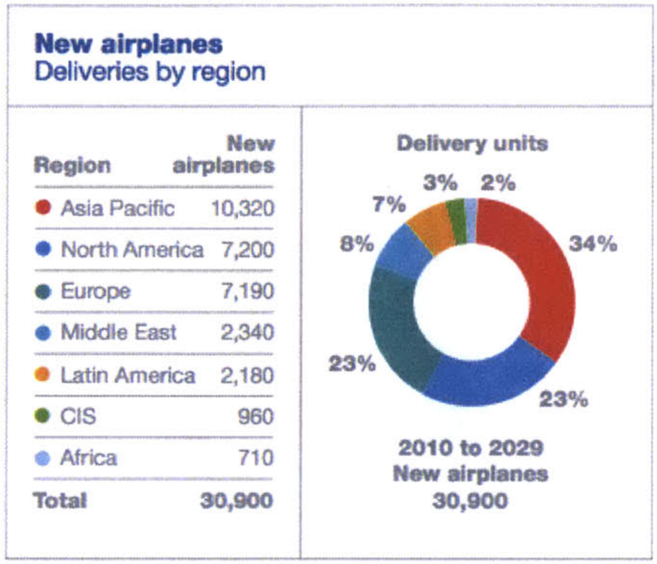


Figure F.5 – Market Outlook – Demand of New Airplanes by Region

Source: Boeing Market Outlook 2010-2029

In terms of type of fleet need for the Asia Pacific region, 64% of the new deliveries are expected to be single-aisle airplanes, and less than 5% regional airplanes.

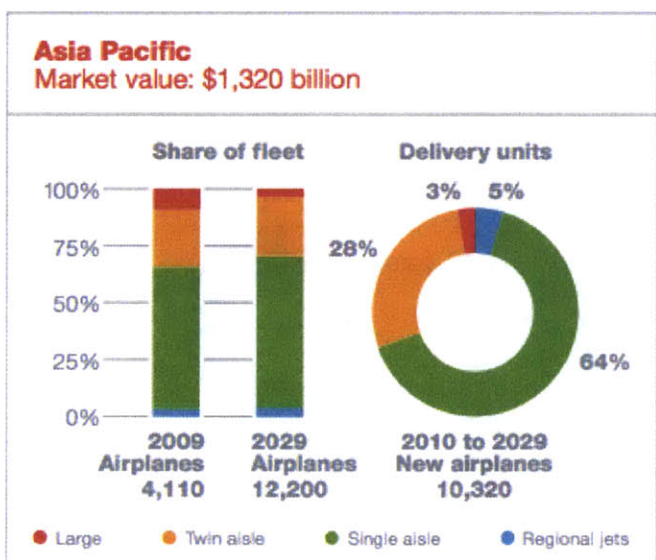


Figure F.6 – Market Outlook – Asia Pacific Region Demand by Fleet Type

Source: Boeing Market Outlook 2010-2029

Boeing versus Airbus Forecasts

Figure below shows how demand for new airplanes exceeded the expectations for both Boeing and Airbus in the 10-year forecast in 2010.

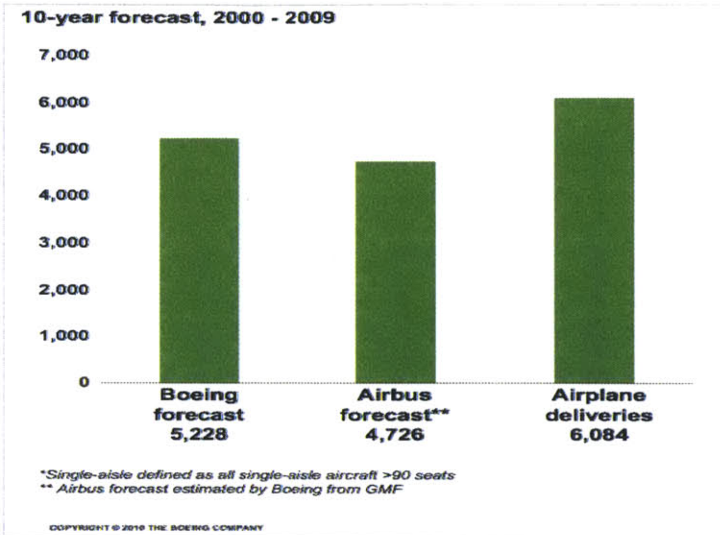


Figure F.7 – Market Outlook – Boeing Versus Airbus Forecasts, Single Aisle

Source: Boeing Market Outlook 2010-2029

Figure below underscores how Boeing and Airbus have had different views of the market, which has led to different strategies.

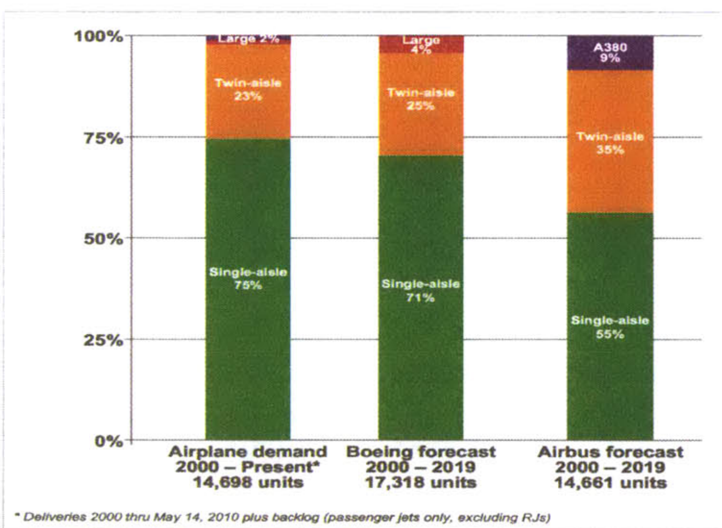
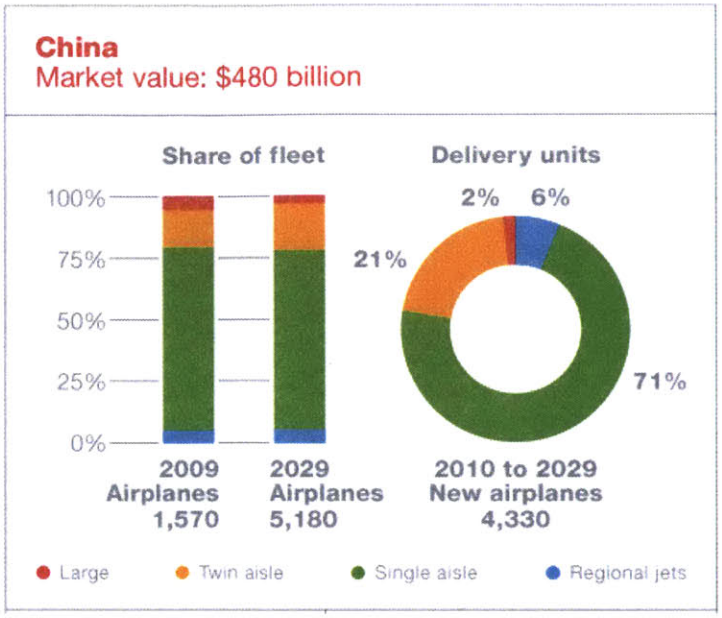


