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7 How to Succeed without Really Flying: The Japanese Aircraft Industry and Japan's Technology Ideology

David B. Friedman and Richard J. Samuels

7.1 Introduction

Since the end of World War II, the United States has spent billions of dollars more on military research and development (R&D) than Japan has.[1] Even today, despite an American recession and sustained increases in Japan's military expenditures, Japanese annual defense R&D spending—less than 100 billion yen—is dwarfed by U.S. spending of more than 5 trillion yen. In Japan, official defense R&D is just 5 percent of all government R&D, while in the United States, government expenditures account for more than 60 percent.[2] But despite the enormous postwar American efforts to foster defense technologies, a massive disparity in nominal spending, and the fact that Japan does not design or build military equipment for export, Japanese commercial manufacturers now exhibit dual-use production capabilities that match or exceed American capabilities in many areas.[3]

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1. Differences in yen/dollar rates, nominal versus adjusted expenditures, and accounting conventions make precise comparisons difficult, but American defense technology investments have, by any measure, been about two orders of magnitude beyond the Japanese effort. For Japan, see Bōeichō . . . Kikakubu (1991, 35). For the United States, see Alexander, (1989).

2. Bōeichō . . . Kikakubu (1991, 35).

3. Studies of the dependence of U.S. producers on Japanese and other foreign producers include Analytic Science Corporation (1990); Office of Technology Assessment (1989, 1990); Defense Science Board (1987); Defense Technical Information Center (1990); and Institute for Defense Analysis (1990).

This has been possible, we argue, in part because Japanese views about technology and national security sharply diverge from comparable American beliefs. It is this divergence between U.S. and Japanese defense technology strategies deriving from fundamentally different ideas about the economy and national security that concerns us here. Cold War U.S. technology strategy focused on making huge public outlays to specialized defense laboratories and contracting firms, justified by the military calculations of national security. While American defense planners recognized that technologies developed for the military might diffuse into the commercial economy, and many spin-offs—such as jet engines or new materials—did occur, no special effort was made to marry commercial and defense industrial capabilities. Indeed, American defense prime contractors developed design, manufacturing, and business practices, or responded to secrecy and classification requirements in ways that impeded effective exchanges of commercial and defense technology. While many U.S. subcontractors mixed military and commercial technologies more freely than the primes, they lacked the stability and resources necessary to expand into new civilian markets.[4] Over time, "spin-away" rather than "spin-off" may more accurately describe the relationship between U.S. military and civilian manufacturing.

In contrast, Japan's firms have made little distinction between military and civilian technology. They have focused instead on three principles: (1) obtaining and indigenizing foreign civilian and military design, development, and manufacturing capabilities; (2) diffusing these capabilities as widely as possible throughout the economy; and (3) nurturing and sustaining the primes and subcontractors to which commercial and military technologies could be diffused and from which indigenous development could be generated. Differences between military and civilian technologies were less important than differences between domestic capabilities and foreign dependence; making things that "go bang in the night" was not as crucial as nurturing the more fundamental ability to design and make "things," period. Whether these things—machinery, electronics, aircraft, vehicles, and so forth—were for military or commercial end use, the know-how enabling their production was diffused aggressively throughout the Japanese economy as a matter of national policy and private practice. Defense technology has been valued for its ability to elevate the fundamental capacities of the economy as well as a means for actually producing military hardware.

Crucial to implementing Japan's technology and security ideology are formal and informal linkages and bargains—which we call a system of *protocols*—that integrate Japan's industrial technology community. Technology protocols, such as informal industry cooperation practices, regional and national

4. One study of the 350 largest companies and corporate divisions participating in the U.S. defense industry shows that the top U.S. defense contractors rely on military production for well over 80 percent of their output (Alexander 1993, 45).

subcontractor associations, R&D consortia, semipublic industry research groups, or vertical and horizontal industrial "cooperation" associations, overlap and bind Japanese producers in ways that create and preserve opportunities for firms to build alliances within the economy. These alliances—metaphorically, sets of "open door" opportunities, or technology highways—stimulate competition while at the same time providing competitors with access to crucial manufacturing know-how. They enable Japanese firms to build and combine their skills with comparative ease to produce even the most complex products, including military equipment. Japanese defense production is simply one of many technology linkages that firms maintain within the domestic economy. Japan's defense prime contractors are far less specialized than their American counterparts, and subcontractors more readily combine defense and commercial production in a wider range of industrial undertakings. As a consequence, defense and commercial technologies interdiffuse—they spin-on and spin-off to each other with comparative ease in Japan.

In this paper, we illustrate the industrial consequences of Japan's technology and security ideology with the case of the aircraft industry. Aerospace provides an ideal case because, as in the United States, it has received the lion's share of military R&D expenditures, and aircraft production has been heavily geared towards defense; four-fifths of Japan's output and two-thirds of American aircraft production has been for the military.[5] Commercial aircraft development in Japan has been a major goal of industrialists and policymakers alike, and has been cherished within the United States as one of the industries in which America dominates global competition.

But the Japanese and American aircraft industrial strategies and structures have diverged. U.S. prime contractors and subcontractors heavily specialize in aircraft production. At the prime level, this specialization has proceeded to the point where there is a sharp, practically impenetrable barrier between civilian and military aircraft operations even within the same firm. American aircraft industry subcontractors more readily combine their commercial and defense capabilities, but generally do not diversify into nonaerospace fields. Japanese aircraft primes and subcontractors, however, are overwhelmingly dedicated to nonaerospace commercial production. The industry is, in effect, embedded in the civilian economy as a whole. Japan's aerospace capabilities result from the combination of skills possessed by companies whose primary business and technology strategies are oriented toward other industries. The disjuncture between commercial and military, aircraft and nonaircraft production characteristic of primes and subcontractors in America never emerged. Instead, even aerospace producers in Japan at the prime level, and especially the country's subcontractors, have been able to spin-on to military applications many of the fruits of their commercial investments, and spin-off defense skills for civilian purposes. In this fashion, Japan has built a thriving, if still small, aerospace

5. Aerospace Industries Association of America (1990, 22).

sector, and it has used aircraft industry technologies to enhance commercial and military capabilities throughout the economy. In short, judged by the criteria of Japan's technology and security ideology, the aircraft industry has succeeded without really flying.

Section 7.2 outlines the three basic tenets of that ideology: indigenization, diffusion, and nurturing. It shows that Japan has embraced and promulgated a vision of national security that elevates local control, national learning, and sustained development over the more conventional procurement criteria of cost, performance, and delivery schedules that dominate in America. Section 7.3 suggests that the Japanese aircraft industry arguably has flourished when measured in conventional terms of sales, output, profits, and growth, despite common perceptions to the contrary. Section 7.4 contends that, even if the caliber of Japan's aerospace capabilities is debatable in conventional terms, the industry is a success under the criteria that inform Japanese industrial thinking. Finally, in section 7.5 we conclude that, since differences in technology ideologies can lead to divergent standards for industrial achievement, different industrial development trajectories, and political and economic conflict, America, Japan, and the Asian region as a whole face significant conceptual and policy challenges in the near future.

7.2 The Origins and Contours of Japan's Technology and Security Ideology

From the moment Tokugawa Ieyasu united nation and state at the turn of the seventeenth century, the Japanese people have been exhorted to make sacrifices to enhance national security in a hostile world. At different times and in different measures, this mobilization has mixed xenophobia, religion, militarism, and nationalism. Japan's early industrialization was led by military industries to enhance national security by "catching up and surpassing the West"(*oitsuke, oikose*). Later, the Meiji era mobilization symbolized by the slogan, "Rich nation, strong army," proved calamitous. In the postwar era, sheltered by the U.S. security umbrella, Japanese citizens have been exhorted to sacrifice for more purely commercial purposes.

Technology has been central to national security in three consistent ways: (1) to achieve *independence and autonomy* through indigenization of technology (*kokusanka*); (2) to *diffuse* this learning throughout the economy (*hakyuu*); and (3) to *nurture and sustain* appropriate Japanese enterprises to which technical knowledge can be diffused and further refined (*ikusei*).

Indigenization, diffusion, and nurturing derive from a pervasive sense that Japan must compensate for its special vulnerabilities in a Hobbesian world. This feeling of insecurity and vulnerability (*fuan*) has been articulated repeatedly throughout Japanese history. In the eighteenth century, a Sendai nobleman, Hayashi Shihei, warned the shogunate (roughly at the same time Alexander Hamilton similarly admonished the fledgling U.S. government) to protect

Japanese manufactures or face foreign domination. A century later, bridling at having to purchase antiquated weapons from the west, Meiji leaders drove Japan to adopt "Western learning with Japanese spirit" (*wakon yōsai*) while they promoted a program of industrial nurturance (*shokusan kōgyō*).[6] Following Japan's defeat in the Pacific war, Navy Minister Yonai Mitsumasa proclaimed, "The loss of the war was a technological defeat."[7] Informed by this perspective, and afforded the luxury of U.S. security guarantees, over the next half century Japan set out to build its general technological capabilities to enhance its national security.

The same perceived vulnerabilities that justified Japanese militarism also influenced the country's commercial strategies. In postwar commercial Japan, direct foreign investments have been discouraged in favor of joint ventures that maximize technology transfers.[8] When domestic manufacturers have lacked capabilities in key areas, they have typically elected to buy licenses rather than to import products. Fundamental to Japan's technology and security ideology is the belief that "security" means comprehensively building the nation's productive and technological capabilities rather than simply amassing military hardware. Japan has sought to compensate for economic, technological, political, and social vulnerabilities that it believes demand special vigilance beyond merely responding to military threats and enhancing military preparedness. Japan's conception of "comprehensive security" (*sōgō anzen hoshō*) is merely the latest and most elaborate articulation of a technonational ideology that has driven its security concerns for more than a century.

Indigenization, diffusion, and nurturing have been, and continue to be, the core values that make up Japanese security thinking. Each reinforces the objectives of the other; together, they undergird Japan's remarkably successful industrial development. Technology indigenization is thought to be essential, so that, at least, Japan can derive higher value from leading-edge design, manufacturing, and production knowledge; at best, it can set the pace for world technology development. Once indigenized, domestic technical knowledge diffusion is essential, so that Japanese producers can collaborate to exploit fully the results of their efforts while competing vigorously to ensure that ultimate commercial (or military) applications are achieved. Finally, firms in Japan are nurtured and sustained by a system of alliances and protocols, so that the knowledge that has been diffused is not lost through calamitous economic dislocations (such as business cycle swings, short-term capital shortages, commercial product failures, market consolidations). Nurturing also assures that, in the future, technology can be diffused to enterprises that have steadily absorbed design and manufacturing knowledge, developing the economic wherewithal to produce first-rank products for civilian or military end-users.

6. Yamazaki (1961, 19).
7. Maema (1989, 169).
8. Mason (1992).

As used in this paper, *ideology* does not mean that Japanese or American technology and security strategies have been determined solely by each nation's national "culture." Rather, as each country has faced its own unique industrial and security challenges, certain basic principles have emerged to guide debates over how best it should respond. These ideas are now institutionalized through years of private and public practice, but they are not unchangeable or immutable. Indeed, we argue below that by understanding the divergence between U.S. and Japanese technology and security thinking, both nations may be able to modify their actions and beliefs to improve bilateral and regional prospects. In this fashion, we argue that ideology does shape a nation's choices about technology and security but it does not determine them; change, learning, and adaptation, however slow and halting, are not only possible but essential.

Let us explore the three interwoven strands of Japan's technology and security ideology in more detail.

7.2.1 Autonomy and Indigenization

Writing of the intellectual origins of modern Japanese bureaucratism, Tetsuo Najita has explained Japan's "unadorned, yet pervasive perception" that national development is a matter of "autonomy," and that "national integrity" can be achieved "only through economic power (*fukoku*)."[9] Japan's first national research institutes were established by MITI's forerunner, the Ministry of Agriculture and Commerce, to fortify Japan, achieve independence from foreign industrial products, and meet the Western imperialists on their own terms.[10] The Meiji leader Fukuzawa Yukichi wrote in his classic treatise, *The Outline of Civilization* (*Bunmeiron no gairyaku*), that both civilization and wisdom were necessary to protect the nation. Wisdom, he argued, could be learned from abroad but was best nurtured and applied at home. From the start, influential Japanese taught that the advancement of independent knowledge and scientific competence were as necessary as military power to achieve security.

In response, throughout the Meiji period Japan strove to learn Western technologies—particularly military technologies—and to indigenize them as soon as possible. Foreign tutelage for national strength was enshrined in the Charter Oath of the emperor Meiji in 1868: "Intellect and learning would be sought throughout the world in order to establish the foundations of Empire."[11] Independent arms manufacture based on imported foreign design and manufacturing skills, the first modern industrial sector in the Meiji era, led Japan's forced march to industrialization.

This process of indigenization is called *kokusanka* in Japanese. From Meiji to the present, private and public procurement decisions have been guided by the "three unwritten principles of *kokusanka:* (1) domestic supply; (2) if do-

9. Najita (1980, 6). This *fukoku* is more familiar as the first half of the Meiji exhortation, *fukoku kyōhei* ("Rich nation, strong army") that defined Japan's course of military technonationalism.

