Japan’s Aerospace Industry

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Japan has been exceptionally successful in the international marketplace in such industries as automobiles, consumer electronics, machine tools, and motorcycles. This success has not been matched in the worldwide commercial aerospace industry, where Japanese companies lag far behind leading firms in the U.S. and Europe. This paper examines the factors affecting Japan's commercial aerospace industry and the strategies Japanese firms are pursuing to effectively compete internationally.

In this essay, I examine the role of Japan in the global aerospace industry by using the theoretical framework set forth by Porter in his books *The Competitive Advantage of Nations* (1990) and *Competitive Strategy* (1980). Section 1 of the essay describes the global nature of the aerospace industry and analyzes the structure of the worldwide aerospace industry by investigating the competitive forces identified by Porter which determine competition in any industry. In Section 2, I examine Porter's four determinants of national advantage in relation to the Japanese aerospace industry. Section 3 describes the characteristics and structure of Japan's aerospace industry. Section 4 discusses Japan's key strategies to succeed in the global aerospace industry. In Section 5, I focus on the characteristics of three key international collaboration projects in which Japanese companies participate. The final section provides conclusions and some predictions.

The aerospace industry includes companies involved in the manufacture and servicing of planes, engines, helicopters, space equipment, and missiles. Demand comes from two sources: commercial companies and government defense-related activity. This paper will focus on the commercial aerospace industry, primarily airplanes and engines. However, the paper will discuss certain military expenditures by governments which have an effect on commercial aerospace capabilities.

Although the manufacture of rockets and other space equipment is part of the aerospace industry, there will be little discussion in this essay of this industry segment. Japan spends only about 1/8 of what the U.S. spends (Nakamoto 1996), and almost all demand comes from the government rather than the commercial market.

All amounts shown in this paper in Japanese yen (¥) have been converted to U.S. dollars ($) at a rate of ¥120/$1 for comparison purposes.

1. Structural Analysis of Global Aerospace Industry

No other industry is more international than commercial aerospace. Yip identifies industry globalization drivers in four areas: market, competitive, cost, and government (1992, 31-65). The aerospace industry ranks first out of twelve industries (including automobiles, computers, and pharmaceuticals) in market and competitive globalization drivers and second for cost globalization drivers.

The commercial aerospace industry ranks highest for market globalization drivers because customers (mainly airlines) in different countries have nearly the same needs for the product and customers search the entire world for suppliers. Competitive globalization drivers are highest for commercial aerospace due to the industry's very high exports and imports and the large number of globalized competitors from different continents and countries. Cost globalization drivers in aerospace outrank almost all other industries because of global economies of scale where no single national market is large enough for competitors to effectively do business. The enormous cost of product development in the aerospace industry drives companies to amortize those costs across markets around the globe. The use of a single currency, the U.S. dollar, for virtually all commercial aerospace contracts also shows the extremely high level of internationalization in the industry.

The global commercial aerospace industry currently has very few prime contractors that manufacture aircraft and engines. The American firm Boeing has about

70% of the worldwide market for planes seating more than 80 persons. Airbus, a consortium of English, French, German, and Spanish firms, has been gaining rapidly and currently holds the remaining 30% of the large aircraft market. Airplane engines, which account for about 20% of the value of advanced aircraft, are manufactured by only three companies. U.S.-based Pratt & Whitney and General Electric run neck and neck for the market lead, and Rolls-Royce in England runs a strong third. There are more prime contractors involved in the smaller-size market for commuter and executive aircraft and engines, but the number of competitors is still quite small. In addition to the prime contractors, the global aerospace industry has numerous medium- and small-sized suppliers of components and subsystems.

Porter describes five forces—threat of new entrants, threat of substitute products, bargaining power of buyers, rivalry among existing competitors, and bargaining power of suppliers—that determine the nature of competition in an industry (1980 3-33; 1990, 34-37). These competitive forces determine industry profitability because they influence the prices firms can charge, the costs they must bear, and investment required to compete in the industry (Porter 1990, 35). The following sections analyze each competitive factor separately in relation to the global aerospace industry.