Figure F.8 – Market Outlook – Boeing versus Airbus Forecasts

Source: Boeing Market Outlook 2010-2029

Appendix G Market Outlook 2010-2029: Specific Report of China



CHINA

Growth measures	(%)	Market size		
GDP growth rate	7.3	New deliveries	4,330	Units
Traffic growth rate	7.6	Market value	480	($B 2009)
Cargo growth rate	7.4	Average airplane value	110	($M 2009)
Fleet growth rate	6.2			
Ratio RPK/GDP growth	1.1			

CHINA

New airplane deliveries 2010 to 2029	New deliveries	Market share by size (%)	Fleet in 2009	Fleet in 2029
Large	70	2	80	130
Twin aisle	890	21	240	1,000
Single aisle	3,090	71	1,170	3,770
Regional jets	280	6	80	280
Total	4,330	100	1,570	5,180

CHINA

The traffic table below is not a complete list of all traffic flows related to "China" as some are too small to display.

	RPKs in billions										Annual growth, %
Traffic flow	2001	2002	2003	2004	2005	2006	2007	2008	2009	2029	2009 to 2029
China to and from Europe	40	43	37	51	61	74	77	78	74	238	6.0
China to and from North America	36	33	25	34	40	49	56	57	51	153	5.7
China to and from Northeast Asia	18	25	20	27	29	30	36	33	30	100	6.2
China to and from Oceania	12	13	11	15	17	19	20	22	19	67	6.4
China to and from Southeast Asia	32	37	28	41	49	49	52	50	47	195	7.3
Within China	87	101	107	144	164	182	211	227	272	1,241	7.9

Source: Boeing Current Market Outlook 2010-2029. Retrieved March 31, 2011 from http://www.boeing.com/commercial/cmo/

Appendix H Patent Scorecard: Aerospace – Top 50 Companies

Top 50 Aerospace companies in the Patent Scorecard are in the table below. Portfolio indicators for the Patent Board Scorecard[48] are as follows:

Quantity Metrics:

Patents Granted: equals the number of industry-specific U.S. patents granted in a given year, excluding design and other special-case inventions. Only industry-specific patent counts are represented for the multi-industry companies.

Quality Metrics:

Technology Strength™: provides an aggregate assessment of patents and innovation by considering the combined quality and quantity aspects of a company's portfolio.

Industry Impact™: quantifies how influential a company's patent portfolio is on the development of technologies in other companies, compared to rest of the industry.

Science Metrics:

Science Strength™: measures, at an aggregate level, the degree to which a company's patent portfolio is linked to core science.

Research Intensity™: tracks a company's level of fundamental research in a given industry compared to other companies, portfolios and patents across the same technology areas.

Speed Metrics:

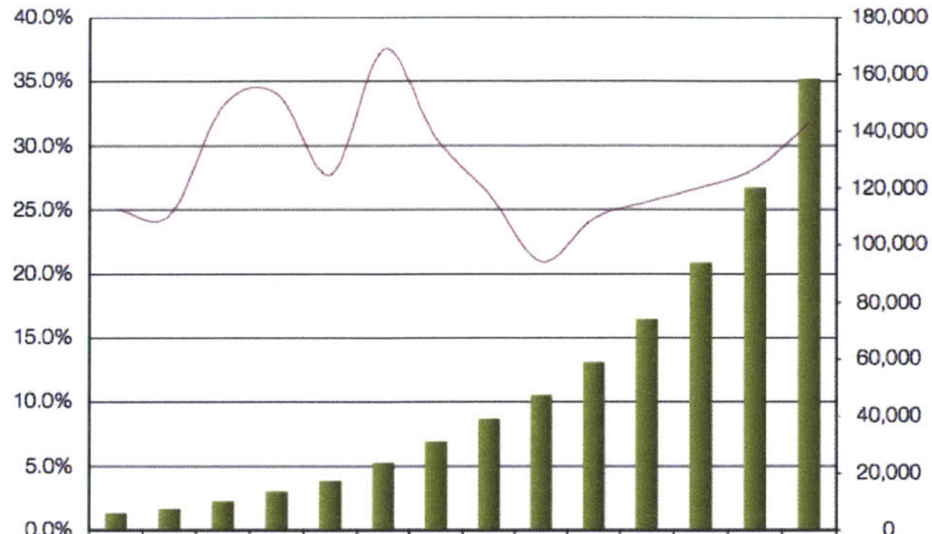
Innovation Cycle Time™: indicates the speed at which a company turns leading-edge technology and core research into patent assets. Measured in years, a lower number is most desirable.