10. Kamitani (1988).

11. Lockwood (1955, 9). See Samuels (1992) for a fuller account.

mestic supply is not possible, licenses should be secured using domestic manufacture and equipment; and (3) equipment should have broader application than specific to the project for which purchased."[12] In accordance with these principles, in both military and civilian cases, each subsequent generation of Japanese product has usually depended less than its predecessor on foreign technology. So crucial has *kokusanka* been in Japanese thinking that some of the most important debates over industrial development and industrial policy in Japan have centered on how to achieve local control of knowledge.[13]

The Defense Production Committee of Keidanren has justified *kokusanka,* which it has championed, in at least five ways: (1) Japan's unique policy of "defensive defense" requires different equipment than that manufactured in Europe and North America; (2) the "special spirit and body size" of Japanese military personnel, as well as Japan's special "land, water, and seas"; (3) licensing breeds dependence of the licenser on the licensee, making upgrading difficult; (4) licensers are less willing to transfer technology to Japan, now that Japan's technological level has improved; and (5) codevelopment with other nations can succeed only if Japan has something of its own to offer.[14] The significance of this and numerous other similar arguments is its almost total lack of any credible military rationale for autonomous weapons developments. Rather, *kokusanka* is justified to avoid foreign dependence generally and to specifically improve Japan's bargaining position when obtaining technologies from abroad. *Kokusanka* is more than self-serving propaganda at budget time; it has been implemented in Japan's procurement practice: using aggregate time-series budgetary data, for instance, Bobrow and Hill found that Japanese military budgets reflect military calculations only in part. In addition, autonomy and dependence concerns explain a significant portion of Japan's defense priorities.[15]

The struggle for technological autonomy has not slackened now that Japan has emerged as a technological superpower. To the contrary, parity with the United States (and the prospect of considerably more intimate bilateral transfers of defense technology) is frequently used by industry and by the bureaucracy to justify demands for increased funding for scientific and technological development and for *accelerated kokusanka.*[16] A group of industrialists convened by the Keidanren responded to demands from the United States for technology codevelopment by arguing for accelerated autonomous defense technology strategies to ensure against a U.S. technology blockade.[17]

Efforts to achieve autonomy are also central to the process of Japan's interna-

12. Adachi (1981, 14).

13. See Anchordoguy (1989) for computers; Mason (1988) for automobiles and electronics; Green (1991) for defense.

14. Keizai . . . Iinkai (1976, 31–33).

15. Bobrow and Hill (1991, 55).

16. Ueda (1991), for example.

17. Jikibō . . . (1990).

tional cooperation. Consider these opening lines of the most recent report on promoting international cooperative aircraft development of the Japanese Machinery Industry Alliance and the International Aircraft Development Fund (IADF):

> It goes without saying that in order to secure a stable rank in international society, it is essential to more fully utilize our nation's meager resources and, moreover, to develop high level industrial technologies, leading the world. In order to do this, we must stir up the will for a technological renovation . . . as well as to reinforce and nurture the capability to develop technology autonomously. . . . In order to overcome the fragility of our resource poverty it is necessary to shift our policies of promoting a technology-based nation, and establish our economic security; this is a major objective that we must aim at especially now.[18]

A survey of Japanese defense production capabilities by the Mitsubishi Research Institute in 1987 was even more blunt about the tactical use of international cooperation to foster autonomous technology development in Japan: "With the exception of some very advanced high technologies, the commercial base of Japanese electronics materials and vehicles technology is equal to or better than in the United States and Western Europe. We anticipate progress in commercial-led R&D for military application. However, in those areas of high technology where domestic technology is behind, it will be necessary to supplement [domestic efforts] with international cooperation."[19]

The drive to indigenize and autonomously control technology remains as vital as ever in Japanese strategic thinking.

7.2.2 Diffusion

But it is not just a concern to indigenize and develop autonomous technical capabilities that is noteworthy about Japan. After all, autonomy is widely accepted as a legitimate goal of every nation's security policy. But Japan is also uniquely committed to diffusing technologies as broadly as possible throughout the economy. In practice, technology is often treated as a quasi-public good that is developed and distributed through elaborate networks of producers and bureaucracies. Participants in the process believe that propriety technology can be distinguished from generic information and that each contributes significantly to Japanese national security. As a consequence, Japan has built an extensive network of "technology highways"—an infrastructure comprising at least as many lanes, but perhaps fewer roadblocks, as its U.S. counterpart. Indeed, because the Japanese system facilitates extensive inbound (but much less outbound) technology traffic from abroad, it is able to exploit the opportu-

18. Nihon Kikai . . . Kikin (1991, i). The term used in this text is *gijutsu rikkoku sokushin no seisaku.* Nakayama (1991), suggests this can also be translated "a policy of technonationalism," although most Japanese tend to restrict use of that term for U.S. policies of technoprotectionism.

19. Mitsubishi Research Institute, survey (1987, 34).

nities other countries have created to promote technology exchanges as well. As a result, Japanese technology highways more effectively acquire and diffuse global and domestic technologies than similar systems in other countries.

Further, roadblocks impeding the interdiffusion of military and civilian technologies are in evidence considerably less in Japan than in the United States. Unlike in the United States, Japan's technology highways can accommodate automobiles, trucks, or tanks with equal facility. We noted above that national power and industrial autonomy were interdependent in the view of Meiji leaders. So too were military and civilian technologies. The first machine tools were manufactured in a government arsenal in 1869, and modern communications technology was first used by the army to suppress the Satsuma Rebellion. As the academic/bureaucrat Kobayashi Ushisaburo explained in 1922, the diffusion of basic technologies initially absorbed for military purposes was later crucial in building Japan's commercial industries.

> While the manufactured articles made as war materials are seldom fit for general use, the tools and machines that manufacture them may for the most part be used for making other kinds of articles wanted by the people at large. . . . One industrial work is apt to cause another of a similar kind, and so on, and the result was the evolution of all sorts of new industries. But that is not all. Workmen who had been employed and trained in the military industry went to work elsewhere in private factories or started little works of their own. (166)

Kobayashi's analysis remains true today. The interdiffusion of military and civilian products, process technologies, and skills has been of incalculable benefit to Japanese national development. Indeed, it has become so ingrained that Japanese managers often disclaim any interest in tracking the diffusion of military technology because "we don't make any such distinction."[20]

The low barriers to the interdiffusion of civilian and military technologies profoundly shaped Japan's postwar development. The country's earliest export successes, such as cameras, watches, and small machinery, were developed under the supervision of former military engineers.[21] Senior executives of many of Japan's most successful firms—including Morita Akio and Ibuka Masaru, the founders of Sony—learned their first lessons about manufacturing and technology management in the laboratories and factories of the Imperial Naval Air Arsenal (Kugisho).

Once the United States began sourcing in Japan for goods and services during the Korean War, Japanese firms used U.S. military procurement as a technological locomotive for the entire economy. This "special procurement" (*tokuju*) resuscitated then-moribund Japanese industries by transferring American

20. Interview, General Manager Aircraft Division, Mitsubishi Heavy Industries, October 8, 1991. This is vigorously denied by some MITI and industry association officials (correspondence, February 3, 1993) but is acknowledged by other MITI officials (interview, August 22, 1991).

21. Maema (1989, 160).

engine and machinery technologies, and introducing production, quality control, and manufacturing process know-how.[22] According to surveys done in the 1960s for the Defense Production Committee of the Keidanren, military demand, and especially technologies first introduced for military production such as materials processing, wireless communications, and propulsion, actively contributed to Japan's commercial economy for at least two decades after the resumption of military production in 1952 (contrary to conventional wisdom).[23] Keidanren repeatedly demanded increased military production, claiming that "the diffusion of modern weapons production raises the technological level of general industry."[24] Engineers noted in surveys that participation in defense R&D "helps raise technological capabilities in other areas" such as systems integration and design.[25]

In part because of the limited size of aerospace and defense production, Japan's prime contractors make little distinction between military and civilian products, except at final assembly, unlike U.S. primes that isolate much defense from commercial production. Japanese components and subassemblies are produced by and tested on the same equipment, regardless of the project for which the equipment was initially obtained or the ministry from which subsidies may have been initially derived at both the prime and supply levels.[26] As long ago as 1966, more than 80 percent of the production equipment employed in the manufacture of military products was used for nondefense products as well.[27]

Knowledge diffusion in Japan occurs at several levels, both inside and among firms and between sectors. It is accomplished through parallel, undifferentiated efforts affecting both commercial and military technologies. In the case of military production, the major defense contractors are diversified manufacturing conglomerates that take special pains to establish mechanisms such as project teams, extensive corporation-wide study groups, and technology focus centers for functional area specialists, to share know-how and experience across divisional lines. Although Japanese prime contractors rarely transfer engineering personnel across applications, they actively seek to transfer knowledge accumulated in one area to others within the firm.[28]

The result is a cadre of multifunctional design and manufacturing specialists

22. Bōei Kiki . . . Iinkai (1968, 49).

23. Ibid.; Keizai . . . Iinkai, ed., 1970.

24. Nihon . . . Kōgyōkai (1987, 57). We acknowledge that many of Keidanren's claims are self-serving.

25. Keizai . . . Iinkai (1970, 180).

26. Kamata (1979) and our site visits to aerospace and defense plants of two of Japan's three largest prime defense contractors (December 1991).

27. Bōei Kiki . . . Iinkai (1968, 16). According to this survey, 80,000 to 92,000 machines were put to military and nonmilitary use. Even in the weapons sector, 83 percent of the production equipment was general use. In military vehicles it was 97 percent.

28. Usually this is organized through the technology headquarters (*gijutsu honbu*) of the firm (interviews with senior technology managers: Shin Meiwa, Mitsubishi Heavy Industries, Mitsubishi Electric, Toshiba, September–December 1991).

who understand their application area comprehensively and who are expected to systematically diffuse their accomplishments company-wide. Even though engineering and technical staff do not typically leave their specific application areas, they each participate in every phase within the program from design to production, and they participate in a range of intrafirm mechanisms that transfer their knowledge. It has thus been comparatively easy for statistical quality control appropriate for military production to diffuse throughout the machinery industry divisions of Japanese primes, for commercial automated manufacturing processes to rationalize fighter aircraft parts production beyond what even the American licensers can achieve, or for aerospace materials to improve automobile and bus body production.[29] In the United States, prime contractor defense production is something to protect, isolate, and classify within the firm. Defense designers only design; process engineers focus only on production. But in Japan, defense production is like any other resource for advanced basic and process technologies within a firm, from which technological wisdom is to be mined and integrated into the firm.

Technology also diffuses horizontally among competitors. Many of Japan's technological capacities were fostered by novel and borrowed organizational practices—institutions such as research consortia—that allow risk-averse competitors to achieve common technical goals before they compete with each other in the market. Japanese firms cooperate in consortia at every level of the development cycle, including basic research, systems development, and, especially in aircraft, manufacturing. While the form and function of these consortia vary, every government program since the 1970s designed to support technology development has provided incentives for additional collaborative research.[30]

The research consortia are just one of several other "external" information networks through which technology is exchanged, traded, or otherwise diffused among competitors in Japan. These networks, coupled with public policies and private practices that are "delocalizing" Japanese research include joint ventures, technology exchange agreements, cross-licensing, second

29. The diffusion of commercial automated machinery techniques in nonaerospace industries to aerospace uses has been achieved both by Japanese primes and by sectoral suppliers who draw on their expertise in other divisions to produce aircraft parts of higher quality and with greater efficiency than their foreign licensers can achieve. The diffusion of statistical quality control techniques has also flowed in the opposition direction, mediated by the technology headquarters of the primes and facilitated by technology study activities undertaken by representatives of suppliers, subcontractors, and the primes in joint consultation with each licensed production activity. Aerospace production has also been used to obtain new materials technology, such as braking devices, lightweight metals, and more pliable structural assemblies in train and bus construction in Japan. Information derived in a series of interviews performed by us in 1991 involving site visits to a major Japanese defense prime contractor in the aerospace sector and seven subcontractors of varying sizes and capabilities located in Kakamigahara, Gifu prefecture. Data collected from these interviews in Japan shall be referred to as "Kakamigahara field study, December 1991."

30. Levy and Samuels (1991).

sourcing, production sharing, and a wide range of informal technology trading and information sharing. Industry associations and regional and prefectural manufacturer associations (*kumiai*) also provide opportunities for specialty equipment or components vendors and subcontractors to exchange technological information.[31] As we will see, efforts to stimulate multiple technology-sharing relationships among competitors are particularly pronounced in the aircraft industry.

An additional technology highway connects suppliers and their customers. It extends to (and indeed defines) the vertical relationships among primes and subcontractors and facilitates both upstream and downstream learning. Japanese prime contracts have been the principal conduit through which knowledge gleaned from licensed production is diffused to supplier and vendors. Typically, with each new project, subcontractors will dispatch teams of engineers to the primes for several weeks or months of training to master design or manufacturing techniques imported from abroad. The primes will also provide technical guidance on equipment purchases such as autoclaves, new NC machinery, or specialty composite materials technology.[32]

There is also substantial bottom-up diffusion; indeed, one of the dominant trends in Japanese manufacturing is the increased role subcontractors play as specialists in applying technology to foster new products. As the subcontractors diversify into new fields, or undertake independent R&D, they often learn unique techniques or skills that they spin-on to their old lines of work. This knowledge is often transferred downstream in generic form, as the subcontractors become more involved in designing or manufacturing new products in collaboration with other firms.[33] As in the United States, prime defense contractors are directly responsible for only a fraction of their nominal production. A 1987 survey by the Mitsubishi Research Institute found that reliance by primes upon their subcontractors for defense production was already high and growing.[34] The volume of upstream and downstream technology diffusion differs among companies and industries; downstream transfer may be comparatively rare in Japanese defense manufacturing, given the heavy influence of licensed production. Nevertheless, it is yet another mechanism by which technologies flow between companies in Japan.

7.2.3 Nurturing

The third strand of Japan's technology security ideology, nurturing, is concerned with creating the conditions under which domestic firms can usefully

31. An example of a horizontal and a vertical organization designed to transfer technology to supply networks is the Kawasaki Gifu Kyōdō Kumiai, described in Kawasaki Gifu Kyōdō Kumiai (1990); Kakamigahara Shiyakusho (1987); Sanemoto (1989).

32. Kakamigahara field study, December 1991.

33. A discussion of bottom-up engineering in the automobile industry is provided in Womack, Jones, and Roos (1990, 104–37); Nishiguchi (1989, 183–94).

34. Mitsubishi Research Institute, survey (1987, 24).

apply and retain the technical knowledge they obtain. Market shifts or technological revolutions can threaten long-term manufacturing capabilities if industrial players—firms, workers, designers—are not able to respond without threatening their very survival. It is therefore just as important to assure that networks and industrial participants survive as it is to obtain or develop technology. As a director of Japan's Aircraft Technology Association explained, Japanese industrial policy is about "targeting technology, not an industry. We are nurturing capabilities, not a sector."[35]

Consistent with this philosophy, the Japanese have constructed an elaborate system of protocols—sometimes tacit and sometimes explicit—which induce domestic firms, even as they compete, to constantly bargain and negotiate with their managerial counterparts and with Japanese bureaucrats to share market jurisdiction and control. These protocols—sometimes as simple as legitimacy afforded to government advisory commissions or as complex as reciprocity accumulated over decades of interaction—force interests as varied as the largest industrial producers, small subcontractors, regional industrial associations, local and national bureaucrats, and financial institutions to take account of each other's needs in shaping the economy. No single interest can ignore the others in making and implementing industrial strategies; no one bureaucracy, multinational firm, domestic industrial association, or union can significantly disadvantage the others through unilateral decision making.[36]

This system contrasts with American views that collaboration is the same as collusion and that economic competition is zero-sum. While U.S. economic bureaucrats have been historically preoccupied with the threat of excessive market concentration, their Japanese counterparts have feared that excessive competition may drive producers out of business that might otherwise contribute to the economy. Bargaining and negotiation protocols help ensure that business cycles, differential access to capital, cutthroat regional development competition, or large-firm market power, which typically generate enormous industrial dislocation in other countries, are mediated so that even "sick" players have a chance to recover, and none moves too far ahead of the other.