Threat of New Entrants

The threat of entry to the commercial aerospace industry at the aircraft or engine manufacturer level is quite low. New airplanes and engines require extremely high investments accompanied with great risk and the inability to get a positive return on that investment for many years. A new 100-seat airplane would cost $3-4 billion to develop; whereas a new 800-seat airplane Boeing and Airbus have recently considered would require an investment of $10 billion or more. General Electric spent $3 billion to develop the GE90 engine for the Boeing 777 plane (Garvin, Samuels, and Masterson 1994). The aerospace industry’s economies of scale, where global sales are required to recover the huge investments, deter entry to the industry by forcing the entrant to come in at a very large scale in order to succeed.

The threat of entry at the aircraft or engine manufacturer level is further reduced by several other factors. Aerospace manufacturing has a long learning or experience curve due to its complex assembly and testing operations and its high content of labor performing intricate tasks. Companies can only go down this learning curve after many years of large amounts of continuous investment in research and development. Companies may require government subsidies, either directly through grants-in-aid or indirectly through military contracts, to enter the industry. It is estimated that Airbus received over $10 billion from European governments between 1970 and 1990 so it could get to the level today where the company can survive on its own (Yip 1992, 229). Now the worldwide aerospace industry has well-established firms with an abundance of resources to retaliate against any potential entrants.

The barriers to entry are less for potential manufacturers of components or subsystems, but they are still quite high in comparison to many industries. During the past decade the aircraft and engine manufacturers have been drastically reducing the number of suppliers, which makes it even more difficult to enter the industry even as a manufacturer of components or subsystems.

Threat of Substitute Products

Prime contractors (e.g., airframe manufacturers such as Boeing and engine manufacturers such as Pratt & Whitney) in the commercial aerospace industry face almost no threats of substitute products because of an airplane's uniqueness in speed and ability to travel over water. For short distances over land, airplanes may sometimes compete against automobiles and trains.

The threat of substitute products exists at the part/component level in the aerospace industry. For example, new material technology can make obsolete the materials previously in common use in the construction of airplanes and engines.

Bargaining Power of Buyers

Airline companies often force cutthroat competition between the aircraft manufacturers, Boeing and Airbus, and the engine manufacturers, Pratt & Whitney, General Electric, and Rolls-Royce. Airlines ordering a large number of planes or even entire countries such as China, who combines orders from state-run airlines, can press for extraordinary concessions from the prime contractors. These orders are a relatively large percentage of the aerospace prime contractors' total sales, so buyers are in an advantageous position to demand price reductions. The switching costs for aircraft and engines are very low, which increases the buyers' power. Airline pilots and mechanics can quickly be trained on other planes and engines. The huge losses of most airlines in the early 1990s made them more desperate to reduce costs, which had a direct impact on the airplane and engine prices demanded by the airlines.

Rivalry Among Existing Competitors

Although the aerospace industry has only a limited number of prime contractors, competition is fierce for the reasons discussed in the above section on '*Bargaining Power of Buyers*'. Aerospace firms desperately seek to win large orders from airlines to try to recover their high fixed costs and their large investments required to develop new aircraft and engines. The industry's prime contractors are equally balanced and have very little differentiation in their product lines, which increases even more the intensity of the competition.

Bargaining Power of Suppliers

The bargaining power of aerospace suppliers is not that strong, but there are exceptions where a supplier may possess key technologies. In general, the prime contractors in the aerospace industry have several suppliers from which to choose.

2. Determinants of National Competitive Advantage - Japanese Aerospace Industry

Porter identifies four determinants of national competitive advantage: factor conditions; demand conditions; related and supporting industries; and firm strategy, structure, and rivalry (1990, 69-130). This essay section discusses these determinants of national advantage in relation to the Japanese aerospace industry.