Table H.1 – The Patent Board Scorecard, Top 50 Aerospace and Defense

Previous Rank		Current Rank	Company	Patent Granted*	Science Strength™	Innovation Cycle Time™	Industry Impact™	Technology Strength™	Research Intensity™
Top 50 - Aerospace & Defense - Week of 3/25/2011									
1	◁▷	1	Boeing Co	697	1430	12.5	1.251	583.22	1.4
2	◁▷	2	Lockheed Martin Corp	396	1965.5	10.2	1.28	341.15	2.02
3	◁▷	3	Raytheon Co	252	1572.3	10.8	1.474	250.83	1.81
5	△	4	General Electric Co*	233	49.5	11	1.236	194.5	0.36
7	△	5	United Technologies Corp*	256	14	16.1	1.102	189.72	0.27
4	▽	6	Rockwell Collins Inc	115	86.5	8	2.352	180.84	0.68
6	▽	7	EADS/European Aeronautic Defense & Space	355	90.8	14	0.7	166.33	0.55
8	◁▷	8	Honeywell Intl Inc*	151	315.5	10.4	1.295	131.65	1.56
9	◁▷	9	SAFRAN	214	40.5	13.7	0.744	107.18	0.59
10	◁▷	10	Northrop Grumman Corp	139	256.3	10	0.968	89.55	1.75
11	◁▷	11	Rolls-Royce plc	162	4.5	16.9	0.744	80.3	0.16
14	△	12	Florida Turbine Technologies Inc	70	0	13	1.578	74.1	0
13	◁▷	13	BAE Systems plc	99	264.3	10.7	1.042	69.17	1.41
12	▽	14	Thales Group	108	179	9.9	0.893	65.01	1.33
15	◁▷	15	L-3 Communications Holdings*	65	113.3	10.4	1.325	57.4	1.25
16	◁▷	16	Goodrich Corp	57	97.8	13.3	0.983	37.52	1.03
17	◁▷	17	General Dynamics Corp	42	207.3	11.6	1.31	36.56	1.32
18	◁▷	18	Alliant Techsystems Inc	43	168	17.8	1.012	29.45	1.72
19	◁▷	19	FLIR Systems Inc	35	127	11.9	0.923	21.53	1.89
22	△	20	Mitsubishi Heavy Industries*	24	0.5	12.3	1.117	18.17	0.25
24	△	21	Omnitek Partners LLC	19	0	18.4	1.414	17.59	0
21	▽	22	QinetiQ Group plc*	16	63.8	12.2	1.623	17.49	2.19
23	◁▷	23	B/E Aerospace Inc	22	0	12.8	1.206	17.39	0
20	▽	24	Finmeccanica SpA	24	32	13.5	0.893	14.24	1.21
28	△	25	Diehl Stiftung & Co KG	32	1	15.1	0.596	12.64	0.14
27	△	26	Saab AB	31	11.3	17.1	0.596	12.4	0.78
26	▽	27	Kawasaki Heavy Industries*	20	1	10.2	0.863	11.84	0
29	△	28	Cobham plc	17	75.5	13.3	0.849	9.54	1.65
25	▽	29	MTU Aero Engines	36	2	15.9	0.387	9.27	0.3
33	△	30	Textron Inc*	22	0.3	19.7	0.447	6.49	0
35	△	31	GenCorp Inc	9	0	20.3	1.102	6.45	0
31	▽	32	European Space Agency	7	57	10.8	1.474	6.39	3.75
38	△	33	IHI Corp*	9	0.5	12.6	1.072	6.15	0.72
32	▽	34	Rafael Advanced Defense Systems Ltd	12	4	15.9	0.729	5.95	0.5
30	▽	35	Heckler & Koch GmbH	9	0	23.4	0.923	5.55	0
34	▽	36	Teledyne Technologies Inc*	6	166.5	11.4	1.31	5.28	3.04
		37	Elbit Systems Ltd	12	44.5	19.3	0.64	5.03	1.72
37	▽	38	Ball Corp*	4	15	9.9	1.265	3.23	4.96
40	△	39	SAIC Inc*	3	40.3	11.2	1.385	2.79	2.03
36	▽	40	Meggitt PLC	8	0.8	14.5	0.521	2.7	0.3
41	◁▷	41	Rheinmetall AG*	9	0	16.2	0.402	2.43	0
39	▽	42	Sequa Corp	4	0	10	0.893	2.2	0
44	△	43	Loral Space & Communications	3	1	8.3	1.117	1.9	0
43	▽	44	Giat Industries	7	0	15.9	0.313	1.39	0
42	▽	45	Bombardier Inc*	2	1.8	27.7	0.67	0.89	0.48
45	▽	46	Armament Systems & Procedures Inc	1	0	14.2	0.983	0.66	0
46	▽	47	BBA Aviation plc	0	0		0	0	

Source: The Patent Board, and The Wall Street Journal Special Edition on Aerospace[49]

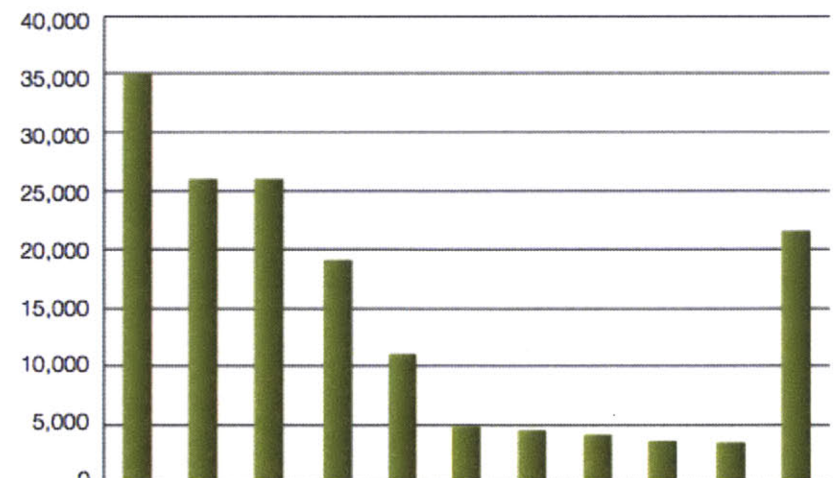
Appendix I Wind Power Industry in China



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Cumulative Installed Capacity (MW)	6,100	7,600	10,120	13,560	17,320	23,820	31,090	39,223	47,430	58,961	74,052	93,835	120,296	158,505
growth rate (%)	25.0%	24.6%	33.2%	34.0%	27.7%	37.5%	30.5%	26.2%	20.9%	24.3%	25.6%	26.7%	28.2%	31.8%