Consequently, small and large producers in Japan share the pain of economic downturns to a greater degree than in the United States; capital is allocated across the board to talented niche producers as well as brand-name corporations; and regions are not subject to huge currents of investment and disinvestment forcing painful social adjustments that endanger skills and manufacturing know-how.[37] Options to "exit" from the economy are made less at-

35. Interview, November 27, 1991.

36. Samuels calls this process of iterative bargaining among stable public and private actors "reciprocal consent." For an extended discussion of efforts to describe the Japanese economy's networks of power and authority, see Samuels (1987, 279–82).

37. Friedman (1988, 129–34) describes how postwar cyclical adjustments have increasingly been borne equally by larger and smaller firms, as the "dual structure" of the Japanese economy receded in the present period.

tractive than collaborative strategies that progressively build the skills of individual firms, regions, and the economy as a whole.[38] And when markets prove irresistible and exit is unavoidable—as in the case of Japan's coal mining districts in the 1960s—the state and consumers are expected to bear their "fair share" of the costs involved in restructuring regions or industries.[39]

Japanese nurturing strategies encompass the public, private, tacit, and explicit bargains that undergird the whole economy. Indeed, military production is so embedded in the commercial economy in Japan that it is difficult to distinguish between support strategies applicable only to military or defense manufacturing. Nevertheless, in several instances, Japanese nurturing has had especially clear effects on the nation's defense capabilities.

One is the creation of geographical regions where arms manufacturing knowledge is systematically strengthened and then retained over time. Unlike many American regions, such as the Rust Belt in general or Detroit in particular, Japanese industrial regions are "sticky"; once capital and technology flow into a region, they almost never flow out.[40] After design, manufacturing, and financial links are forged between producers and investors in specific industries, all of the participants exert considerable effort to keep them intact. In lean times, to diversify their options or learn new skills, regional producers often enter new industries, building relationships with new banks or firms. But these relationships supplement, rather than destroy, existing ties. New regional networks are built on top of the old.

Consequently, Japanese regions can sustain whole industries in suspended animation; like pictures burned into a television screen, certain regional capacities may dim with changing times, but they do not fade completely. Later, they can flare again into sharp definition should circumstances permit. As we shall see, this process has been characteristic of the aircraft industry. Immediately after the war, and then again in the late 1970s, Japanese producers kept alive the country's aerospace options during severe slumps by turning to other sectors while awaiting new military or commercial opportunities. In the immediate postwar period, aircraft industry intercorporate links were preserved for close to a decade and a half without significant production. Then, as defense orders blossomed in the early 1960s and commercial subcontracting expanded in the 1980s, the same firms and personnel successfully resuscitated Japanese aircraft production. Regional production skill development in Japan is cumulative rather than disjunctive, as is often the case in America.

As we will see, this strategy has been crucial in developing Japan's defense industries. Japanese military manufacturing has been limited by comparatively low, cyclical military expenditures. But as the country's defense was sustained by regional producers, aircraft, tank, or warship builders minimized the poten-

38. Basic concepts of exit, voice, and/or loyalty in response to change are first set forth in Hirschman (1970).

39. See Lesbriel (1991) and Samuels (1987, chap. 3) for reviews of this process.

40. See Friedman (1993) for an elaboration of sticky regions.

tial loss of accumulated know-how and skills during lean times, and could more readily meet the nation's procurement requirements as conditions changed for the better.[41] Not incidentally, they were also positioned to further enhance their capabilities through imports of foreign technologies or commercial R&D.

Horizontal and vertical relationships between firms also nurture long-term stability and skill retention by preventing debilitating intercorporate struggles for power. On the horizontal dimension (as we describe below in the case of aircraft), Japan's defense industry has been shaped by collaborative arrangements between the largest firms, which seem to ensure that each participates in at least a piece of every major project. Substantial market consolidations that would force many military production participants out of the industry—typical in other countries—rarely occur. Rather, historical players, and occasional new entrants, are able to share in learning and applying defense-related technology.

Similarly, primes and subcontractors have developed relationships that enhance skill retention by reducing the kinds of intercorporate exploitation that frequently threatens the existence of smaller producers in many other countries. In much of the prewar period and in the early postwar economy, Japanese primes—consistent with current and historical American practices—used their subcontractors as shock absorbers when the economy turned sour. Concerted political action on behalf of suppliers and subcontractors, the rise of producer associations that could bargain with the primes and with the government, the provision of massive financial and technological support to smaller firms, and the decline of mass, standardized production in Japan largely reversed this trend.[42]

Today, it is unusual for larger Japanese firms to force their supply networks to bear unequally the costs of economic adjustments. Indeed, when asked if they do, Japanese defense production managers often express genuine surprise that prime contractors in other countries could, or would want to, treat their suppliers in this fashion.[43] Conversely, representatives of U.S. primes and defense subcontractors are usually puzzled that the Japanese would *not* take ad-

41. An unpublished survey by the Mitsubishi Research Institute found in 1987 that "surge" capability in most sectors is considerable—ranging from 1.5 to 10 times current production during a rapid mobilization—including the rapid conversion of capital equipment in most sectors.

42. See Friedman (1988). See also Nishiguchi (1989) for discussion of the collaborative manufacturing strategies that have come to characterize Japanese manufacturing networks. In essence, Japanese firms both large and small rely on each other to market and produce the subsystems in which they specialize. As a result, it becomes extremely difficult for a large firm to cast off its smaller firm suppliers in bad times, since it is frequently closely relying on those firms for indispensable subsystems, technology, and manufacturing skills. See also the discussion by Asamuma (1989, 1–30). It states that Japanese firms increasingly specialize and rely on each other's skills in manufacturing hierarchies, which mitigates against buffer roles that would tend to disadvantage one part of the hierarchy to the advantage of another.

43. Kakamigahara field study, December 1991.

vantage of their suppliers to cushion themselves from market shocks.[44] The dense local, regional, national, political, and industrial networks that shape how firms are vertically organized in Japan do not facilitate the "cut and run" strategies typical in the United States. Rather, Japanese primes and subcontractors share market pain and grow together during economic upturns. The result is that the country's defense suppliers are better able to retain their military production skills, and can more easily experiment over the long term with spin-ons and spin-offs involving commercial and defense applications.

Japanese beliefs about the strategic contributions of technology to national security have therefore generated a national commitment to indigenizing technology, diffusing it throughout the economy, and nurturing firms that could benefit from indigenization and diffusion. Pursued separately and measured in conventional economic terms, each has effects that are costly and inefficient. Pursued jointly and understood in their ideological context, these principles have led to industrial strength and national security. Indeed, they have helped create a defense industry—if not an entire economy—organized differently than is typical in America. Industries are valued for the knowledge that they provide as well as for the products they can make. Relations between industrial players are guided less by price considerations than by the desire to continuously amass and apply knowledge over the long term.

In making this claim, however, we are not arguing that the defense sector in Japan has been the most important source of technology for the Japanese economy as a whole. Rather, as Japan's security and technology ideology has played out in practice, defense production has been subsumed within the commercial base, and defense technology is simply one of several technology options that Japanese firms engaged primarily in commercial production can and do draw upon. Further, we do not claim that this outcome resulted from state control, that industry has uniformly triumphed over politicians, that it has been uncontested politically, or that Japan's responses were preordained in accordance with the nation's basic security and technology ideology.

Finally, nothing about Japanese strategies reflects cultural peculiarities; non-Japanese thinkers such as Joseph Schumpeter and Friederich List have put forth ideas that coincide closely with the country's technology and security ideology. Schumpeter's claim that technology is the central component of economic competitiveness resonates throughout Japanese economic practice.[45] So does List's argument that a nation's independence and security depends on the independence and vitality of its manufacturers.[46] Japanese industrialists, secu-

44. Information regarding the manufacturing strategy, financial position, and intercorporate links in the U.S. aircraft industry is derived in part from a series of field interviews we conducted, first in Puget Sound, Washington, January 1992 with a major defense and commercial prime contractor and six affiliated subcontractors, and interviews with subcontractors in Los Angeles in January 1992. The Puget Sound study will be referred to hereinafter as "Puget Sound field study, January 1992"; the Los Angeles interviews will be referred to as "Los Angeles field study, January 1992."

45. Schumpeter (1950).

46. List (1927).

rity planners, and policymakers have been more informed by Schumpeter's belief in the centrality of technology and List's belief in the importance of domestic industrial and technological capabilities, than have their counterparts in America and other nations where different principles were widely adopted. Autonomy, diffusion, and nurturing, the core values of Japan's technology ideology, may not be uniquely Japanese, but Japan combined them to generate effective industrial practices, public policies, and criteria measuring the success of an entire industry. Japan is demonstrating that a nation may have less need for an explicit technology strategy if it embraces ideology that holds technology to be strategic. This is nowhere more apparent than in the case of the Japanese aircraft industry.

7.3 Aircraft Production and the Japanese Security Ideology

By the early 1990s, the Japanese aircraft industry was small but growing and carefully cultivated. Yet it is widely regarded as a failure. Certainly, the Japanese industry remains small by international standards. It is barely one-fifteenth the size of its $110 billion U.S. counterpart. Its exports are less than 0.1 percent of U.S. aircraft exports, and the production of the entire industry is just 10 percent of the production of Toyota Motors alone. It is less than 2 percent the size of the Japanese electronics or automobile industries. Few completed airplanes are built—just 188 in 1989 compared to 2,448 civil and 1,227 military aircraft in the same year for the United States.[47] No airline flies more than a handful of Japanese aircraft, and those that are flown are vintage-1960 YS-11 turboprops. The largest aeroengine manufacturer, Ishikawajima Harima Heavy Industries (IHI), has never designed and sold a commercial jet engine. How successful has Japanese industrial policy been? Has Japanese aircraft production been as disappointing as many suggest? Let us explore answers both conventional and unconventional.

Explanations for the "failure" of Japanese commercial aircraft production typically include some or all of the following.[48]

Late start. Between 1945 and 1952, the U.S. occupation prohibited aircraft production. Japan missed the start of the jet engine technology age and has been behind ever since. Licensing established knowledge is a good way to keep up; it is not a good way to get ahead.

Military dependence. For the past several decades, 70–80 percent of Japanese aircraft production has been for the Japan Defense Agency (JDA). Japanese

47. Aerospace Industries Association of America (1990, 30–31); Ono (1991, 15); data include transports, helicopters, and general aviation craft.

48. This litany is recited variously in Nihon Ritchi Sentaa (1982); Abegglen (1991); Nihon . . . Kōgyōkai (1979); Moxon, Roehl, and Truitt (1987); Long Term Credit Bank of Japan (1986); Frenkel (1984); Keizai Dōyūkai (1979); Mowrey, (1987); Rubin (1983).

government policy prohibits the export of military aircraft, and so the Japanese aircraft industry has had few opportunities to achieve economies of scale.

Small domestic market. Japanese travelers rely on trains rather than aircraft, and Japanese domestic airlines carry only 5 percent of the world's airline passengers.[49] This small home market makes it impossible for Japan to repeat the protected infant industry strategy that worked so well in steel and automobiles.

Lack of systems integration and design skills. Licensed production has deprived Japanese manufacturers of the opportunity to learn how to integrate complex aircraft systems. The point of successful design and systems integration is that the whole is more than the sum of its parts.

Inability to provide adequate aftermarket support. Japanese manufacturers lack an established marketing network in a global market where a large percentage of sales comes after delivery and payment for the original equipment.

Inappropriate industrial structure. Japanese heavy industrial firms are highly diversified, and not one of Japan's prime contractors specializes in either airframes or engines. Within the parents firms, the aircraft divisions have long been viewed as "poor cousins" that drain resources. Parent firms, with a considerable range of other options, reportedly have viewed aircraft as too risky.

Prohibitively high entry costs. This risk aversion is related to high entry costs. The cost per unit sold of aircraft is the inverse of that for integrated circuits. The significantly greater value added combines with the significantly smaller number of units sold to make aircraft a high risk. It is easier and more attractive to continue as coordinated, subsidized subcontractors than to set out as independent competitors.

Powerful foreign competitors. There are only three major integrated commercial airframe manufacturers in the world. The $29 billion Boeing Company enjoys more than half the world's civil transport market and has full order books into the twenty-first century. Airbus, now the number-two producer, needed billions in subsidies to enter the market. Today Japanese aircraft producers probably face even more substantial competition.

This is a formidable set of claims for one of Japan's more conspicuous commercial failures, but on consideration each claim becomes less compelling. In conventional terms the industry's performance is, at the very least, mixed.

Late starts can be advantageous. As the Japanese machinery industry demonstrated in the Meiji period and as the electronics industry has shown more

49. Frenkel (1984); Keizai Dōyūkai (1979, 70).

recently, a late start is not a permanent handicap and may even be an advantage. Later developers avoid the expensive mistakes made by market pioneers. Japanese firms have systematically learned from established world producers. The question is not whether latecomers will catch up but whether leaders will continue to innovate.

Military production can provide flexibility, experience, and stability. Military procurement actually provides substantial advantages. Though less profitable than commercial markets, military demand is more stable. Low barriers between military and civilian production enable producers to train and maintain a cadre of aerospace engineers and to nurture key technologies while preparing to compete in commercial markets. Moreover, gaps in Japan's technological capabilities can be and are reduced by defense programs. Finally, Japan's aerospace military dependence is not high by international standards, and commercial projects have followed military ones in Japan as elsewhere. Uchino Kenji, former vice president of the Commercial Airplane Company (the firm established to organize the subcontracting for Boeing's 767), has observed that "we cannot nurture an industry from collaborative development in commercial aircraft. The only way is to use military demand . . . to bring along civilian [demand]."[50] While the commercial market is more attractive to Japanese producers who look to wean themselves from dependence on the JDA, commercial production is neither a replacement for nor adversely affected by military demand.

Domestic market size is largely irrelevant. Like most markets for Japanese manufactures, the aircraft market is global. In the early 1980s, Japanese firms shifted strategy to cash in on significant opportunities as subcontractors and components manufacturers.[51] Even after the 1985 yen revaluation, which should have *reduced* Japanese exports and *increased* imports, exports increased 57.6 percent and imports decreased 27.1 percent.[52] Total nominal exports increased by nearly 40 percent between 1989 and 1991, and nominal exports do not include much electronics equipment and displays. The Society of Japanese Aerospace Companies (SJAC) projects exports will continue to grow at twice the rate of total production, amounting to more than 15 percent of total production by 1994.[53] In absolute terms, reported exports rose from $290 million in 1987 to $538 million in 1989; these figures, compiled by the Ministry of Finance, exclude exports of generic electronics, materials, or components. Ex-

50. Quoted in Takase (1979, 15).
51. See, for example, the "Long Term Vision" of the Society of Japanese Aerospace Companies, produced in 1990.
52. Kukita (1990, 43).
53. *Aerospace Japan,* November 1991, 29. This is partly accounted for by an expected decline in military production, until the FS-X comes on line.

ports reached nearly $1 billion in 1991—growth of more than 200 percent in four years.[54]

Japan's domestic production steadily expanded from a very low base in both relative and absolute terms. In 1983, Japanese aircraft output was about one-thirtieth that of its U.S. competitors. In 1985, it was one-twentieth. In the early 1990s, it was one-fifteenth the size. In absolute terms, aircraft production rose nearly 250 percent between 1978 and 1988 alone and grew at nearly twice the rate (10 percent) of the Japanese economy (5.7 percent). Between 1981 and 1989, the Japanese aircraft industry grew slightly faster than the French, British, Canadian, or U.S. industries. Its growth lagged behind only Italy in the global industry. The industry is positioned for a near-term future in which 30 percent of the value added of aircraft will come from components, up from the current 20 percent.