Nations are most likely to succeed in those industries where the determinants as a system are favorable. Within an industry, a nation's circumstances favor competing in particular segments and with certain competitive strategies. A company's home nation shapes where and how it is likely to succeed in global competition (Porter 1990, 72, 598, 599). After discussing the structure of the Japanese aerospace industry in Section 3 of this essay, Japan's strategies to succeed in the global aerospace industry are analyzed in Sections 4 and 5.

Factor Conditions

Although aerospace companies compete on a global basis, they almost always carry out production in their home countries and export their products, which makes domestic factor conditions very significant. Factor conditions relate to the factors of production such as human resources, capital resources, physical resources, knowledge resources, and infrastructure.

Japan's highly educated population and its very high number of engineering graduates per capita provide Japan a strong advantage. However, competitiveness in the aerospace industry requires significant R&D investments over many years to obtain the required advanced and specialized factors in knowledge and human resources. Japan has one of the highest levels of R&D spending of any nation, but almost all of the spending is directed to non-defense areas. A high level of military R&D spending in aerospace can lead to many direct and indirect benefits for commercial aerospace projects. For example, the Boeing 747 aircraft, the world's most popular long-range plane, was originally a military aircraft design that lost in a U.S. Government competition for a large military transport plane (Porter 1990, 96). Over many years, Japan has developed its advanced and specialized factors in commercial aerospace through licensed production of U.S. military aircraft and components and through its strengths in manufacturing process technologies.

Demand Conditions

Porter's discussion of demand conditions focuses on home country demand conditions for the industry product (Porter 1990, 86-100), and he argues that effectively competing in home country markets builds international competitiveness for firms in the industry. Not only is the nature of domestic demand important, the size of the market is critical to national competitive advantage for industries, such as aerospace, that have significant economies of scale and learning curves.

Unlike the huge, extremely competitive Japanese home market for autos, steel, and computers, Japan does not have a large enough domestic market to support an all-Japanese commercial aircraft. Although Japanese airlines have built one of the world's largest fleets of long-range passenger jets and have many planes supporting a well-developed domestic commercial air system, the Japanese market is still much too small to recover the significant investments required for the development of new airplanes and engines. Although domestic defense-related demand has provided much impetus to Japanese aerospace over the last four decades, Japanese firms have been greatly restricted since 1967 by the government's ban on military product exports.

In contrast to Japan, the U.S. dominates aerospace because of very favorable home country demand conditions since the end of World War II. While Japan had a ban on aircraft production from 1945 to 1952, U.S. firms moved early to meet the huge military and commercial aerospace demand. The large demand encouraged U.S. firms to make investments in technology development, large-scale manufacturing facilities, and productivity improvements. The American aerospace industry made significant R&D investments over many years to meet the stringent demands for overseas flights of American international airlines and to meet the demanding performance specifications of the U.S. military.

The relatively small domestic market forces Japanese aerospace companies to seek export activities. Since Japan does not produce any indigenous commercial aircraft or engines, the aerospace firms must participate in the worldwide industry as a supplier of components and subsystems.

Related and Supporting Industries

This determinant of national advantage relates to the presence in a country of supplier industries or related industries that are internationally competitive. A few large Japanese firms make up most direct sales to foreign prime contractors, but these firms have well-developed networks of internationally competitive small- and medium-sized subcontractors and suppliers. The Japanese are extremely strong in certain related industries that have many aerospace applications, such as electronics, advanced materials, and machine tools. This strong base of suppliers and related industries allow Japanese aerospace firms to gain ready access to technological innovations. One area where Japanese firms have little competitive strength is the overhaul and repair of aircraft and engines.

Japan’s aerospace trade association, the Society of Japanese Aerospace Companies (SJAC), plays an active role in promoting links between firms involved in aerospace, including defense and space as well as commercial. SJAC sponsors, with assistance from government funds, numerous collaborative projects to promote R&D in propulsion, airframe manufacturing, controls systems, and other basic aerospace technologies (Samuels 1994, 285, 316-318).

Firm Strategy, Structure, and Rivalry

This fourth determinant of national competitive advantage relates to how firms are created, organized, and managed as well as the nature of domestic rivalry. Porter believes that perhaps the single greatest determinant of Japanese international success in certain industries is the presence of a number of fierce domestic rivals. This intense domestic competition creates pressure to improve and innovate in ways that will create and sustain competitive advantage, both at home and in international markets. (1990, 411-415).