Figure I.1 – Growth of Global Wind Power Cumulative Installed Capacity

Source: GWEC, China Wind Energy Outlook 2010



	USA	China	Germany	Spain	India	Italy	France	UK	Portugal	Denmark	Others
Camulative Installed Capacity(MW)	35,064	25,805	25,777	19,149	10,926	4,850	4,492	4,051	3,535	3,465	21,391

Figure I.2 – Top 10 countries for Wind Power Cumulative Capacity

Source: GWEC, China Wind Energy Outlook 2010

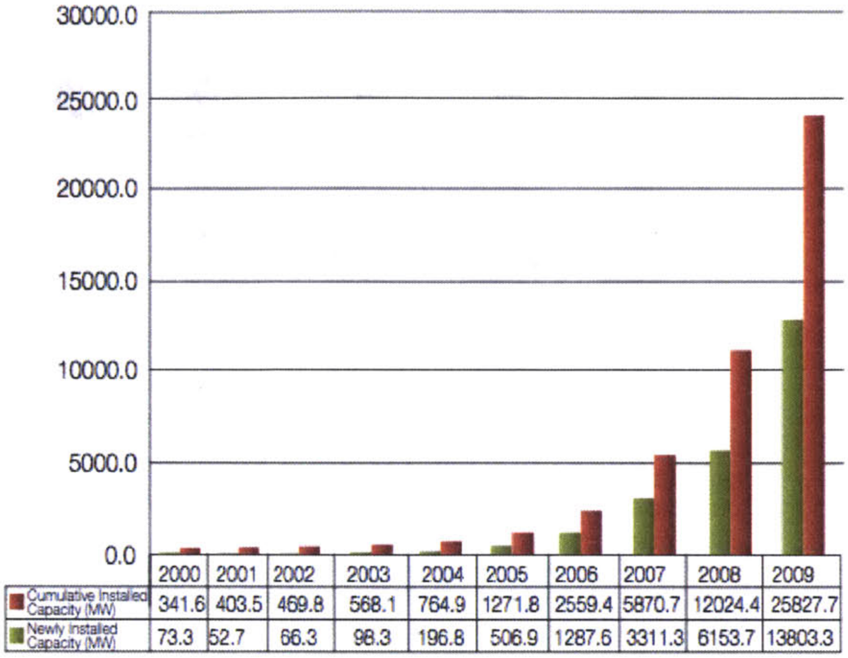


Figure I.3 – Growth of Wind Power in China

Source: GWEC, China Wind Energy Outlook 2010

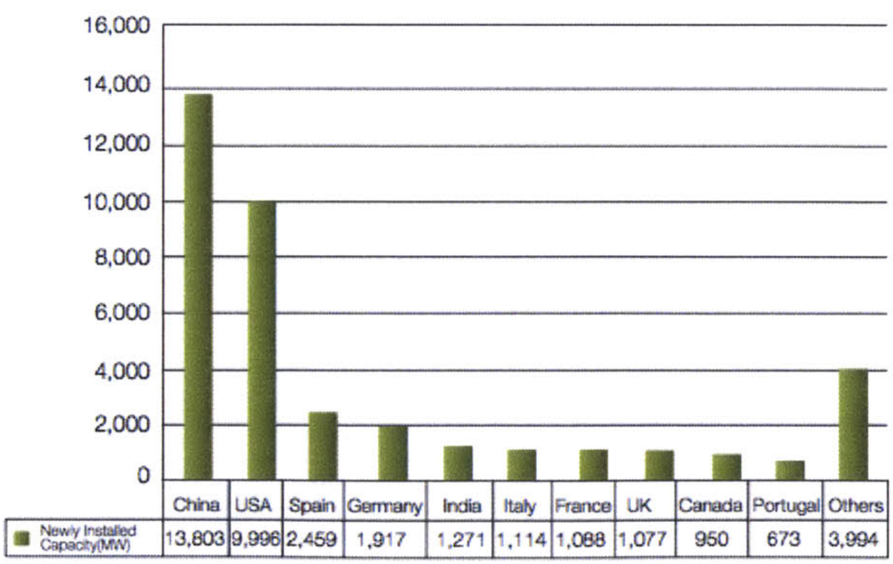


Figure I.4 – Top 10 countries for Newly Installed Capacity

Source: GWEC, China Wind Energy Outlook 2010

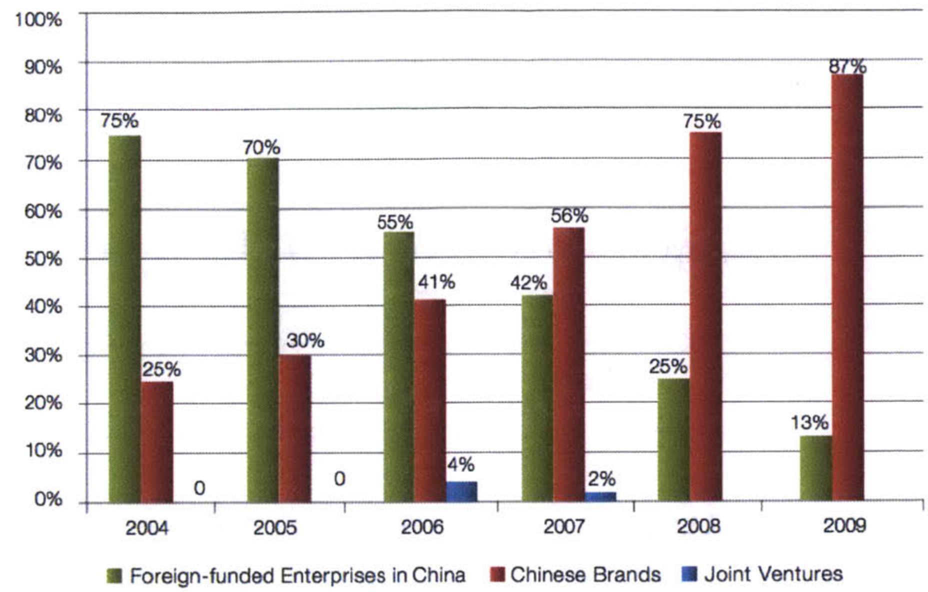


Figure I.5 – Comparison of Newly Installed Capacity Market Share between Domestic and Foreign Companies in the Chinese Wind Power Market