Clearly, Japanese strategists have found a method—"international collaboration"—to overcome their small domestic market.[55] The calculation is quite deliberate—if Japanese airlines must import finished products, Japanese manufacturers should supply as high a share of the value added in those products as possible. One analyst observed sardonically that "the four Heavy Industries will never admit it publicly, but they are merely 'parts makers.' Everything in Japanese commercial aircraft is *parts.* Everyone knows this, but it is a matter of pride not to acknowledge it."[56] Still, derision aside, this has been a high growth strategy, as seen in table 7.1. Further, in 1990, the aircraft and engine divisions of Japan's heavy industrial parent firms enjoyed significantly higher operating profits than did the parent firms overall. Profits for aircraft systems/components divisions were 5.9 percent, versus 6.5 percent for the parent firms overall; those for engines/airframe divisions were 5.0 percent versus 3.3 percent.[57]

Although the industry's output declined slightly in 1993 due to the global recession and flagging Boeing orders, Japan's global aircraft industry entry strategy is overcoming its small domestic market limitations, generating sustained, if not spectacular, volume expansion, financial achievements, and growth in technical capabilities.

Japan already possesses, and readily can develop, systems integration and design skills. Japanese aircraft producers have already demonstrated the capability to design high-quality aircraft, and each of the major airframe makers has touted the "paperless" airplane—designed by computer—as the next challenge.

54. Using a different base line, SJAC reports that aircraft imports by Japanese airlines increased by nearly 116 percent between 1975 and 1984. By this calculation, Japan's trade deficit in aircraft-industry manufactured goods has continued to widen (private correspondence, February 3, 1993).

55. Adachi outlined this strategy in 1981; Kukita did so in 1990.

56. Interview, former official, SJAC, November 27, 1991.

57. Chōgin Sōgō Kenkyūjo (1991, 104). SJAC reports, however, that net profits for the aircraft and engine divisions remained lower than for the parent firms.

Table 7.1 Japanese Aircraft Production, 1983 and 1988 (billion yen)

	Military		Commercial			
			Domestic		Export	
	1983	1988	1983	1988	1983	1988
Aircraft (including helicopters)	109.9	188.6	0.5	—	8.4	9.2
Fuselage parts	28.9	68.7	2.3	32.8	4.3	37.0
Engines	52.0	56.0	2.0	—	—	1.1
Engine parts	21.3	36.2	5.3	11.8	1.1	5.5
Other parts						
Landing gear	0.96	1.6	—	—	—	—
Propellers/rotors	2.1	0.1	—	0.1	—	0.1
Auxiliary equipment	2.9	17.8	0.04	0.6	1.1	1.1
Actuators	1.3	11.5	0.01	0.1	0.2	1.3
Power systems	—	0.8	—	—	—	—
Instruments	10.6	22.2	2.0	0.1	0.1	0.9
Avionics	9.5	31.6	0.4	—	—	0.1
Training equipment	5.6	10.3	0.4	—	—	—
Other components (seats, galleys, lights, entertainment system)	5.1	0.4	0.1	—	0.3	1.4

Source: Nihon . . . Kōgyōkai (1992).

Note: These data are based on a survey of thirty-three large firms that excludes auto consumption, Toray and other materials makers, virtually all below-first-tier subcontractors, and repairs/maintenance. As a consequence, they probably underestimate the scope and breadth of the industry by a significant extent.

Through "mere" licensed production, Japanese producers obtain complex manufacturing knowledge and (in design changes) glimpse how major producers integrate new technology or parts into a completed aircraft.[58] Kukita Sanemori demonstrates in a series of case studies—including hydraulic systems, air pressure and climate control systems, automated flight management systems, surveillance radars, and fuel systems—how licensed production has combined with domestic projects and international collaboration to provide both the know-how and the market access that have enabled equipment suppliers to challenge foreign manufacturers. Over time, many Japanese firms have become key subsystems suppliers or even sole sources for products they once licensed.[59] According to data published by the Japanese National Institute of Science and Technology Policy, the number of patent applications in aerospace in the United States between 1971 and 1984 was virtually unchanged, while

58. Even machinists in extremely small shops will frequently redesign components that they make for the largest American primes. Moreover, even quite small subcontractors have CAD/CAM systems that can use digitized data to create on-screen cutting paths and blueprints, which subcontractors can then manipulate in collaboration with the prime to enhance part quality (Puget Sound field study, January 1992).

59. Kukita (1990, 66). Teijin Seiki, a division of the larger textile firm, is now sole source of flight control equipment for McDonnell Douglas's MD-11 and is designing the equipment for the MD-12. Its experience with the Defense Agency's T-2 CCV jet trainer qualified it to supply fly-by-wire flight controls for the Boeing 777.

during this same period the number more than doubled in Japan.[60] Finally, we note that Japanese manufacturers have considerable experience with other kinds of complex systems, including nuclear power plants, satellites, and the most elaborate rail transport network in the world.

Components production and subcontracting make after-service capabilities less important. The absence of a worldwide service network for Japanese aircraft products would be a critical problem if the Japanese actually wanted to build and sell their own commercial transports. But this goal is not an important part of Japan's short- to medium-term aerospace strategy. In the longer term, there is little question about Japan's ambition to design, build, market, and service its own aircraft. We are reminded that the absence of a service network, faced by Sony in the 1960s and Toyota and Nissan in the 1970s, has been ovecome by other Japanese producers.

Japan's aircraft industrial structure is a strength, not a weakness. Unlike U.S. aircraft manufacturers, Japanese producers build aircraft and construction equipment, nuclear power plants, and machine tools and jet engines. Eighty-five percent of the combined sales of Japan's major airframe and engine manufacturers is in nonaerospace businesses, compared to only 40 percent of the combined sales of U.S. manufacturers. Total sales of the entire Japanese aircraft industry are a small fraction of Boeing's or McDonnell Douglas's, but total sales of individual heavy industrial firms are larger than the total sales of any single foreign aircraft manufacturer save Boeing. As a consequence, Japanese firms enjoy enormous flexibility in deploying their considerable resources, in combining military and commercial capabilities, in marrying aircraft and nonaircraft production skills. By the late 1970s, the value-added rates of their aircraft businesses surpassed that in other sectors, and as a consequence manufacturers found it easier to compete for capital within their firms. Mitsubishi Heavy Industries' (MHI) aerospace sales, for example, grew 50 percent in the early 1980s, catapulting its aerospace division from last to first among seven. During the same period, IHI's engine business, once the weakest in a diversified portfolio of shipbuilding and machinery production, became the most profitable division in the firm. Highly innovative sectors, such as new materials and electronics, in which these firms excel, provide opportunities for rapid spin-on of nonaerospace technologies. As John Alic observes, "The family of design methods, production processes, and inspection techniques required for polymer matrix composites—ranging from filament winding to ultrasonic inspection—represents a shift as great as that faced in earlier years by the electronics industry in moving from vacuum tubes to transistors to integrated circuits."[61] Moreover, Japanese aerospace firms learned much earlier

60. Kagaku Gijutsuchō Shigen Chōsajo (1987, 86).
61. Alic (1989, 20).

than their foreign competitors how to share tasks and collaborate on major projects—one of the most important factors driving technological diffusion and reducing risks in the economy.

These structural advantages are acknowledged in a detailed report of Japan's IADF, which argues that the fact the industry does not focus on aircraft is a source of strength. The ability to apply advanced technologies in different businesses within the same firm "deepens the capabilities of the company and provides Japanese aircraft-related firms strength beyond what is visible."[62]

Entry costs are less significant for components manufacturing and subcontracting. Japanese producers do not currently have the physical infrastructure to produce commercial transports for the world market. But while the level of capital investment is still small by global standards, investments in aerospace-related capital equipment and the operating expenses of the top twenty-four Japanese aerospace producers have increased very rapidly: in 1975, total investment in aerospace-related capital equipment and operating expenses was 8.5 billion yen; in 1980, it was 52.3 billion yen; and in 1988 (even before tooling for the Boeing 777 began), it reached 85.6 billion yen. Government-endorsed strategies, such as risk-sharing subcontracting with overseas producers, and access to the enormous financial resources of *keiretsu* firms, further reduce entry barriers. Finally, in 1993, the JDA began construction of Japan's first high-altitude test facility, intended as a "means of research and development for the Japanese aviation industry [and to] enable Japan to establish an integrated development and production system, to include design, experimental production, testing, and volume production."[63] In Japan, aircraft are seen as integrated systems of the highest-technology, high-value-added components. The process of integrating these components adds value still.

Limited number of global competitors can facilitate market participation. Global market leaders are willing to cede portions of their aircraft production to Japanese manufacturers in the expectation of sales to Japanese airlines. Exploiting their leverage, Japanese firms have insisted on becoming integrated into the design phase. In every successive project with Boeing, for example, Japanese suppliers have achieved a larger work share and greater technological responsibilities. According to one analysis, 70 percent of Boeing's foreign procurement for the 767 came from Japanese firms, and Japanese designers are now integrated directly into the development and engineering phase of the 777.[64]

Despite contractual restrictions, Japanese producers seem able to apply knowledge gleaned from one foreign partnership to work with another—one

62. Nihon Kikai . . . Kikin (1991, 7).
63. *Mainichi Shimbun,* December 29, 1992.
64. Fuji (1990, 7). Boeing officials claim that this figure is far too high and that they "cannot recreate" it (correspondence, June 10, 1992).

well-known case is Boeing "Supplier of the Year Award" winner Fuji Heavy Industries (FHI), which provides McDonnell Douglas with composite fuselage subassemblies that it first learned to produce under contract with Boeing. Similarly, Kawasaki Heavy Industries (KHI) developed a fuselage panel mounting tool for Airbus from its commercial experiences with Boeing, enabling Airbus to perform tasks it was previously unable to achieve.[65] A variety of military and commercial producers and engine makers contract with the same Japanese firms (see appendix A).

At the very least Japan's aerospace producers have found a growing, profitable niche in the global industry and are far from a failure in conventional terms. Their strategy, to "develop the equipment used in the world's aircraft" rather than build complete aircraft, has already paid substantial dividends.[66] While the Japanese aircraft industry remains small, it has begun to succeed without really flying.

But there is more to the story than building aircraft and components. Measured against the criteria of Japan's technology and security ideology, the industry's success is far more unambiguous. Aerospace producers have achieved a remarkable degree of technological autonomy and have strengthened the domestic technology base. They have helped diffuse advanced technologies widely in the domestic economy. Finally, Japanese companies have nurtured relationships among producers so that acquired knowledge could be sustained and applied over the long term to aircraft production and to "unrelated" civilian industries.

7.4 Aircraft and Japan's Technology and Security Ideology

7.4.1 Indigenization: The Paradox of Autonomy through Dependence

Perhaps the most significant feature of the Japanese aircraft industry is the staggering number of technology-transfer relationships—including joint ventures, licenses, coproduction and codevelopment programs, maintenance, retrofit and overhaul contracts—it has sustained with leading-edge foreign military and commercial producers. There is no authoritative public accounting of these relationships, and those accounts that are available are widely divergent. According to unpublished data compiled by the Machinery and Information Industries Bureau of MITI, 556 separate inbound licensing agreements designed to acquire technologies applicable to aircraft production were completed between 1952 and 1987.[67] The SJAC, on the other hand, lists 672 *active* licensing relationships in 1992.[68] According to a study recently completed by the U.S. congressional Office of Technology Assessment (1991), in fiscal year

65. Interview, U.S. aerospace executive, Tokyo, November 8, 1991.
66. Nihon . . . Kōgyōkai (1987, 39).
67. Data provided by Aircraft and Ordinance Division, MITI.
68. Nihon . . . Kōgyōkai (1992).

1991 alone, Japanese royalties to the United States for aerospace licenses were reported to be to $816 million, roughly the same amount as Japan's official defense R&D budget. According to Department of Defense data, payments to the United States for military aircraft licenses (over the life of a program) can be as high as $2 billion for the SH-60J helicopter, $1.9 billion for the F-15, and $900 million for the P-3C antisubmarine aircraft; payments for missile systems amount to hundreds of millions of dollars each, and the licensed sale of Raytheon's Patriot missile is expected to result in a flowback of $2.4 billion to the United States. Excluding direct sales of U.S. military equipment under the terms of the Foreign Military Sales Program and current air defense and ground programs—excluding aircraft—will result in license fees of $3.9 billion over the course of these programs. Aircraft coproduction and licensing fees may add another $5.9 billion.[69]

Large firms may have dozens of such technology agreements with foreign firms, and it is not uncommon for even medium-tier suppliers to have ten to fifteen separate aerospace technology-transfer agreements with U.S. and European firms.[70] Consider the representative relationships shown in table 7.2.

Japanese aerospace producers use alliances with U.S. manufacturers to accumulate skills with broad competitive implications. Each of Japan's prime aircraft contractors has now worked with a range of U.S. licensers. As we shall see below, not only has this strategy enhanced the capabilities of each participant, but by maintaining stable alliances among the primes and their vendors, knowledge gleaned from international collaborations has been diffused throughout the economy. Even the Technical Research and Development Institute, the agency responsible for indigenization within the JDA, acknowledged the massive benefits of licensed production.

> We began indigenous production based upon the introduction of licenses for U.S. and other military equipment. Although these new technologies were intended directly for military purposes, the special technologies to manufacture these exceptional products spilled over into the commercial world and before long they found their way into every area of the economy—superior large scale systems engineering, environmental testing, quality reliability control—such that it is impossible to ignore the huge contributions that licensed military production made to the rapid elevation of our nation's industrial technology base. . . . Even now, for a variety of reasons, in a variety of areas, licensed production continues to enable us to absorb many advanced foreign technologies."[71]

69. Unclassified data, current as of July 1989, made available by the Mutual Defense Assistance Office, U.S. Embassy, Tokyo.