An intense level of domestic competition is notably lacking in the Japanese aerospace industry. Even though Japanese aerospace companies compete against each other for government contracts and support and for commercial contracts, the overall level of competition between Japanese aerospace firms is not high. The Japanese government encourages collaborative research projects and joint participation of Japanese companies in international collaboration agreements. The government nurtures the aerospace industry to develop its international competitiveness, to ensure its ability to autonomously meet the nation’s defense needs, and to promote technological benefits for related industries. Although Porter’s theory of intense domestic competition may not be applicable to the Japanese aerospace industry, the fierceness of competition in the worldwide aerospace industry serves the same purpose to create pressure on Japanese companies to improve and innovate.

Role of Government

Porter considers government's role in national competitive advantage is in influencing the four determinants previously discussed, rather than government being the fifth determinant of national competitive advantage. The important role of government in Japanese aerospace is discussed throughout this essay, including the previous sections on the four determinants of national competitive advantage.

The Japanese government plays two key roles in the aerospace industry: the primary buyer of aircraft and the source of financial subsidies. Japan's Defense Agency provides most of the current aerospace demand, even though defense budgets have been shrinking in recent years. This defense demand for aircraft and engines assists in the development of skills and experience that can be applied to commercial projects. The government also provides significant financial support to the aerospace industry. Much of the support is funneled through the International Aircraft Development Fund (IADF), made up of Japan's four largest aerospace firms with the Ministry of International Trade and Industry (MITI) as a silent partner (Samuels 1994, 253). The IADF primarily distributes support to organizations involved in international collaboration projects, such as the Japan Aircraft Development Corporation (JADC) for the Boeing 777 project and the Japanese Aero Engines Corporation (JAEC) for the V2500 engine project.

Porter mentions that efforts by the Japanese government to develop the aerospace industry have largely failed to produce true international competitors, because Japan brought no other advantages to the industry (1990, 414). While it is true that Japan has had few advantages in the aerospace industry in comparison to the U.S. and some European countries, I disagree with Porter's characterization that the government efforts have 'largely failed'. After analyzing the structure of the Japanese aerospace industry in the next section, the remainder of the paper will discuss Japan's strategies for successfully competing in the worldwide aerospace industry.

3. Structure of Japanese Aerospace Industry

The Japanese aerospace industry is currently quite small in comparison to other Japanese industries and in comparison to the aerospace industries in other countries. Based on 1995 figures, Japan's aerospace industry exports are only a fraction of those of other industries: general machinery (1/100), automobiles (1/50), steel (1/17), and shipbuilding (1/10) (Nihon Kôkû Uchû Kôgyôkai 1997, 63). However, in 1996 Japanese aerospace exports increased almost 90% to ¥180 billion ($1.5 billion) (Nikkan Kôgyô Shimbun 1997), primarily due to participation of Japanese companies in international collaboration projects and to favorable economic conditions throughout the worldwide aerospace industry. Japan's aerospace industry sales (including both commercial and military sales but not space-equipment and related sales) in 1996 of ¥890 billion ($7.4 billion) were about 1/18 of the U.S.'s aerospace sales and less than 1/2 of the aerospace sales in England, France, and Germany (Nihon Kôkû Uchû Kôgyôkai 1996, 5).

Japan's aerospace industry depends on military demand for 75% of its sales in comparison to the U.S., France, Germany, England, and Italy, where military demand accounts for only 45% to 57% of total industry sales (Nihon Kôkû Uchû Kôgyôkai 1997, 284). However, in 1996 the industry's orders from Japan's Defense Agency went down for the third straight year (Nikkan Kôgyô Shimbun 1997). The Senior Managing Director of the Japan Aircraft Development Corporation (JADC) stated that Japan's goal is to change the military/commercial ratio of aerospace sales to about 50-50 (Holley 1994).