Source: BTM; Global Statistics Reports of 2004-2009; Shi Pengfei, Chinese Wind Power Installed Capacity Statistics, via GWEC, GWEC, China Wind Energy Outlook 2010

Table I.1 – China - Cumulative Market Share of Top 10 Equipment Manufacturers in 2009

Market share distribution of cumulative installed capacity		
Name of enterprise	Installed capacity (MW)	Market share
Sinovel	5,652	21.90%
Goldwind	5,343.85	20.70%
Dongfang	3,328.5	12.90%
Vestas	2,011.5	7.80%
Gamesa	1,828.75	7.10%
GE	957	3.70%
Mingyang	895.5	3.50%
United Power	792	3.10%
Suzlon	605.25	2.30%
Windey	594	2.30%
Others	3,814.45	14.80%
Total	25,805.3	100.00%

Source: GWEC, China Wind Energy Outlook 2010

Table I.2 – Global Wind Turbine Manufacturing Industry

No.	Company	Newly installed in 2009 (MW)	%	Cumulative (MW)	%
1	Vestas	4,766	12.9%	39,705	23.6%
2	GE Wind	4,741	12.8%	22,931	13.6%
3	Sinovel	3,510	9.5%	5,658	3.4%
4	Enercon	3,221	8.7%	19,738	11.7%
5	Goldwind	2,727	7.4%	5,315	3.2%
6	Gamesa	2,546	6.9%	19,225	11.4%
7	Dongfang	2,475	6.7%	3,765	2.2%
8	Suzlon	2,421	6.5%	9,671	5.7%
9	Siemens	2,265	6.1%	11,213	6.7%
10	REpower	1,297	3.5%	4,894	2.9%
Total for other companies		7,034	19.0%	26,331	15.6%
Total		37,003	100.0%	168,446	100.0%
Top ten companies		29,969	81.0%	142,115	84.4%

Source: Wind Power (March 2010) and BTM Consult via GWEC, China Wind Energy Outlook 2010

Table I.3 – 2009 Export of Chinese Wind Turbines

Company	Model	Number of sets	Capacity	Exporting country
Sinovel	SL1500/82	10	15	India
Goldwind	GW77/1500	3	4.5	USA
Sewind	W1250/64	5	6.25	Britain (3 sets); Thailand (2 sets)
New United (Changqian Xinyu)	SD77/1500	2	3	USA (1 set); Thailand (1 set)
Total		20	28.75	

Source: GWEC, GWEC, China Wind Energy Outlook 2010

Appendix J Comac ARJ21 - Technical Specifications and Program Overview

COMAC ARJ21

Transports
November 2010

Richard Aboulafia
Vice President, Analysis
raboulafia@tealgroup.com

Source: General Electric

Program Briefing

The ARJ21 series is a family of regional jets built by Aviation Industries of China 1 (AVIC 1). So far the 78-seat -700 is the only launched version, but there are plans for a -900 100-seat stretch. First announced in 2000, the ARJ21 is scheduled to enter service in the third quarter of 2011.

Manufacturer

AVIC 1 Commercial Aircraft Corporation of China (COMAC, formerly ACAC)
22-23/F Business Building
Zhaofeng Plaza
1027 Changning Road
Changning District
Shanghai 200050
Tel: (86 21) 52 41 37 37
www.acac.com.cn

Final assembly will take place at Shanghai Aircraft Manufacturing, which will also build the horizontal stabilizer.

Subsystems

Airframe

Standard RJ design with swept wings and rear-mounted engines and a T-tail. It looks a lot like a DC-9. Composites make up 5% of the -700 by structural weight. Seating is either 2-2 or 2-3.

Airframe Subcontractors

- Chengdu Aerospace (AVIC 1): nose section
- Liebherr Aerospace: landing gear
- Saint-Gobain Sully: windshields and windows
- Shenyang Aircraft Manufacturing (AVIC 1): empennage
- Xian Aircraft Company (AVIC 1): wings, fuselage sections

Propulsion

Engine

The ARJ21-700 and -900 are equipped with two rear-mounted General Electric CF34-10A turbofans with FADEC. On the -700, they are rated at 15,332 lbst. On the -900, they are rated at 17,057 lbst.

Propulsion System Subcontractors

- Meggitt (Vibro-Meter): engine vibration monitoring system and engine interface control unit
- Smiths Aerospace thrust reverser actuators

Electronics

- Eaton Aerospace: cockpit panel assemblies and pulse width modulation dimming
- Rockwell Collins: avionics, including AHS-3000 attitude heading reference system
- Sagem: flight deck control suite

Other Systems

Other Contractors

Other contractors involved in miscellaneous subsystems are as follows:

- Aircraft Braking Systems: braking system
- B/E Aerospace: oxygen equipment
- Evac: waste and water system
- Fisher Advanced Composite Components: interior
- Goodrich: tires and brakes
- Goodrich Aerospace (Hella): lighting
- Hamilton Sundstrand (UTC): power systems
- Honeywell: primary flight controls
- Kaiser Electroprecision: throttle control module
- Kidde Aerospace: fire protection system
- Liebherr Aerospace: environmental control, bleed air system, wing anti-icing system
- MPC Products: auxiliary power unit door system, throttle actuator
- Parker Hannifin: fuel, hydraulic systems and flight control systems
- Sagem: cabin systems
- Zodiac Air Cruiser: emergency evacuation equipment
- Zodiac-Monogram: water/waste systems
- Zodiac-Sicma: crew seats

Specifications

	ARJ21-700STD	*ARJ21-900*
Length overall:	109 ft 9 in (33.5 m)	119 ft 4 in (36.4 m)
Height overall:	27 ft 8 in (8.4 m)	same
Wing span:	89 ft 5 in (27.3 m)	same
Weight empty:	55,016 lb (24,955 kg)	57,915 lb (26,270 kg)
Max. T-O weight:	89,287 lb (40,500 kg)	96,157 lb (43,616 kg)
Max. cruise speed:	Mach 0.78	same
Max. range:	1,200 nmi (2,225 km)	same
Seating:	78-85	98-105

Costs

Development of this plane has been estimated at $1.2 billion. Some $400 million will come from private investors, and the rest from AVIC 1 funding. Aircraft prices are unknown.