70. According to published company data, Teijin Seiki, a Japanese aircraft supplier, had fifteen "major technological cooperation agreements," including a long-term joint venture housed with Sundstrand (STS Corp); another Japanese subcontractor, Kokukikaku Kōgyō (Aero-spec Products, Inc.), a company of 250 employees, sustains thirteen "technology tie-ups" with U.S. and German producers.

71. Bōeicho . . . Honbu (1977, 36).

Table 7.2 Selected Japanese Aircraft Industry Vendors and Their Foreign Technology Relations, 1991

Manufacturing Licensees	
Kayaba	
Allied Signal Industries	landing gear, hydraulics, brake lining
Aircraft Braking Systems	wheel brakes
Pneumo Abex	actuators, flight control systems
Murdoch Machine and Engineering	actuator parts
BF Goodrich	brake components
Aircraft Porous Media	helicopter modules
Loud Engineering	power steering
York Industries	helicopter parts
Arkin Industries	master cylinders, pumps, coolers
Ozone Industries	bumper parts
Carleton Technologies	cylinder bulbs
Dynapower and Stratopower	pumps
Vickers-Steerer	brake cylinders
Yokohama Rubber	
Aeroquip Products	hoses
Research and Chemical	sealing materials
Manville	heat-resistant materials
SSP	metal ducts and bellows
Vesper	metal/nonmetallic ducts and bellows
Engineered Fabrics	fuel tanks
Lucas Aerospace	spray mats
HR Textron	bulbs
Wyman-Gordon Composites	armor panels
Brunswick	radomes
Technit	radiation shielding
Ferro	prepreg composite materials
Alcoa-Tre	external tanks
Vickers/Tedeco	chip detectors
Trading Company Representation	
Yamada Yoko Corporation	
Emerson Electronics	antisubmarine electronics
Chandler-Evans	engine fuel controls
GE Aerospace	satellite equipment
General Instrument	electronic countermeasures equipment
Gould	towed sonar
GTE	laser radar
ITT	traveling tubes
Kelsey-Hayes	hydraulics, engine components
Loral	simulator, infrared countermeasures
Loral Aerospace	Sidewinder missile, laser target designator
Lucas Western	pylon
Marquart	ramjet engine

Table 7.2 (continued)

Trading Company Representation	
Motorola	displays, radar equipment
Perkin-Elmer	optical equipment
Systron-Donner	security systems
Teledyne Brown Engineering	displays
Teledyne Ryan Electronics	doppler avionics
Tracor Aerospace	chaff/flare dispenser
Westinghouse Electric	target drones

Source: Nihon . . . Kōgyōkai (1992).

Technology-transfer arrangements include virtually all phases of commercial and military aircraft production, including airframes, electronic and mechanical equipment, and materials. Domestic firms specialize and operate as nodes within the Japanese economy for accessing and indigenizing foreign technologies applicable for aircraft production. As one senior procurement manager explained his company's military sourcing strategy, "First, we determine if a Japanese firm makes the required part or equipment. If not, then we try to find a domestic company that can either develop the capability quickly or obtain it from abroad. If not, we are forced to import. Then we worry about price and delivery." And while Japanese aircraft industrialists often argue that in commercial procurement there is less concern with indigenization, when asked they rarely recall an instance when a foreign company displaced orders let to Japanese firms despite countless instances where domestic companies displaced overseas producers.[72]

Consequently, Japanese aircraft industrial development, centered on military systems, has followed a nearly linear path in which successive projects usually—but not always—have a larger domestic share than the previous ones. When successive projects do create significant foreign dependencies as in the case of the F-15, internal program licensing is used to close these gaps; as noted above, Japanese firms eventually became key subcontractors to the F-15 program through licensing even though they lacked indigenous capabilities at the outset.[73] Further, subsequent projects are often designed to acquire or autonomously produce the technical skills or products that were not indigenized in earlier aircraft programs.[74]

72. Kakamigahara field study, December 1991. An SJAC official provides four examples involving hinges and serrated plate for the Boeing 767 subcontracted by KHI (correspondence, February 3, 1993).

73. Aboulafa (1991, 11–12).

74. The FS-X is such a program. See Samuels and Whipple (1989). Further, a respected aerospace reference service notes: "The size or nature of the threat Japan faces is not the primary consideration in the manufacture of the SX-3 [FS-X]. Rather, it is an effort to acquire the design and manufacturing know-how necessary to create a first-rate indigenous jet fighter. The SX-3 will not be canceled for budgetary reasons, or because 'peace has broken out'" (Aboulafa 1991).

In this way, Japan has been able to transform itself from a buyer to a developer of weapons systems, including jet fighters. Indeed, this process took place quite rapidly. In the early 1950s, Japanese defense aircraft were supplied by the United States, and then were purchased with borrowed funds. Within a decade and a half after the 1954 Mutual Defense Assistance Agreement, and after numerous technology transfer, retrofit, and overhaul agreements with (largely) U.S. firms, Japanese companies were able to provide most of the components and perform the final assembly for almost all of Japan's military aircraft.[75]

Licensed production, retrofit, overhaul, and coproduction arrangements are sometimes denigrated by foreign observers as transferring only the most limited technical or manufacturing knowledge. Japanese producers are said to learn simple "metal bending" or the "how" but not the "why" of aerospace production.[76] It is true that since 1952 Japanese firms have licensed or coproduced nineteen different U.S. airplanes and helicopters without developing a significant "fly-away" industry of its own. Licensed production does not teach everything the licensee needs to know to build a domestic industry, nor does it ensure the indigenous financial commitment required to establish a world-class aerospace industry. But, as the JDA openly acknowledges, Japan's aircraft technology indigenization effort has nevertheless enhanced its military and civilian industrial capabilities in several ways.[77]

First, Japanese producers obtain from their licensed production and retrofit/overhaul activities extensive basic production knowledge, including blueprints, machining techniques, quality control methods, and design methodologies. In some instances, U.S. licensers even provide the informal notes skilled machinists had made concerning manufacturing "tricks" they had learned in American factories.[78] Japanese firms use U.S. manufacturing standards and testing techniques to set goals for their own operations. Unless prohibited by contract, they typically develop their own manufacturing plans (including NC machine

75. This includes virtually all ships (99 percent) and ammunition (87 percent). The Japanese Ordnance Association claims that these figures would be even higher if Japan were not forced to purchase American weapons for political purposes. See Asahi Shimbun Shakaibu (1987, 116). Note also that the gun mounts, radar displays, data link receivers, VHF receivers, instrument displays, 20-mm guns, radar, and inertial navigation system of the F-15J are made in Japan. Adachi (1981) reports that in June 1955 virtually all the components of the T-33 and F-86 jets were "knock-down" kits supplied by the U.S. Air Force. But within two years, domestic content was 48 percent. Likewise, in the first phase of the F-104 project (Japan's follow-on to the F-86), less than 15 percent of the electronics were manufactured in Japan. In the second phase of the project, this figure rose to over 80 percent. By 1975, less than 5 percent of Japan's military equipment was supplied from abroad.

76. For a review of skeptical arguments relating to the effects of licensing, see the sources and materials cited in footnote 50 above; also interview, Boeing Asian managerial staff, July 1991.

77. For an official (and controversial) evaluation of how coproduction of U.S. military systems was used by Japanese contractors to enhance commercial technological development, see U.S. General Accounting Office (1982). The Defense Agency's own *Defense of Japan* (1976 and 1988) details the way Japanese firms have learned from licensing U.S. military technologies.

78. Hall and Johnson (1970).

routes) and quality control systems in an effort to meet or exceed American standards. They have been notably successful: the defect rate for Japanese parts can be ten to fifteen times less than that for imported products made by the licenser or the original vendor.[79]

Licensed production and retrofit/overhaul work also stimulates cost control and manufacturing process improvements. Japanese primes and their subcontractors are able to learn the best process practices of American aircraft companies and then set out to improve upon them. they have become so proficient that, unlike common practice with other countries, most foreign licensers now simply provide project specifications on the assumption that Japanese production skills match or exceed their own. Japanese supplier firms lead the world in automated, flexible aerospace parts production capabilities, which can increase actual machine tool cutting time from 60 to 90 percent. They also readily spin-on process technologies that they employ in other industries to improve on the standards they have learned from licenser companies. In some instances, aircraft producers measure their process technology success not by the standards of foreign aerospace firms but by the capabilities demonstrated by their nonaircraft production facilities.[80]

Nor do initially limited roles with foreign producers preclude more extensive design/systems integration opportunities. CAD-CAM equipment and specialized design divisions are a ubiquitous feature of even the smallest Japanese aircraft subcontractor doing build-to-print work for larger firms, suggesting a commitment to learning design skills together with manufacturing techniques.[81] From the inception of Japan's postwar aircraft technology tie-ups, domestic producers have participated in, or have themselves generated, program change orders that provide opportunities—if small in scope—to design subsystems or parts. Occasionally, Japanese firms have improved on U.S. designs with autonomous developments, solving structural or design problems with ingenious solutions. In 1991 alone, Japanese firms submitted 775 engineering change proposals (ECPs) to their U.S. coproduction partners. These ECPs provide general technical descriptions of engineering changes aimed at improving existing U.S. designs and production. Among these were 341 changes to the Patriot missile system. Five ECPs for the SH-60 helicopter have now been incorporated as part of Sikorsky's design, as have Japanese enhancements of the Lockheed P-3C antisubmarine aircraft.[82]

Further, as they have increasingly mastered sophisticated manufacturing processes, Japanese aircraft companies have insisted on sharing in the design of new commercial and military aircraft. In 1991, over 250 Japanese engineers were resident at Boeing facilities in the United States, and in 1993 designers

79. Kakamigahara field study, January 1992.
80. Ibid.
81. Ibid.
82. Personal correspondence, Mutual Defense Assistance Office, U.S. Embassy, Tokyo, February 7, 1992.

in Japan will soon be on line with Boeing's American computers to work on the 777. On the military side, Japan was induced by the United States to abandon a totally indigenous fighter project in favor of the FS-X codevelopment deal with General Dynamics.[83] At the very least, Japanese designers can obtain advice regarding their proposed designs by collaborating with experienced foreign engineers. But they are also now involved at the ground floor in world-class commercial design efforts like the 777, as well as advanced, if not cutting-edge, military development projects such as the FS-X and Patriot missile systems. In 1990, the governments of Japan and the United States agreed to pursue three military codevelopment projects, including ducted rocket engines.

Finally, years of pursuing aircraft licensed production, retrofitting, and overhaul work have indigenized ancillary industries, most notably machine tools and their electronic controllers. The NC machinery industry in the United States was initially created precisely to meet new machining needs for military aircraft. But licensed production enabled Japanese machine tool producers to adapt their products for the aerospace industry. In short order, they displaced American or European equipment in most Japanese factories, and then made significant inroads into U.S. facilities as well. Indeed, while American machinery still can be observed in U.S. and even some Japanese facilities, it is usually older in vintage than Japanese equipment. American aircraft prime and subcontractor managers often ruefully confess that their next purchase will be a Japanese product. A similar process can be observed in selected components and materials where specialist Japanese producers of items such as flight controllers or plastics have emerged as sole or dominant sources for many foreign manufacturers.[84]

Japanese indigenization contrasts with American strategies. U.S. firms, unlike their Japanese competitors, actively transfer technologies abroad. In part because U.S. programs are so mature by the time foreign production begins, U.S. firms make comparatively little effort, however, to obtain significant flowback of process, manufacturing, or design skills from the overseas firms to which they transfer technology. While it is typical for American managers involved in joint ventures or licensing programs to tour Japanese plants once or twice a year, few have developed a systematic program to monitor or acquire Japanese practices.[85]

83. Noble (1992).

84. Friedman (1988, 26–32); see also Noble (1984). The Puget Sound, Kakamigahara, and Los Angeles field studies, 1991–92, suggested current machinery purchases by both primes and subcontractors in America and Japan were of Japanese equipment. Some Japanese primes initially purchased American machines during the late 1960s and 1970s, but those that still have functioning American equipment are replacing them with new Japanese equipment.

85. According to one engineer involved in the FS-X General Dynamics/MHI collaboration in Nagoya, General Dynamics placed over seventy engineers on site in a special building at the MHI plant, none of whom spoke Japanese fluently. (Later, Japanese-speaking employees were added.) He reported Japanese designers frequently held detailed technical meetings either before the Americans come to work, or more frequently, after they leave at 5:00 P.M.

Japanese industrial leaders recognized early on the role of the aircraft industry in fostering technology indigenization in the economy. A Keidanren report concluded that "because [licensed military] aircraft technology has to respond to a demanding environment with high reliability, small scale, and light weight, it will clearly have a positive effect on commercial aircraft development and production, as well as on other general industries."[86] Indeed, by learning how to meet demanding industrial standards, producing new equipment and materials, and increasingly applying design skills to aerospace systems integration projects, the Japanese industry has fashioned an impressive (but as yet incompletely documented) record of commercial spin-offs of military technology that, taken together, constitute substantial indigenization of technology.[87]

7.4.2 Diffusion: From Highways to Jetways

The aircraft industry has also accomplished a remarkable degree of technology and manufacturing diffusion throughout the economy along four dimensions: (1) horizontally, between major domestic prime contractors; (2) vertically, among primes, subcontractors, and suppliers; (3) across military and commercial aircraft applications; and (4) between aircraft manufacturing and unrelated industries.

That aircraft manufacturing is valued in Japan for its capacity to promote diffusion has been evident in several influential industrial and policy analyses of the industry. MITI's famous 1970 "Vision," which identified aerospace, nuclear power, and information as Japan's three future "strategic" industries, treated aerospace as the archetypal "knowledge-intensive" sector that must be fostered for its capacity to stimulate widespread advances in economic capabilities. MITI depicted the industry's links to other industries in the form of a tree, whose roots (key materials, fabrication, control, and processing technologies) bear fruit in the form of innumerable products in virtually every other part of the economy, such as vehicles, machinery, energy, electronics, leisure, and housing.[88]

Even more revealing is the way that the Japanese aircraft industry itself characterizes why aerospace is important when bidding for financial support before an often skeptical political or bureaucratic audience. An official industry postwar history cites the four major contributions aerospace made to Japan in the

86. Kikai . . . Iinkai (1965, 283–84).

87. Comprehensive data regarding Japanese spin-offs from the defense industry to commercial uses are not available due to Japanese domestic and international political concerns. One of the few public sources, compiled in appendix B, describes a series of spin-offs from postwar military projects to the Japanese commercial sector as compiled by the Keidanren, which has incentives, of course, to portray the ancillary benefits of defense spending in as positive a light as possible. Given the magnitude of funding for these projects, some spin-off is to be expected. Whether or not this justifies the expenditure is an empirical question awaiting more definitive analysis.