The Japanese aerospace industry is dominated by four companies who account for 69% of the industry's total 1996 sales (including space-equipment and related sales) of ¥1,120 billion ($9.3 billion). The table below shows statistics for these four companies (Nihon Kôkû Uchû Kôgyôkai 1996, 3, 200, 216, 295, 313):

Company	1996 Aerospace Sales ¥ (billions)	$ (billions)	% of Total Industry Sales
Mitsubishi Heavy Industries (MHI)	¥394	$3.3	35%
Kawasaki Heavy Industries (KHI)	¥195	$1.6	17%
Ishikawajima-Harima Heavy Industries (IHI)	¥136	$1.1	12%
Fuji Heavy Industries (FHI)	¥55	$0.5	5%

The top firms in the Japanese aerospace industry listed above are virtually the same enterprises that dominated the industry before World War II (Samuels 1994, 259), which provides evidence of the high barriers to entry into the industry. These four companies depend on aerospace for only about 15% of their total revenues (Nakamoto 1997). They all provide a wide range of aerospace products, but they have certain specialties.

IHI concentrates on engine production, but MHI and KHI are also involved in the production of engine components. IHI accounts for approximately 70% of Japan's total annual engine and engine components production (Ishikawajima-Harima 1995). Since 1959 IHI has won every prime engine contract from the Japanese military (Samuels 1994, 208), and IHI is the lead company for international engine collaboration projects.

MHI, KHI, and FHI concentrate on the manufacture of airframes and related components. KHI and MHI also have significant involvement in helicopter development and production. MHI has a leading role in the development and production of H-II and H-IIA rockets. In late 1996, an agreement was signed to use these domestically-produced rockets to launch ten U.S. commercial satellites over a five-year period from the year 2000 (Masuko 1997, 92). This was the first time a Japanese-produced rocket will be used to launch a foreign commercial satellite.

4. Japan's Strategy

The basis of Japan's current strategy in the world aerospace market can be traced back to 1986, when the Aircraft Industry Promotion Law was revised. Article One was changed from 'promotion of domestic development of aircraft and aeroengines and the subsequent reduction of the trade deficit' to 'promotion of joint international development of aircraft and aeroengines and the subsequent facilitation of international business exchange' (Samuels 1994, 253). Many leaders in government and industry still have the goal of indigenous production of aircraft and engines, but it would be pursued through long-term international collaboration.

Samuels sets forth three values that are the basis of Japan's technology and security ideology: autonomy (*kokusanka*), diffusion (*hakyû*), and nurturance (*ikusei*) (Garvin, Samuels, and Masterson 1994; Samuels 1994, 42-54). These three values form the foundation of Japan's strategic initiatives in commercial and military aerospace.

Autonomy or indigenization (*kokusanka*) refers to the ability of Japan to design and produce its own aircraft without dependence on foreign countries. Diffusion (*hakyû*) involves the adaptation, assimilation, and diffusion of technologies, often acquired from foreign countries, throughout the economy. The aerospace industry's demanding technologies can lead to technological advancement in other industries such as electronics, machinery, materials, shipbuilding, and automobiles (Nihon Kôkû Uchû Kôgyôkai 1997, 12-13). Nurturance (*ikusei*) describes the efforts by the Japanese government to simultaneously manage industry competition and to nurture technological advancement.

Japan's specific strategies in the aerospace industry are discussed in more detail in the following sections:

International Collaboration

During the past two decades Japanese firms have entered into several international collaborations that link them with foreign firms in the design, development, and production of advanced commercial aircraft and engines. Collaboration arrangements provide firms with strategic organizational flexibility to more readily access research technology, and international markets (Anderson 1995, 3). Prime aircraft and engine contractors enter into collaboration arrangements for several reasons, including the following: share financial and technical risk of costly, complex projects; obtain market access to certain foreign countries; secure critical engineering and manufacturing technologies and resources; and have dedicated suppliers who produce at high quality and low cost. Prime contractors enter into these collaboration agreements even though it leads to reduced short-term profits, less manufacturing volume, and shared technology with potential future competitors. Since indigenous aircraft and engine production is not currently economically feasible, Japanese aerospace firms have eagerly sought collaboration arrangements with foreign firms for the following reasons: learn design and large-scale systems integration skills; acquire where possible the latest and most advanced technologies; and obtain experience in marketing and product support. Section 5 of this essay provides details on specific international collaboration projects.