Sales/Deliveries Data

Orderbook

User	Version	Ord./Del.	
Institute of Electronics/China Academy of Sciences	-700	2/—	
GECAS	-700	5/—	20 options
Lao Airlines	-700	2/—	
Shandong Airlines	-700	10/—	
Shenzhen Financial Leasing	-700	20/—	
United Eagle Airlines	-700	30/—	
Total	**-700**	**69/—**	

Program Overview

History

Fragmented Origins

China has attempted to build a national jet for decades, without success. The closest it got was the Shanghai Y-10, a Boeing 707 knockoff that was built and flown in prototype form in September 1980. Wisely, it was quashed after two prototypes were built.

There were several Chinese jet projects in the aftermath, as China liberalized and opened up to joint ventures. The most notable was the MPC-75, a 75/90-seat regional jet in the ARJ21 class proposed in the late 1980s. This was a cooperative project between China's CATIC and MBB, now part of EADS. Also, China built 35 MD-80s under license to McDonnell Douglas. It also almost built the MD-90, but this was cancelled (see reports).

In the mid 1990s Airbus, AVIC, and Singapore Technologies worked on the AE-100, a 100-seat jetliner. It went nowhere. The next project was the closely related Airbus/AVIC AE31X, also a 100-seat design that was killed in June 1998.

For an excellent history of Chinese transport aircraft, see Richard Fisher's history of the subject at http://www.strategycenter.net/research/pubID.113/pub_detail.asp.

Enter The ARJ21

In late 2000 the Chinese government announced that it would go its own way. It announced the NKJ-76, a 70-seat plane that was scheduled to enter service 2005. This was part of the PRC five year plan, covering state-run industrial activities in 2001-2005. AVIC 1 formed a project management entity with responsibility for development, certification, and marketing of the new jet.

This plan was slightly complicated by Chinese acquisition of Fairchild Dornier in July 2003. D'Long International Strategic Investment Group of Xinjiang bought the company, including the rights to and prototype of the 50/90-seat 528/728/928JET family. This, however, quickly sank without a trace, and D'Long went out of business. Also in 2003, sister company AVIC 2 announced plans to develop a 30/50-seat regional jet with foreign assistance. The government gave the project go-ahead approval, but it quickly disappeared.

Progress, Or Something Like It

In November 2001 Rolls-Royce reached an agreement with AVIC to explore the potential use of the BR700 turbofan for the ARJ21. Despite this, in November 2002 GE won the competition to power the plane, becoming a risk-sharing partner. The company, however, limited its risk by only agreeing to pay for propulsion system development, which amounts to very little since the jet uses a mostly off-the-shelf engine. After that development, GE will provide engines on a fixed-price basis, rather than taking a share of program revenue (as typically is the case with risk-sharing partnerships).

Also in 2002 AVIC contracted with Boeing Commercial Aviation Services as an engineering consultant, primarily for avionics. Boeing did not invest in the project.

In 2003, AVIC 1 announced that the ARJ21 would enter service in 2007. This was later changed to 2008. In September 2005 design changes forced an in-service delay, from August 2008 to mid 2009. Weight and supplier contract negotiations were cited as the primary reasons for the delay.

ARJ21 Variants

So far, the -700 is the only version. The -900 stretch will likely be the next version launched. At the June 2007 Paris Air Show Bombardier agreed to play an unspecified role in the -900, promising a $100 million investment. Other concept variants include a -700 freighter and a -700B business jet.

First Flight

In November 2008 the ARJ21 made its first flight. Three additional aircraft were added to the test program, with the third aircraft flying in September 2009.

Current Plans

The first ARJ21-700 prototype was built at the Shanghai Aircraft Manufacturing Factory, an entity absorbed by AVIC 1/ACAC. First delivery was scheduled for the third quarter of 2009. Three were to be delivered that year, 14 in 2010, and 30 in 2011. However, in March 2998 ACAC (now part of COMAC—Commercial Aircraft Corporation of China) announced a six month delay to the first flight. In October 2008 they announced another month's delay.

In November 2009 China's National Reform and Development Committee approved ARJ21 "mass production." In 2009 and 2010, the aircraft needed significant design changes, and as of November 2010 service entry was scheduled for the third quarter of 2011.

Teal Group Evaluation

Great Leap Backward

There are two ways to create an aviation industry. One is to be like Japan, and build a broad portfolio of risk-sharing work and subcontracts, learning new technologies from foreign partners, diversifying to maximize gain and avoid risk, and creating public-private partnerships. The second way is to be like Indonesia and focus all resources and attention on a national plane. The risks are high, and all the value added work is imported from foreign contractors.

To put it differently, there are two ways to build an aviation industry. Smart and dumb. This project isn't the smart one.

Just because the ARJ21 is a bad idea doesn't mean that it won't go ahead. But consider the market. Exports, beyond irrelevant markets like Laos (the first and only international customer), are very unlikely due to AVIC's inadequate product support, sales, and financing capabilities. Programs mandated by a government five-year plan seldom produce competitive jets.

The China RJ market is pretty small. It's well catered to by Embraer and Bombardier. China could force its national airlines to take these planes and violate the WTO ATCA agreement (it only holds "observer" status, so that wouldn't be a problem). But that would damage the airlines' competitiveness, just as they are increasingly subject to competition from foreign carriers. The government, in effect, would need to choose between a national aircraft and healthy national airlines. And the airlines don't care. As McDonnell Douglas found out, Chinese airlines are looking for the best values and the most appropriate planes, not something built in-country. Also, the order book isn't exactly reassuring. Only 69 are firm, with about 170 more options. One hundred of these are for Kunpeng, a joint venture with Mesa that operates about half a dozen planes. Joy Air is largely an AVIC creation. Meanwhile, the Chinese regional market is struggling. Five GECAS orders (incorrectly touted as 25) are the only good news. But since GE has a much higher goal here (China market development for the entire corporation), those orders don't mean anything.

Then there's the ARJ21 design. It offers exactly nothing new. In fact, it's 15% heavier on a per-seat basis than any of its competitors. It looks very much like the DC-9, a classic example of re-inventing the wheel. The -700's weight looks particularly wretched. That assumes the manufacturer's specifications stay as-is, an optimistic assumption. The engines and avionics are pretty much identical to any other RJ designed ten years ago.