88. See Nihon . . . Kōgyōkai (1987, 47–49); Keizai Dōyūkai (1979); and Kōkūki . . . Bukai (1985) for representative statements of this "roots to fruits" metaphor. Samuels and Whipple (1989) reproduce the tree.

following order: (1) the aircraft industry's knowledge intensity raised the level of the industrial base as a whole; (2) its high value added secured the Japanese economic base; (3) it contributed to Japanese national security by building defense systems; and (4) it contributed to the national transport system.[89] In this recitation, the industry's effect on national transportation is far down on the list. Contributions to industrial knowledge and economic capabilities generally are more highly touted.

In practice, the most striking evidence of a concern for diffusion is the systematic way that key prime contractors repeatedly cooperate in major aerospace programs in Japan. The Japanese aircraft industry is unlike any other industry in Japan in the extent to which rivals collaborate. Competition between primes is usually limited to upstream, precontract R&D. Downstream production and sales functions are accomplished in an exceptionally cooperative manner. Each of Japan's prime contractors has played a role in every major postwar aerospace project. While the firms compete to become prime contractors for JDA, they do so in the knowledge that their competition will not be winner take all. Failed bidders routinely become subcontractors and receive a fixed work share and participation in the design or licensing process.[90]

It is little different on the commercial side. The same airframe manufacturers who were partners in the domestic YS-11 (and every military project) are again cooperating as risk-sharing subcontractors in the Boeing 767 and 777 projects. KHI, MHI, and FHI share indirectly public funding through the IADF, created in 1986 to provide them guidance on prospective projects and loans. As a result of collaboration through this fund, these firms have created nominally independent "development corporations" to coordinate their collaboration in the 767, the 777, and other projects. They partner also with IHI in the Japan Aero-Engine Corporation—another IADF project to coordinate their collaboration with the V2500 engine project with Rolls-Royce and Pratt and Whitney (see table 7.3).

In short, the Japanese aircraft business is a cozy "friendship club" (*nakayoshi kurabu*) in which each of the participants has, over decades of cooperation, become intimately familiar with the capabilities of each of the others.[91] One defense contractor from the more competitive electronics sector said sardonically that "in aircraft, like in construction, it's all rigged [*dango*]."[92]

89. Nihon . . . Kōgyōkai (1987, 41).

90. In a typical case, a Japanese prime will subcontract over 65 percent of its total business; 20 percent goes to other primes; 45 percent is directed to domestic specialist parts suppliers; 17 percent is accounted for by work let to "backshops" or manufacturers with close links to the primes; and 18 percent is spent on imports (derived, with permission, from proprietary data received from one of Japan's prime aircraft contractors, January 1992). Sources indicated that they had knowledge of other primes' subcontracting ratios, and that they were generally similar. For a related account of the U.S. case, see Kurth (1990).

91. For example, the plant managers of Japan's two largest aerospace works, MHI-Nagoya and KHI-Gifu, worked together on collaborative projects in both the military and civilian sectors—both in Japan and in Seattle (interview, December 18, 1991).

92. Interview, senior manager, October 28, 1991.

Table 7.3 Selected Postwar Japanese Aircraft Projects

Japanese Prime	Project	Licenser
Mitsubishi Heavy Industries	F-86F	North American
	F-104J	Lockheed
	F-4EJ	MDD
	T-2	**Domestic**
	F-1	**Domestic**
	F-15	MDD
	FS-X	General Dynamics
Kawasaki Heavy Industries	T-33A	Lockheed
	P2V-7	Lockheed
	P-2J	**Domestic P2V-7**
	C-1	**Domestic**
	P-3C	Lockheed
Fuji Heavy Industries	T-34	Beechcraft
	T-1	**Domestic**
	T-3	**Domestic**
Nihon Kokuki	YS-11	Domestic
Shin Meiwa	PS-1	**Domestic**
	US-1	**Domestic**

Source: Ono (1991).

While some attribute this collaboration to the rising costs of aircraft projects (each being roughly four times that of the previous one) and to the fact that the number of projects has declined overall, in other economies the number of firms would have been reduced in response to the same pressures. But in Japan, partners are considerably more stable, even if they are simultaneously competitors. Sharing tasks, rather than ruthless industry consolidation, is the strategy most consistent with the diffusion goals of Japan's technology and security ideology.

Keidanren has been a leader in exhorting horizontal collaboration. In a 1965 report, it acknowledged that large-scale projects required the integration of enormously complex technologies from disparate fields. It urged that interfirm, interdisciplinary teams of engineers be created to undertake national projects: "While it is valuable that each firm in the aircraft industry undertakes its own research and development, it is even more important that each specialized firm come together in a comprehensive body in a spirit of fellowship, and that government-business cooperation be achieved."[93] Or, as a former deputy director of the MITI Aircraft and Ordinance Division put it, "When the Japanese aircraft industry was provided chances to develop aircraft, almost all related companies, determining each other's comparative advantage in advance, shared the tasks and integrated the work. . . . Through this process it was possible to take a step-by-step approach. In other words, the Japanese aircraft industry did

93. Kikai . . . Iinkai (1965, 282).

not simultaneously pursue more than one or two projects. . . . it put to use what was learned in previous projects, explored new areas, and strengthened its technological base."[94]

Private firm strategies closely track these sentiments. Companies argue for their inclusion in major projects, for example, on the grounds that technology diffusion will help them, and the economy as a whole, compete against the rest of the world. In 1986, when the Japanese government's Key Technology Center subsidized the country's advanced turboprop (ATP) engine project, corporate participants, many of whom duplicated each other's skills and capabilities, variously justified their roles on the basis of (1) how much the project would contribute to their ability to "confront Western makers" (MHI and Sumitomo Precision); (2) the capacity to expand Japanese global market share (Ishikawajima Harima Heavy Industries); or (3) "to be able to compete with Western firms" (FHI). Each of the leading participants also saw clear linkages between the ATP project and their commercial activities. KHI and Kobe Steel both expressed their expectation that the ATP project would afford access to advanced equipment and the "application of the results to other business activities."[95]

The ATP engine project is only one of at least a dozen separate consortia in aircraft propulsion, materials, or components that are undertaken with public support in Japan. In each case, virtually all of the major industry players are assured a substantial role. While Japanese firms compete vigorously, this vigor has its limits, and competition is rarely allowed to compromise prospects for access to resources that would stimulate technological advantage for domestic firms or the nation.

As in the United States, technology also diffuses through the vertical links that bind Japanese primes to their suppliers and subcontractors. Like many other industries in Japan, subcontracting is vital to aircraft manufacturing. Roughly 70 percent of Japanese aerospace work is subcontracted by the leading primes. Each maintains roughly 300–500 direct relationships with domestic materials, components, and parts vendors.[96] As the primes develop their networks of suppliers and affiliated firms, which in turn resubcontract, thousands of Japanese firms throughout the economy participate in the industry. As we shall see, unlike U.S. cases, these relationships are often exceptionally durable; like the *nakayoshi kurabu* the primes have created, subcontractors and suppliers, organized into horizontal cooperation associations (*kyōryoku-kai*) or vertical regional producer associations (*kumiai*), are each able to assure access to technology and skills from the primes in a fashion that does not favor or exclude selected firms, but diffuses knowledge as widely as possible.

94. Hasegawa (1987, 14).

95. Nihon Kiban Gijutsu Sentaa, internal planning document, 1987.

96. Derived, with permission, from proprietary data received from one of Japanese prime aircraft contractors, January 1992.

But unlike most sectors in Japan, aircraft industry subcontractors—and even many suppliers—have not yet assumed primary responsibility for product design and integration. The heavy emphasis on military and commercial licensing or subcontracting has generated what is usually a one-way flow of knowledge from the primes, or the specialist suppliers that have direct technology tie-ups of their own, to lower-tier producers.[97] In most cases, technology or manufacturing know-how is transmitted at the start of each commercial or military project when a team of engineers from the subcontractors will be dispatched to the primes for weeks or months of detailed training. The subcontractors are instructed in the techniques, quality goals, design specifications, and production roles that the primes have negotiated with their foreign partners. After both sides are satisfied that the subcontractors comprehend their tasks and can meet the production objectives of the project, the team will return to their firm and begin to apply what they have learned.

Over the course of the project, the subcontractors and primes monitor performance and solve production problems in a number of ways. A steady stream of supplier and subcontractor engineers and technical staff interact with their counterparts at the primes on close to a daily basis. Each subcontractor is also subjected to at least an annual, and sometimes a six-month, inspection during which a detailed report card, which actually grades the subcontractor in a variety of categories on an A–D basis, is generated. This report is then often used as an action plan by the subcontractor to upgrade its capabilities and performance.[98]

Many subcontractors also hire retired technical staff of the primes to obtain production knowledge or, in effect, to buy direct access to the prime's resources through the retiree's personal contacts. Through these and other regular contacts, primes and subcontractors exchange advice concerning manufacturing equipment purchases or other capital investments that will affect their collective capabilities to compete for and meet contract goals. NC machinery purchases for aircraft production are made in close consultation with the prime,

97. In fact, since the subcontractors have little opportunity in the industry to develop unique manufacturing niches as in most other sectors in Japan, and are required by JDA regulations to supply detailed financial data to the primes, they are extremely protective of *their* technology. Their primary economic leverage comes from developing some method for producing parts that the prime can make, and has a good idea of the cost for making, at a price that earns a profit. One strategy, using lower-wage workers, is increasingly difficult because of the labor shortage in Japan. No one will work in factories for a fraction of wages they could earn elsewhere. More common are efforts to devise new cutting methods or use novel equipment to beat the prime's cost standard. Very few subcontractors stated that they would freely supply such knowledge to the primes, although, when queried, they could not explain how they could assure that frequent visitors from the primes, or former prime employees, would not obtain such knowledge. There are, however, examples where subcontractors do teach larger firms (like electrochemical machining technology) how to use technologies that they imported into Japan (Kakamigahara field study, December 1991).

98. Ibid.

to complement or supplement the prime's internal machining capabilities, and to assure that the selected machinery meets required standards. Purchases of large-scale equipment such as autoclaves for metal bonding or composite manufacturing by subcontractors are similarly coordinated with substantial input from the primes.[99] In this fashion, supplier and subcontractors use their relationship with the primes to secure access to defense and commercial aircraft technologies.

The third axis of aircraft industry diffusion is between commercial and defense technologies. It is uniformly the case at the prime, subcontractor, and supplier level in Japan that commercial and military work are performed by the same shop personnel on the same equipment, usually in the same facility. At the prime level, large-scale projects are often managed by individuals who have, over time, become specialized in specific programs. But despite legal formal proscriptions, the interdiffusion of military with commercial aircraft production is apparent everywhere else. The same work groups, on the same machines, will produce batches of parts for jet fighters, missiles, and Airbus or Boeing with equal facility in the same day. Scattered around a typical factory are pallets of work intermingling titanium F-15 components, hardened missile cases, and aluminum 767, MD-11, or A-321 fuselage parts. Indigenous trainers such as the T-4 are equipped by teams that can and do shift with ease to civilian projects. Blueprints for military and commercial aircraft are stacked next to, if not on top of, one another in even the largest factory. And in assembly areas, military aircraft take shape next to subassemblies for commercial transports.[100]

Finally, there is substantial diffusion between aircraft technologies—commercial and military—and the general economy. A 1979 SJAC survey estimated, for instance, that the sales generated by products derived from aircraft industry technologies were *sixteen times greater* than other products the same technologies produced. In addition, the report concluded that there were substantial economy-wide process improvements fostered by the aircraft industry's production-technique diffusion: "Elevating the product quality in other industries through quality control systems designed for the aircraft industry was a consequence that began with the licensed production of aircraft and aircraft parts that rapidly spread, so that today quality control is just common sense in every sector, regardless of the scale of the firm."[101]

A decade later, SJAC completed Japan's most detailed study of technology diffusion between the aircraft industry and sixteen other sectors, identifying a range of mechanisms by which technologies are transferred.[102] In the case of submersible craft, marine engineers were dispatched to the aircraft divisions of their parent firms for training and for the collection of data on materials

99. Ibid.
100. Ibid. and MHI field study, December 1991.
101. Nihon . . . Kōgyōkai (1979, 6).
102. Nihon . . . Kōgyōkai (1985).

and manufacturing processes. They also received "technical leadership" from competing submersible manufacturers. In the case of the space industry, engineers and designers were transferred in-house across divisions to take advantage of their experience in aircraft materials and testing. The study also found that aircraft engine technology was transferred through technical exchanges between large and small manufacturers, through joint development projects involving users and makers, through technology exchange agreements between engine makers and systems controls manufacturers, and through the active use of "controlled leaks" of technological information.[103]

All told, the report suggests that product and process technologies in nine different aerospace areas, including general systems and control technologies, aerodynamics, flight control technologies, structural technologies, materials, electronics, and testing were applied in thirteen different product areas in the Japanese automobile industry, including shock absorbers, clutch linings, fuel tanks, air bags, manufacturing process controls and so forth. Aircraft know-how also contributed to the manufacture of submarines (materials, design, testing), industrial machinery (CAM, locknuts, materials), robots (encoders, alloys), materials (fabrication, design), petrochemicals (fasteners, high-function synthetic materials, sports equipment, tires), and electronics (displays, computers, switches). The study documented more than five hundred cases of technology diffusion, 60 percent of which originated in the aircraft sector.[104]

The capacity to spin-on or spin-off commercial and military aircraft technologies to other industries varies with the scale and organization of the firms involved. The process is least impressive at the prime level. Although Japanese primes are generally smaller divisions of larger, nonaerospace companies, they usually house their aircraft facilities in factories geographically separated from the rest of their commercial activities. Few workers, engineers, or managerial staff members are ever transferred interdivisionally. Yet most primes report that they foster interdivisional diffusion on a more systematic basis, by creating elaborate networks of research committees assigned to consolidate a firm's knowledge of technology in specific functional areas. At Shin Meiwa and at MHI, for example, the technology headquarters sponsors firmwide study teams that coordinate at both the plant and corporate level on functional topics such as electrical machinery, heat treatment, inspection, and so forth. Each study team meets quarterly to enable engineers responsible for disparate applications within diversified firms to share their know-how.[105]

Thus, despite the physical isolation of aircraft operations from other divisions at the prime level, there is considerable evidence of technology interdiffusion. In constructing an advanced phased-array radar (APAR) for the FS-X

103. Ibid., 208–9.
104. Ibid., 231.
105. MHI, Kakamigahara field study, December 1991; interview, general manager, Shin Meiwa Industries, October 18, 1991.

project, for example, Japanese engineers from Mitsubishi Electric's radar group briefly transferred to Mitsubishi Electric's (MELCO's) electronic devices group, where they received training in the gallium arsenide (GaAs) chip manufacturing technology they needed to make APAR high-frequency transponder modules. Leveraging MELCO's GaAs commercial memory technology, they were able to produce, with just a fraction of the government R&D support American firms received, an APAR prototype that many regard as fairly close to leading-edge U.S. capabilities. Aircraft and nonaerospace technology interdiffusion, with significant strategic implications, does occur even inside Japanese primes.[106]

Japanese subcontractors and suppliers achieve even more systematic interdiffusion of aerospace and nonaerospace technologies because their aircraft production is less segregated from other activities. Unlike the United States, Japanese lower-tier producers are primarily *not* aircraft manufacturers. Typically, 80–90 percent of their production is in nonaircraft industries; top-caliber aerospace manufacturing operations occupy just a corner of their facilities.[107] The resulting direct combination of aircraft and nonaircraft production in Japanese subcontracting plants facilitates an enormous cross-fertilization of technologies and skills. Consider four examples of this process.[108]

1. In one case, a firm of about 250 employees originally specialized in packaging for air defense ordnance and general machining. To enhance its capabilities, it imported electrochemical machining (ECM) technology from the United States and began using ECM techniques for Japanese aircraft production. To stimulate sales, the company launched a number of workshops for both primes and subcontractors, and began to supply technical support and machinery to implement ECM in Japanese aerospace factories. As demand for sophisticated routing and milling technology increased in the automobile industry, it adapted ECM technology for use in making auto parts. The firm now designs and builds an electrochemical device (ECD) for nonaerospace parts producers that is based almost entirely on the ECM technology it originally imported for aircraft industry use. One year after development, 15 percent of the firm's revenue was accounted for by ECD sales, which were expected to grow to 45 percent by 1993.