Licensed Production

Japan has used licensed production of U.S. components and systems for many years to obtain technology for defense and commercial aerospace projects. Licensed production of U.S. military aircraft sustained the growth of the Japanese aerospace industry from the 1960s to the 1980s. Japanese firms gained especially valuable experience and technologies during the licensed production of the technically-advanced F-15 fighter aircraft from the late 1970s to the early 1990s. In several areas of defense systems, most notably aircraft, Japan has pursued a strategy of moving from purchased U.S. systems to licensed production to indigenous development. Japanese industry has also diffused technology acquired through military aircraft programs to commercial applications. For example, IHI first produced long shafts for F100 fighter engine licensed production and now dominates the worldwide commercial market for this component (National Research Council 1995, 4-5).

Specialization

Japanese aerospace firms have followed the strategy of focusing on strong niche technology areas to compete effectively in the global market. They are very strong competitors today in composites, other advanced materials, fuselage panels, flat panel displays, and sophisticated electronic components.

IHI exemplifies the Japanese strategy of specialization. IHI excels in long shafts, large disks, and lightweight composite materials that account for a growing share of many advanced aircraft engines. For example, the company pioneered the development of a carbon-fiber blade with special grooves designed to circulate air in a way that keeps engines from overheating. IHI participates in multiple collaboration arrangements with all three prime engine contractors to build a range of jet engines based on different technologies and designed for different markets. IHI's strategy ensures that it gets a portion of most large engine sales, even though the three prime contractors continually compete very intensely. IHI currently has about 5% of the world market for engines and related components, even though it does not produce any complete engines for the commercial market (Glain 1997; Garvin, Samuels, and Masterson 1994; Samuels 1994, 257-258).

Indigenous Aircraft and Engine Production

The stated objective of the Japanese aerospace industry is to achieve total functional capability in basic technology research, development, production, sales, and after-sales service support covering all areas including airframe, engine, parts, and materials (Nihon Kôkû Uchû Kôgyôkai 1997, 79). In other words, Japan wants to establish complete indigenous capabilities that will allow the country to compete at the top level of aerospace manufacturing.

This objective of complete indigenous capabilities does not mean that most industry and government leaders favor the development and production of their own aircraft with no assistance from foreign countries. Japan would need to overcome numerous daunting challenges: huge development costs; little experience in design, systems integration, marketing, and after-sales support; strong, entrenched competitors; and the need to develop a family of planes and engines (3 to 7) to effectively compete. Moreover, Japanese engine manufacturers currently do not have the capability to effectively produce a large commercial jet engine due to lack of design capability and experience, especially in certain leading-edge technologies (U.S. Department of Commerce 1993, 2, 7). Japan's only postwar indigenous commercial aircraft was the 60-seat propeller-driven YS-11, produced from the late 1950s to the early 1970s. Even though the aircraft was technically sound, it was a commercial failure, with less than 200 eventually being sold. The move of the industry to jet engines and the Japanese lack of marketing capability caused this market failure (Nakamoto 1997). Even though the YS-11 was a domestic design, it still relied on imported or coproduced engines, avionics, and other major subsystems (Samuels 1994, 236).

Although in the 1990s industry and government leaders had discussions about and the government provided financial support to investigate a Japanese-built YXX 150-seat plane and a YSX 50- to 100-seat plane, both of these potential projects now appear to be dead. Since the 1980s, Japan's primary strategy in the aerospace industry has continued to be participation in international collaborations.

5. Key International Collaboration Projects

All of the major Japanese aerospace companies (i.e., MHI, KHI, IHI, and FHI) have entered into multiple international collaboration agreements during the last two decades. This section analyzes the three most important international collaboration projects: Boeing 767 and 777, F-2 fighter plane, and V2500 engine.