It's also important to remember that aircraft development costs stay high after the plane is designed and built; ramping up series production is an expensive process too.

This uncertainty about funding, coupled with the dismal order book and doubts about the wisdom of this project, and looking at China's mediocre aircraft production track record, leads us to question whether this aircraft will enter series production. Right now, we have a relatively light forecast, but we give it a 25% chance of outright cancellation. As China's government shifts its attention towards the C919, they have an easy rationale to de-prioritize the last-generation ARJ21.

Production Forecast

User (Variant)	Through 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
AVIC 1												
All users* (ARJ21)	—	—	—	4	6	6	6	4	4	2	2	34

**Excludes six test aircraft.*

Appendix K Comac C919 - Technical Specifications and Program Overview

COMAC C919

Transports
July 2010

Richard Aboulafia
Vice President, Analysis
raboulafia@tealgroup.com

Source: COMAC

Program Briefing

The C919 is a 130/200-seat narrowbody jet being developed by China's COMAC. Launched in 2008, the C919 will use General Electric Leap-X engines. It is scheduled to fly in 2014 and enter service in 2016. No orders have been booked yet, but the plane is being heavily marketed to Chinese airlines. It is intended to compete with Airbus's A320 and Boeing's 737.

Manufacturer

Commercial Aircraft Corporation of China (COMAC)
22-23/F Business Building
Zhaofeng Plaza
1027 Changning Road
Changning District
Shanghai 200050
Tel: (86 21) 52 41 37 37
www.acac.com.cn
www.comac.cc (Chinese only)

COMAC is owned by the Chinese Government's State Assets Supervision and Administration Committee (31.5%), the Shanghai Government's Shanghai Guo Sheng investment arm (26.3%), Aviation Industries of China (AVIC, 26.3%), CHINALCO (5.3%, Baosteel (5.3%), and Sinochem (5.3%). Final assembly, design work, and customer suppor will all take place in Shanghai.

Subsystems

Airframe

Largely constructed of aluminum alloy, but the center wing box will use carbonfiber composite. Seating will be 3-3, with a cross section similar to an A320.

Airframe Subcontractors

- AVIC Aircraft (Xian): inner wing, outer wing boxes, movable surfaces, mid fuselage
- AVIC Defense (Chengdu): nose
- AVIC Defense (Hongdu): forward and aft fuselage
- AVIC Defense (Shenyang): tail
- Liebherr: main and nose landing gear

Propulsion

Engine

CFM International (GE/Safran) is providing its new Leap-X1C engine, rated at 30,000 lbst. AVIC Commercial Aircraft Engine (ACAE) will act as a Chinese partner in this project, and is building the assembly line and test center for the Leap-X1C.

ACAE is also developing a Chinese engine for the C919. The first of these is scheduled to be built in 2016.

Propulsion System Subcontractors

- Nexcelle (joint venture between GE Aviation's Middle River Aircraft Systems and Safran's Aircelle, in partnership with AVIC

Aircraft): integrated propulsion system

Electronics

- GE Aviation (JV with AVIC): open-architecture, integrated modular avionics core processing system; flight deck large-area display system; on-board maintenance system; flight recording system
- Rockwell Collins (JV with China Electronics Technology Avionics): communications and navigation
- Rockwell Collins (JV with China Leihua Electronic Technology Research Institute-LETRI): integrated surveillance system, combining weather detection, traffic alert and collision avoidance, Mode S surveillance and terrain awareness and warning functions

Other Systems

Other Contractors

Other contractors involved in miscellaneous subsystems are as follows:

- Eaton Corp. and Shanghai Aircraft Manufacturing Co. jointly will develop and produce its fuel and hydraulic conveyance systems
- Goodrich (with Jiangsu Tongming Automobile Lamp): lights
- Hamilton Sundstrand (United Technologies): electrical power generation and distribution systems
- Hamilton Sundstrand Kidde (UTC): Integrated Fire and Protection System
- Honeywell (with Hunan Boyun New Materials and Changsha Xinhang Wheel & Brake; a joint venture will be formed to provide the wheels and brakes system): pedal-to-ground solution, including wheels and brakes, Brake Control System (BCS), and tires
- Honeywell (JV with AVIC Engine): 131-9(C9C) APU, starter and generator
- Honeywell: fly-by-wire flight control system
- Moog (JV with AVIC Systems): high lift system, including flap and slat actuation
- Parker Aerospace (JV with AVIC Systems): primary flight control actuation systems, fuel inerting systems

Specifications

	C919
Length overall:	126 ft 7 in (38.6 m)
Wing span:	116 ft 1 in (35.4 m)
Max. cruise speed:	Mach 0.785
Max. range:	3,000 nmi (5,555 km)
Seating:	156

Costs

Development of this plane has been estimated at 60 billion yuan, or $8.3 billion. Aircraft prices are unknown.

Program Overview

History

A Long Techno-Nationalist Road

China has attempted to build a national jet for decades, without success. The closest it got for 40 years was the Shanghai Y-10, a Boeing 707 knockoff that was built and flown in prototype form in September 1980. After a miserable flight test, It was quashed after two prototypes were built.

There were several Chinese jet projects in the aftermath, as China liberalized and opened up to joint ventures. The most notable was the MPC-75, a 75/90-seat regional jet in the ARJ21 class proposed in the late 1980s. This was a cooperative project between China's CATIC and MBB, now part of EADS. Also, China built 35 MD-80s under license to McDonnell Douglas. It also almost built the MD-90, but this was cancelled (see reports).

In the mid 1990s Airbus, AVIC, and Singapore Technologies worked on the AE-100, a 100-seat jetliner. It went nowhere. The next project was the closely related Airbus/AVIC AE31X, also a 100-seat design that was killed in June 1998.

In December 2005 Airbus signed an MoU with China's National Development & Reform Commission to establish an A320 final assembly line (FAL) in China. The first plane rolled off the line in June 2009.

The second Chinese jet to actually proceed to the flight test phase (after the Y-10) was the ARJ21 regional jet (see report).