2. Cross-fertilization can also occur in a less direct fashion. A well-established aerospace machine-shop subcontractor of about one hundred employees discovered that chip removal for the sophisticated NC machine tools involved in aircraft production was quite difficult. It began experimenting with conveyor systems and telescopic covers for NC equipment, forming a joint venture with a German firm to import technology. At present, the company has designed and produced, under its own nameplate, world-renowned conveyors

106. Interview, general manager, MELCO Radar Group, October 8, 1991.
107. Kakamigahara field study, December 1991.
108. All examples are from ibid.

and covers and has made sales throughout Japan and the world. It also produces the speciality machines required to *make* the conveyors. While remaining an integral part of the Japanese aircraft industry's subcontracting network and participating in several prime contractors, the firm relies on aerospace work for just 15 percent of its revenues; machine tool accessories now account for about 85 percent of its business and nearly all of its profits.

3. A third example of the enormous cross-industrial interdiffusion Japanese aircraft subcontractors and suppliers can achieve is the case of a plastics and seat manufacturer. While a first-tier aerospace supplier, the company's aircraft machining and passenger-seat production earnings account for just 17 percent of its business. Nevertheless, the firm continuously applies technologies from one industry to another. By learning to make lightweight, durable military ejector seats, for example, the firm made significant improvements in commercial transport seat design. It sells its seats to aircraft equipment suppliers and primes worldwide. Both commercial and military aircraft seat technology made possible new designs of lighter Shinkansen, or bullet train, seats necessary to facilitate announced plans to speed up the trains. More fuel-efficient buses also resulted. The company has also leveraged its reinforced fiberglass and composites technology into aircraft and nonaerospace business. Aircraft manufacturing led the company to purchase a large autoclave, with technical assistance from a Japanese prime, to produce composite and fiberglass materials. Building in part on the knowledge it obtained, the company now constructs an impressive array of composite products, from aircraft fairings to ski-lift canopies, and from bus bodies to cars for Tokyo Disneyland attractions.

4. A final example illustrates nonaircraft commercial *spin-on* capabilities. One of Japan's most successful textile firms is also a highly sophisticated aircraft component supplier, specializing in fuel injectors and flight control equipment. Approximately 25 percent of the company's sales are in aerospace; the remainder are in textile equipment, robotics, and industrial machinery. The production of robotic transfer gear systems, the firm discovered, actually involved tolerances more acute than aircraft parts specifications. Further, many of its foreign competitors or licensers were unversed in state-of-the-art nonaircraft manufacturing techniques and therefore were unable to learn from process innovations made in other sectors. To improve efficiency and quality, the firm began to adapt its nonaircraft quality control and process techniques to its aerospace operations, dramatically increasing the quality and reducing the cost of its products. In turn, the firm achieved a commanding presence in certain segments of the world aircraft market in which it competes. In at least one case, the company is now a sole source of flight control equipment for a major overseas commercial aircraft program; in many others, it is one of two or three remaining sources worldwide.

Japanese horizontal, vertical, military/commercial, and aircraft/nonaircraft diffusion markedly contrasts with U.S. experiences. Competition among American primes does not ensure that losers in the process share in military and commercial projects; they rarely exchange information or know-how more extensive than requests for price quotes with their subcontractors (although they do collaborate, of necessity, in design with their specialist subsystems suppliers); and most studies suggest that interdiffusion between military and commercial or aircraft and nonaircraft functions is comparatively rare today. As one analyst notes, "Even among those firms [that have defense and military divisions] there is very little integration at the plant level between the defense operations and the civilian operations.[109]

American subcontractors and suppliers, however, can and do mix commercial and civilian aerospace technologies and machinery, but they have been generally unable to apply their skills in nonaircraft business.[110] Unlike the Japanese, who have found that there is often very little distinction between meeting customer needs in either the aircraft or other industries, comparable intersectoral diversification has eluded U.S. suppliers and subcontractors. Many, such as one first-tier U.S. supplier, admit that their firms lack the confidence that they can make a successful foray into industries "where standards are lower."[111] A survey of U.S. defense and aerospace subcontractor capabilities by an American defense consultant came to a similar conclusion.

> The foraging, casting (foundry) and fastener industries share several important characteristics. In each of these industries, firms which manufacture products for the defense industry do so almost exclusively for defense and aerospace customers. The products they sell are manufactured in very small quantities and are of high quality relative to products sold in . . . commercial markets. . . . As a consequence of the specialized production equipment, test equipment, and labor and management skills required to manufacture these products, these firms are generally unable to compete in commercial markets for high volume, low technology products. Although they are technically capable of making commercial products, they are usually unable to do so in an economic fashion. At the same time, firms which manufacture in large volume for commercial markets are usually unable to compete in de-

109. While it is often asserted that in the early postwar period military and commercial technology diffused quite rapidly at the prime level in the United States, most studies have concluded that this process has become less evident in the current period. There are numerous examples of efforts by defense firms to convert to commercial products that have failed, including Grumman's effort to build canoes and then city buses, and Rockwell's attempt to enter the aircraft overhaul business. Most studies of this issue conclude that there is very limited integration at the plant level or at the division level between commercial and defense activities of prime U.S. contractors. See, for example, Alic et al. (1992); Gansler (1989, 1984).

110. Unlike U.S. primes, for instance, studies show aerospace subcontractors in fact often perform military work jointly with commercial business. A survey of Puget Sound defense suppliers, for instance, showed that over 75 percent of the subcontractors in the region sold less than half of their output to the military or in military projects (Sommers, Carlson, and Birss 1992). Field studies of aircraft subcontractors and suppliers in both Los Angeles and Washington also demonstrated that nonprime U.S. manufacturers frequently combined defense and nondefense aerospace work with the same facility as did the Japanese (Los Angeles and Puget Sound field studies, January 1992). See also Kelley and Watkins (1992) for survey research that demonstrates significant dual-use activities among metalworking subcontractors.

111. Puget Sound field study, January 1992.

> fense and aerospace markets because they lack the necessary skills and equipment. In those instances where it may be possible to manufacture a product, it generally cannot be done economically, again because of the inappropriateness of the equipment, the people and the organization to do the job.[112]

Most striking in this analysis is that virtually all of the matter-of-fact conclusions explaining why aircraft and nonaerospace production are incompatible apparently *do not* apply in Japan. Indeed, Japanese producers routinely achieve profound intersectoral diffusion.

7.4.3 Nurturing—Assuring that Technology Highway Travelers Stay in the Race

We now turn to the third strand of Japan's technology and security ideology, the importance of nurturing firms that can indigenize and diffuse technology. Through a variety of means, Japanese companies are afforded substantial resources to assure that, as they master industrial capabilities, they have sufficient stability to exploit what they have learned. We earlier referred to this system as an economy of protocols; while pursuing individual ends, players in Japanese industry are caught in a web of mutual obligations or "reciprocal consent" that moderates the chance that fratricidal competition, rapacious industry consolidations, or external cyclical market shocks will threaten their existence.[113]

We have already discussed some of the features of the protocol economy apparent in the aircraft industry. These include (1) the system of work sharing that virtually ensures that each Japanese aircraft prime contractor participates in every major aerospace project; (2) joint collaborative research consortia, such as the ATP project, which spreads public R&D funding across the widest possible range of industry players; and (3) networks of suppliers and subcontractors that leverage stable vertical and horizontal business into technological and market advantages.

The effects of Japan's protocol economy in nurturing opportunities in the aerospace industry can be further appreciated by focusing on a specific region, Kakamigahara in Gifu prefecture, which has been a center of Japanese aircraft production since before World War II. Kakamigahara illustrates how Japanese primes and their subcontractors accommodate each other's needs to generate a stable economic environment in which indigenization and diffusion can productively occur.

Kakamigahara is home to KHI's main airframe production and assembly facility, the Gifu Works, which employs about four thousand workers and adjoins a Japan Air Self Defense Force (JASDF) air base. The region was one of

112. Institute for Defense Analysis (1990, 3). (Contrast this finding to Kelley and Watkins 1992).

113. Ronald Dore calls this "relational contracting." See Dore (1987, 109–92).

the major fighter production centers in Japan during World War II. Major postwar military projects in which KHI has participated as a prime or subcontractor at the Gifu Works are shown in table 7.4.

In addition, KHI is a contractor for 737, 747, 757, A-321, and MD-11 production, is a principal participant in the FS-X and 777 development projects, and has performed extensive overhauls of close to six thousand commercial and military aircraft since 1955. The firm is the second largest Japanese aircraft prime contractor, accounting in 1990 for 29 percent of the aerospace production of the nation's top six firms and 11 percent of Japan's total defense contracts (150 billion yen). Its aircraft sales, exclusive of jet engines, more than tripled in 1981–90, rising from just under 60 billion yen to over 200 billion yen during the decade. Additional KHI factories in Akashi, west of Kobe, and Tobishima, south of Gifu, produce aircraft engines and assemble 767 fuselage components, respectively.[114]

Surrounding KHI is a network of suppliers and subcontractors with long-term roots in Kakamigahara. Most of its principal suppliers of components, subsystems, or materials are organized into a "cooperation committee" popularly known as *Kawajū.* In addition, KHI's thirty-six primary local subcontractors are organized into a regional production association called the *Kawasaki Gifu Kyōdō Kumiai.*[115] The *kumiai* represents a typical Japanese organizational innovation in which competing firms stabilize their relationships with key customers and each other, but do not constrict their industrial options.

Japanese aircraft manufacturing was suspended during the U.S. occupation, a devastating event for Kakamigahara's wartime aerospace subcontractors and KHI.[116] By 1948, however, newly reconstituted and renamed, KHI had developed a bus design, the KBC-1, around which the regional production network reformed.[117] Many of the former subcontractor managers, often working of necessity in the retail or restaurant business, began to reopen small machine shops to participate in the region's new bus-building activity.[118]

In 1951, the twenty-two largest subcontractors organized into the *Kawasaki-Gifu Seisakujo Kyōryoku Kōjo Kyōdō Kumiai* (literally, Kawasaki-Gifu Collaborative Association of Cooperating Factories) to address two problems.[119] The

114. KHI financial and promotional material for the Gifu Works, 1991.

115. Details on the regional organization of KHI suppliers and subcontractors are from several sources: Kawasaki Gifu Kyōdō Kumiai (1990); Kakamigahara Shiyakusho (1987); Sanemoto (1989).

116. During the war, aircraft production was accomplished in the forerunner to KHI, which bore a different name. For simplicity, we refer to KHI here for each of these entities.

117. Kakamigahara Shiyakusho (1987, 691–94).

118. Kakamigahara field study, December 1991.

119. *Kumiai* also perform numerous other services: (1) building apartment dwellings for member employees; (2) conducting technology seminars for members; (3) serving as a focal point for other industries to contact suppliers in the region; (4) conducting political lobbying and liaison with local, regional, and national bureaucracies; and (5) organizing social activities such as bowling clubs, travel, and so forth (Kawasaki Gifu Kyōdō Kumiai 1990, 10–24).

Table 7.4 **Kawasaki Heavy Industries, Gifu Works, Military Prime and Subcontracting Project Participation, 1959 to April 1, 1991**

Type	Kind of Aircraft	Period of Manufacture	Remarks
Fixed-wing aircraft	T-33A jet trainer	1955–58	210 planes
	P2V-7 ASW patrol airplane	1958–65	48 planes
	F-104J jet fighter	1961–67	207 planes (coproduction)
	YS-11 medium transport plane	1962–72	182 planes (coproduction)
	P-2J ASW patrol airplane	1967–78	83 planes
	F-4EJ jet fighter	1969–81	138 planes (coproduction)
	C-1 medium transport airplane	1970–81	31 planes
	P-3C ASW patrol airplane	1978–	66 planes
	F-15J fighter	1978–	140 planes (coproduction)
	Boeing 767 passenger airplane	1978–	388 planes (coproduction)
	T-4 medium trainer	1985–	56 planes
	EP-3 utility airplane (EW)	1988–	1 plane
Helicopters	Kawasaki-Bell 47	1952–75	439 helicopters
	Kawasaki-Vertol 107 11A	1963–	160 helicopters
	Kawasaki-Hughes 369	1969–	300 helicopters
	Kawasaki BK 117	1982–	343 helicopters
	CH-47	1986–	28 helicopters
Missiles	Type 64 antitank	1964–	ATM
	Type 79 antilanding craft/antitank	1979–	H-ATM
	Type 87 antitank	1987–	M-ATM
Space equipment	geodetic satellite	1986–	
Repairs	fixed wing	1953–	3,990 planes
	helicopter	1954–	1,993 helicopters

Source: Kawasaki Heavy Industries, promotional data, Gifu Works (1991).

first, and most critical, was to ensure that KHI did not try to allocate work to select subcontractors due either to personal favoritism or in an effort to drive down contract prices. The *kumiai* operated as a collective interface with KHI, establishing basic expectations regarding contract procedures and work volume to which the entire region would adhere. In addition, the *kumiai* forged close alliances with regional, prefectural, and national authorities to create political resources with which to protect their interests. As their business relationship developed, KHI and the *kumiai* became enmeshed in a multilayered network of local and national contacts that precluded destabilizing, unilateral actions on both sides. Indeed, the extent of the *kumiai*'s ability to form visible links with influential political authorities can be appreciate in its forty-year commemorative publication of 1990. The handsome 152-page book offers messages of personal congratulations from the acting MITI minister, the Chubu region MITI bureau chief, the governor of Gifu prefecture, the head of the national small and medium enterprise association, the head of the Commerce Manufacturing Union Central Bank (a public small-firm lending institution), and the mayor of Kakamigahara.[120] From an early period, the *kumiai* members exploited their opportunities in the Japanese protocol economy to induce KHI to make long-term business commitments to their region.