Not only is the Japanese Defense Agency totally funding the development and production of the F-2 fighter plane, the Japanese government also provides significant support for commercial aerospace projects. In 1996, the government provided ¥2.9

billion ($24 million) for the Boeing 777 project and ¥1.6 billion ($13 million) for the V2500 engine project (Nihon Kôkû Uchû Kôgyôkai 1996, 400). In addition, the government provides financial support for advanced research projects in aerospace. For example, the government provided ¥3.8 billion ($32 million) in 1996 for Japanese participation in the eight-company international collaboration doing research into the materials and systems for a supersonic transport (SST) aircraft of the future and the five-company international collaboration researching the SST engines (Nihon Kôkû Uchû Kôgyôkai 1996, 400).

Boeing 767 and 777

Japan's largest and most important commercial aerospace international collaboration is with Boeing on the 767 and 777 aircraft. Japanese companies have about 15% of the 767 program, which started in the late 1970s. Boeing's agreement on the 767 is with Japan Aerospace Development Corporation (JADC), who divides up the work between MHI, KHI, and FHI. The Japanese have responsibility to produce the fuselage sections for the widebody twin-engine 767 aircraft.

The Japanese, through JADC, have a 21% share in the much larger twin-engine Boeing 777 aircraft, which had its first commercial flight in 1995. This collaboration program has brought significant benefits and experiences to the Japanese aerospace industry. The Japanese companies have worked very closely with Boeing in the design of the plane, including access to Boeing's design/build concurrent engineering software and to Boeing's system of process and material control (Samuels 1994, 255). FHI produces a very critical section, the wing center portion of the fuselage that must endure heavy stress. KHI and FHI have built new factories in Nagoya to support the 777 program, and MHI completely renovated an existing factory in Hiroshima (Garvin, Samuels, and Masterson 1994). The Japanese are also involved in marketing and product support for the Boeing 777 plane. Besides the 767 and 777 program workshares for JADC, many other Japanese companies besides MHI, KHI, and FHI are involved with both of the programs through direct contracts with Boeing. These contracts cover systems such as hydraulics, actuators, and gears (Samuels 1994, 248).

Boeing still protects its advanced technologies. Masterson, a Boeing Director, says that the body sections produced by the Japanese are ‘fairly simple structural components’, and Boeing still retains full responsibility for high technology areas such as the wings, tail fins made from composites, and cab systems (Garvin, Samuels, and Masterson 1994).

F-2 Fighter Plane

The F-2 fighter aircraft program, funded by Japan, is the first U.S.-Japan joint development and production of a weapon system, which makes it quite different than previous licensed production agreements. Development on the F-2 program began in 1989, and the U.S. and Japan signed an agreement in 1996 to produce 130 aircraft over the next 15 years at a cost of about $80 million apiece. The F-2 is a significantly modified derivative of the U.S. Air Force’s F-16 fighter aircraft.

Japan had many discussions in the 1980s about the development of an indigenous fighter aircraft, but Japan felt forced to develop and produce it jointly with the U.S. for three reasons: need for U.S.-produced fighter engine; lack of system integration skills and experience; and political pressure to support U.S. in this joint program (Green 1994). Japan receives about 60% of the F-2 development and production work, with MHI serving as the prime contractor. Other Japanese subcontractors include FHI, KHI, and IHI, and the principal U.S. subcontractors are Lockheed Martin, a large defense firm that produces the F-15, and General Electric.