For an excellent history of Chinese transport aircraft, see Richard Fisher's history of the subject at http://www.strategycenter.net/research/pubID.113/pub_detail.asp.

Enter The "Jumbo"

The first reference to the new Chinese jet came in 2006 when the PRC Government announced its 2006-2010 five year plan. It refered to a "jumbo" jet, but initial drawings indicated something in the 767 class. In February 2007 the PRC State Council decalred that China needed a large jetliner, with an anticipated delivery date of 2020. This was later brought forward to 2016.

Launch

The C919 received official launch approval, albeit without orders, in May 2008. The same month, COMAC was formed, although initially it was referred to as CACC. COMAC is not part of AVIC, but it is made up of AVIC assets, including the Shanghai Aircraft Manufacturing Factory (SAMF).

COMAC began looking for foreign suppliers, including a foresign engine. In March 2009 the aircraft was designated C919. It's designation refers to "C" for China, "9" for its similiarity to a Chinese word meaning "forever" and "19" for 190 passengers.

Technical Features

In December 2009 CFM's Leap-X was chosen as the C919 engine. Ultimately, there will be a Chinese engine developed as well.

Most of the C919's critical systems will be developed and produced by joint ventures between Western and Chinese companies. One of the biggest will be a GE Aviation Systems/AVIC JV that's responsible for the aircraft's avionics core processing system, display system and onboard maintenance system. Another GE/Aircelle/AVIC Engine JV will provide the C919 with the world's first integrated propulsion system (IPS).

The long-range version of the C919 will have 3,000 nmi range. A standard range version will have 2,200 nmi range.

Current Plans

The first version of the C919 will be the -200, which will be just slightly larger than the A320. It will seat 156 passengers in two-class configuration, or 161 in all-economy or 180 in high density. A nose section was completed in December 2009.

First orders should be announced some time in the second half of 2010. The aircraft will fly in 2014 and enter service in 2016.

Initial output will be 5-10 planes per year in 2016 and 2017, with a production capacity of 120 planes per year. COMAC plans to manufacture 2,300 C919s.

Teal Group Evaluation

National Jet, Or At Least A National Stepping Stone

China offers a terrific market, superb engineering talent, and reasonably low costs. Developing a national aircraft industry makes a lot of sense, and it has been given high priority by the government. The only thing that could possibly go wrong is to approach plane design the way China's government does.

The problem with national jets is that airframes are no longer important. We know what a jetliner looks like, and the C919 looks like all the other 150-seat jetliners built over the past five decades. Almost all technological innovation in the business today happens at the propulsion, subsystem, and materials levels. The C919's makers are providing cost savings estimates without any discussion of technological enablers, or even weight figures. Why should they care when their only mandate is to build some kind of airframe?

Since innovation mostly happens at the subsystem level, everyone needs to realize an important jetliner lesson: vertical integration is a very bad idea. Jetmakers need to be free to select "best-in-class" content for their jet from a wide range of suppliers with no permanent links to the primes.

That is the primary reason why this industry is increasingly global. Embraer, the only new company in the world to successfully enter the aircraft business since World War Two, isn't just a Brazilian export powerhouse. It's also one of Brazil's biggest importers. They survey the world for the best suppliers, and build very little in-house.

Unfortunately, the Chinese Government has provided very little of that freedom to source globally. Wu Guanghui, the C919's chief designer, says that "COMAC will choose international suppliers through bidding, but priority will go to foreign suppliers that design and manufacture products with domestic companies." This means Western suppliers need to give away technology to play on this jet. It also means that this aircraft is designed by people whose hands have been tied. If you were to design a plane, you'd look to Honeywell, Rockwell Collins, or Thales for your avionics system. Using GE's former Smiths unit only makes sense if you felt they were giving you the best technology transfer. It makes less sense from a lowest risk for best value perspective.

Meanwhile, the Chinese Government also speaks about developing a domestic aviation systems industry. AVIC has announced the creation of a commercial aero engines unit, and other projects emphasize nacelles, composites, and other components. Creating this indigenous supplier base would be an understandable move. After all, what's the point of building a national jet if 70-80% of its value would go to foreign component and system suppliers? Yet how could a government-run airframer not favor products, even inferior ones, from government-run subsystem companies? The result would look like Brazil's strategy with Embraer... gone horribly wrong.

Worse, fear of enabling a china competitor could keep Western suppliers from bidding their latest and best technology on the new jet. Intellectual property (IP) rights have been a longstanding concern for Western manufacturers in China, but dealing with state-owned companies makes the problem even worse. Foreign companies won't have an easy time against the Chinese Government in an IP dispute. The fact that the C919 looks like an A320—now built by Airbus in Tianjin—is all the reason Western manufacturers need to maintain a cautious stance regarding technology transfer.

Right now, it's difficult to tell what kind of Western technology is going into this jet. Some of it certainly sounds impressive, but appearances can deceive. For example, that Leap-X1C is arriving way too early to be a real Leap-X. It might just be a heavily upgraded CFM56, doomed to obsolescence when the real Leap-X arrives on an Airbus or Boeing product.

If fearful Western suppliers bid last generation equipment, it will wind up like the ARJ21. Like the C919, the ARJ21 regional jet was touted as proof that China would be the next big jetmaker. Instead, it has turned into an overweight and stunningly obsolete product that has no relevance outside of China's tiny regional airline sector.

There is one positive: given the lavish resources available to Chinese industry on this project, and given the high level of attention provided by Western contractors, this could be a respectable aircraft. It might not be the latest and best (much depends on what Airbus and Boeing do to upgrade their current narrowbodies), but it won't be a total disaster like the ARJ21. It will probably be built in respectable numbers for local use. But either way, all that technology transfer will help create a domestic aviation industry that might get it right...next time.

However, there is the very serious risk that by the time the C919 enters service (we think three years late is a good estimate) Airbus and Boeing are offering products that make this jet look obsolete. In that case, the Chinese Government will need to decide whether it wants healthy airlines that are free to buy what's on the world market, or a healthy national jetliner champion, prospering because the luckless local carriers are forced to buy an inferior jet.

Production Forecast

User (Variant)	Through 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
COMAC												
All users* (C919)	—	—	—	—	—	—	2	3	—	—	4	9

**First six are test aircraft.*

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