The U.S. General Accounting Office concludes the F-2 program has strengthened Japan’s aerospace industry by providing Japanese engineers with valuable design and system integration experiences that are applicable to other military and commercial aircraft projects. The F-2 program prompted Japanese firms to purchase new equipment and construct new facilities, partly with Japanese government subsidies, that can be used for future projects. By making extensive changes to the original F-16 design, Japan has maximized its use of indigenous design concepts and technologies, and it has ensured a key role for several Japanese aerospace companies. The U.S. General Accounting Office believes Japan's participation in the F-2 program increases the likelihood of future autonomous Japanese aircraft development projects. (U.S. General Accounting Office, 1995, 1, 4, 7, 42)

General Electric and IHI entered into a licensed production arrangement that will allow IHI to produce about 60% of the engine for the F-2 fighter. However, IHI will not gain any significant new capabilities since critical engine technologies are not being licensed by General Electric in accordance with U.S. restrictions on transfers of leading-edge technologies (U.S. General Accounting Office 1997, 10, 16).

V2500 Engine

The V2500 engine project was the first and largest international collaboration in which Japanese companies have participated to develop and produce commercial jet engines. In 1983, International Aero Engines (IAE) was formed to design and manufacture a new high-performance, low-noise engine for mid-size planes seating 120 to 180 persons such as the Airbus 319, 320, and 321 and the Boeing MD-90 (McDonnell Douglas until late 1996). IAE has shareholders from five countries—Pratt & Whitney (30%), Rolls-Royce (30%), Japan Aero Engine Corporation (JAEC) (23%), MTU in Germany (11%), and Fiat in Italy (6%). JAEC is a collaboration led by IHI, with lesser participation by KHI and MHI.

The Japanese companies involved in IAE have benefited greatly from their significant work share to design and produce the fan, low-pressure compressor, and other parts in the engine. Japanese personnel have been involved in V2500 sales, marketing, and after-sales support, areas in which Japanese engine manufacturers have had very little experience until this project. The Japanese aerospace supplier infrastructure, including many material fabrication, bearings, and electronic controls manufacturers, also benefited widely from the V2500 project (Samuels 1994, 252). But there have been some limitations for IHI, KHI, and MHI. The Japanese have found out first hand how long it takes to recover the significant investments required to develop and produce a new engine. It took nearly 15 years before the V2500 project started to generate positive annual cash flow (Nihon Keizai Shimbun 1996), and it will take many more years before cumulative cash flow turns positive. Two factors have somewhat limited Japanese learning on this project. First, the Japanese companies in IAE have responsibility for the sections of the engine that run at lower temperatures and lower pressures, which are relatively not as technologically difficult to develop and manufacture as those sections assigned to the other companies that make up IAE. Second, the assembly and testing of the engines are performed at Pratt & Whitney and Rolls-Royce facilities with their own personnel.

6. Conclusions and Predictions

Several key conclusion can be reached from this essay's analysis of the Japanese aerospace industry:

- Japan effectively competes today in the international aerospace industry in the manufacture of aircraft and engine components through its strategy of participating in international collaboration projects and focusing on strong niche technology areas.
- Based on Japan's learning on the F-2 fighter program and their international collaborations, the country will soon possess the capability to develop and produce an indigenous aircraft, but it still lacks critical technologies to effectively produce a large aircraft engine without foreign assistance. Even though Japan may have the

ability to produce an indigenous aircraft, it would be a strategic error to pursue this project alone due to its huge cost and commercial risk.

- Japanese aerospace companies still have weaknesses in certain areas such as systems integration, assembly, design, and marketing, but they are actively seeking to gain experience and improve their skills in these areas by participating in key international collaboration projects.

Based on the worldwide and Japanese aerospace industry trends analyzed in this paper, I offer some predictions of the future:

- Japanese companies will continue to join in international collaboration projects and will demand more significant participation in future projects—both larger percentage workshares and more critical and high technology sections of planes and engines. Japan will achieve this by exploiting the intense rivalry of the international prime contractors. Building on their Boeing collaboration projects, the Japanese will gradually increase their participation in Airbus projects.
- Within twenty years, and maybe much sooner, the Japanese will join with a current prime aircraft or engine contractor in a 50/50 joint venture to develop and produce a new aircraft or engine. This joint venture might be similar to the successful CFM engine joint venture between General Electric and the French company Snecma.
- Japan will never launch a totally indigenous commercial aircraft or engine program, but in the future Japanese aerospace companies will participate as equal rather than junior partners in international collaboration projects.

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