The second goal was to facilitate joint applications for financing.[121] Despite their close contacts with KHI, itself affiliated with one of Japan's major *keiretsu* groups, none of the *kumiai* members received investment or other financial support from the firm or affiliated banks. They relied instead on family equity, retained earnings, and local bank financing to build and expand their businesses. To reassure regional banks during the postwar industrial slump, *kumiai* members applied for loans as a group, combining their collective manufacturing and management expertise into a single package.[122] They also benefited, like subcontractors in other industries, from the specialized regional financial institutions Japan created to fund sophisticated equipment purchases and capital expansion undertaken by smaller firms.[123] Consequently, Kakamigahara subcontractors organized to avoid price and wage exploitation by the region's dominant economic enterprise while collaborating to secure independent capital from dedicated small-firm lenders, as was true of other lower-tier producers throughout early postwar Japan.[124]

The result was a set of vertical and horizontal links that fostered the skills and stability of Kakamigahara's aerospace subcontractors in several ways. First, as we described above, KHI and its subcontractors maintained substantial personnel, management, and training contacts that helped indigenize and diffuse technology, especially licensed production techniques, in the course of military and commercial projects. The commitment to mutually foster business opportunities also led KHI to share the burden of aircraft production cutbacks more or less equally with its subcontractors. Unlike U.S. practice, no one in Kakamigahara could recall an instance where KHI used its suppliers as a buffer for economic shocks, retracting work to maintain its internal operations at the expense of its subcontractors. Nor could they remember a case where KHI refused to place orders with a *kumiai* member because of past production problems; rather, the preferred solution was for KHI to maintain business volume while insisting on improved performance.[125]

The subcontractors also used their stable relationship with KHI as a springboard into new industries and business networks. They initially diversified their production among various KHI divisions, especially aircraft and bus bod-

120. Ibid., 2–9.

121. Kakamigahara Shiyakusho (1990, 701).

122. Kakamigahara field study, December 1991; Kakamigahara Shiyakusho (1982, 701).

123. Friedman (1988, 192–95). Aircraft subcontractors in Kakamigahara also rely almost exclusively on regional banks rather than the *toshi ginkō*, or other *keiretsu* affiliates of the primes (Kakamigahara field study, December 1991).

124. For details of Japan's postwar political struggle between small and large firms and the regional organizations subcontractors developed and utilized to obtain protection from larger firms, see Friedman (1988, chap. 4–5); Nishiguchi (1989, chaps. 3–4).

125. Kakamigahara field study, December 1991.

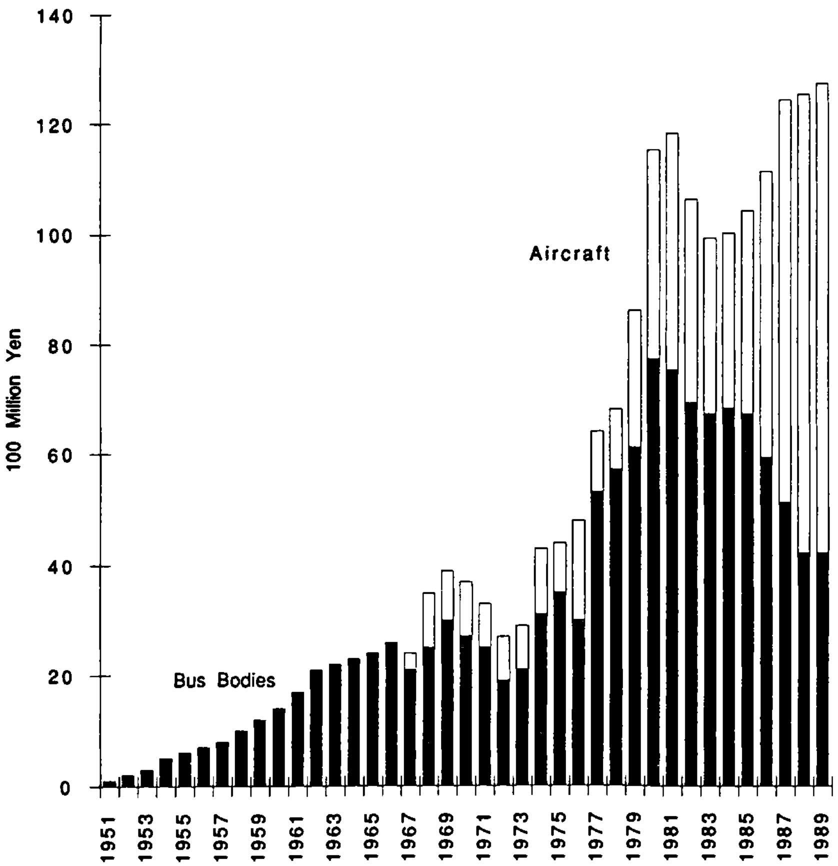

Fig. 7.1 Kakamigahara Kawasaki Kyōdō Kumiai bus bodies and aircraft business volume, 1951–89

Source: Kawasaki, Gifu Kyōdō Kumiai (1990, 128).

ies. By the mid-1980s, nineteen of the thirty-five members participated in both the bus and aircraft divisions of the *kumiai.* This enabled the subcontractors to shift their KHI production from one division to the other in response to market trends. Between 1951 and 1966, for instance, while aircraft subcontracting languished, bus-body production sustained the regional network. From 1967 onward, bus and aircraft manufacturing were largely complementary. During the oil-shock-induced 30 percent slump in KHI aircraft production of 1977–80,[126] for example, *kumiai* bus output almost doubled; as *kumiai* aircraft subcontracting grew almost 300 percent from 1983 to 1989, bus production fell by nearly 50 percent, as shown in figure 7.1.

126. Kakamigahara Shiyakusho (1987, 700).

Kumiai members also diversified their relationships with other aircraft and transportation producers and by entering other industries. In the 1950s and 1960s, the region's subcontractors relied on KHI for close to 80–90 percent of their work. By the early 1980s, however, just 35.9 percent of *kumiai* total sales were KHI-related. Over 10.5 percent of their work was with other aircraft producers, notably MHI and IHI, and 18.9 percent was with the automobile industry (table 7.5). At the same time, average *kumiai* member reliance on KHI for sales fell. Only 31 percent of the member subcontractors relied on KHI for more than 51 percent of their business (table 7.6).

Stable relations with their leading customer, KHI, therefore enabled Kakamigahara's subcontractors to diversify while maintaining their ties to the region's aircraft industry. Collectively, they were able to exploit aerospace industry technological and financial resources while pursuing other options. Some of the *kumiai* members simply used aircraft work to fill in cyclical production gaps that occurred in their primary business. For these firms, aircraft work afforded more financial than technological resources. Others actively sought to utilize aircraft technologies or process techniques in nonerospace sectors; their participation in the industry enhanced their overall manufacturing capacities. And by continually participating in and mastering military aircraft production techniques through licensed production, the region's firms developed skills that have made them increasingly competitive in commercial aerospace as well. New factories are springing up throughout Kakamigahara as the region's subcontractors, anticipating large increases in 777 subcontracting, smoothly shift from defense to civilian production. As military procurement languished in the late 1980s, large increases in international commercial project work generated for the regional aircraft industry a subcontracting growth rate of close to 300 percent for the decade.

The Kakamigahara experience contrasts squarely with American aircraft industry practices. Most U.S. primes do not form enduring regional ties or gener-

Table 7.5 **Distribution of Total Sales by *Kumiai* Members, 1981**

Kumiai Members' Customers	% of Total *Kumiai* Member Sales
KHI bus body, parts, and assembly	24.3
KHI aircraft parts and assembly	11.6
Other Japanese aircraft manufacturers	10.5
Automobile industry	18.9
Transportation-related industries	8.0
Agriculture/construction machinery	8.3
Machine tools	7.6
Electrical/construction industries	10.8

Source: Kakamigahara Shiyakusho (1985, 704).

Table 7.6 ***Kumiai* Member Reliance on KHI Bus/Aircraft Sales (percentage of total sales)**

Degree of Reliance on KHI (%)	% of Members
0–10	11.5
11–30	15.4
31–50	38.5
51–70	11.5
71–100	19.2

Source: Kakamigahara Shiyakusho (1985, 704).

ate "sticky" industrial regions; instead they actively shop for social or labor concessions from their suppliers by threatening to move, and actually moving, production to other states, regions, or countries—a process that unsettles thousands of aerospace jobs and hundreds of subcontractors. There are few, if any, arrangements in which local subcontractors collectively build regional and national political and industrial networks to bargain with U.S. primes. Interfirm information exchanges between primes and machining subcontractors are usually limited to the circulation of blueprints to several firms simultaneously for bids. Subcontracts must continually lobby teams of non–technically trained buyers at the prime even to get on a bid list, let along receive an order. Buyers move frequently from division to division and to other firms; when they do, subcontractor links with the primes can rapidly deteriorate. When asked, few American subcontractors can articulate the basis on which bids are accepted; in some cases award-winning subcontractors in one year can suddenly find, to their surprise, that their work has been cut off in the next.[127] And while Kakamigahara is flooded with investment for an expected surge in 777 orders, Puget Sound subcontractors who traditionally have close ties to Boeing have seen their work cut back so severely that many took the unprecedent step of confronting Boeing publicly with the problem.[128]

The cutbacks even prompted one of the luckier first-tier Boeing subcontractors to note that "they [Boeing] expect us to take over and maintain the links with second-tier companies. But my [subcontracting] shops are going bankrupt so fast that soon we'll have no one to subcontract to up here [in Puget Sound]."[129]

127. Puget Sound field study, January 1992.

128. There have been several accounts in the popular press about the tension between Boeing and Puget Sound subcontractors. See *Seattle News-Tribune,* December 30, and June 21, 1991; *Seattle Post Intelligencer,* June 22, 1991. According to published accounts, there are several potential explanations for the Puget Sound subcontracting work fall off, including (1) Boeing's apparent efforts to direct relationships to a smaller number of suppliers; (2) growing efforts to subcontract to non–Puget Sound regions such as Wichita, Kansas, or Tennessee; (3) moving work to foreign countries, including Japan; and (4) reducing costs by putting pressure on area subcontractors.

129. Ibid.

Kakamigahara therefore suggests how the protocol economy sustains aircraft industry producers in the game so that technology and skills accumulate and are diffused to new uses throughout Japan's production network. It is not a story of altruism or culture, but of novel organizational forms and incentives. The aircraft industry has indigenized technology, has diffused it broadly, and is organized to help assure that domestic beneficiaries are able to exploit what they learn. Even though it has not yet produced (and may not produce for several years) a competitive fly-away commercial or military aircraft, the Japanese aircraft industry is nevertheless successful because its leaders value an industry both for its ability to foster and spread knowledge and for the products it makes. They are willing to commit substantial public and private resources to maintain industries that meet these criteria, where American practice would let them die. In the process, not only does Japan build its core economic capabilities, but it also is able to embed an increasingly sophisticated defense production network in the commercial economy. In the final section, we consider some of the industrial and strategic implications of this achievement.

7.5 Conclusions

7.5.1 Ideology Matters

As we discussed above, defense and aircraft are but additional lanes on a very busy Japanese technology highway. Despite often vigorous postwar debates about how to build and maintain these lanes, it long ago became clear that commercial and dual-use technologies are racing ahead of purely military applications in Japan and in the United States. Some may argue that Japan's achievements in this regard are accidental or that Japan enjoyed a "free ride" on U.S. security guarantees during the Cold War. Still others may credit Japan's strategic vision in fostering a dual-use economy.

But none of these "explanations," we believe, sufficiently account for the institutional and strategic choices Japan made in generating its dual-use capabilities. Other nations, enjoying similar security alliances with the United States and in similar strategic circumstances, have evolved quite different dual-use capabilities. It is also difficult to credit accident with an industrial outcome that is so strikingly consistent with Japan's fundamental set of beliefs about security and the interdiffusion of technology. Finally, while Japan's particular defense industry strategies have in fact varied widely over the last century, it has nevertheless sought, if often in an ineffective and halting manner, to realize the touchstones of Japan's technology and security ideology: indigenization, diffusion, and nurturance.

The Japanese experience therefore shows that beliefs about national security and technology affect decisions about industrial structure and the way a nation evaluates its comparative global strengths and weaknesses. Japan, we believe, values industries differently than does America. Japan's security and technology ideology fosters a national consensus so basic that it is now unquestioned by virtually all industrial and political actors—that industries have importance beyond the goods they produce. Acting on this belief, the Japanese are driven to procure or develop skills and knowledge that they may lack for their domestic economy so that nonproduction benefits—especially learning and diffusion—can be realized at home. Industrial policy in Japan is guided by the effort to maintain the nation's knowledge and technology base rather than to produce a specific product to which a domestic firm might affix a nameplate.

In the United States, by contrast, companies displace one another in competition for markets or contracts, leading to wholesale capacity losses, or even complete domestic skill displacement from the American economy, which Japan would never tolerate. While many argue that the production consequences of these losses are, in fact, beneficial if overall prices fall, this position ignores the potential long-term loss that may result from the knowledge diffusion, skill development, and commercialization that will not occur. As we have seen in the aircraft industry, Japan is willing to pay (and pay dearly) for the same technical knowledge that the United States is willing to transfer abroad, because Japan values the ancillary industrial results of that knowledge as much, or more than, the ability to make specific goods.

There is, moreover, a vast gulf between U.S. and Japanese thinking about the importance of maintaining industry support mechanisms to nurture competent firms to which technology has been transferred and diffused. While Japan exerts significant efforts to assure that opportunities to form alliances, compete, and exploit learning in different ways are preserved by reducing fratricidal and exogenous market shocks, America believes that whole regions, sectors, and industries can be "given up" in the hope that new industries will emerge. But, compared to firms nurtured in systems like Japan, which consistently *build* skills and networks over time, U.S. producers may be successively weakened as they experience unshielded market shocks that are not shared by their overseas competitors.

The ideological divergence between U.S. and Japanese technology and security thinking is particularly apparent in the post–Cold War era. As the U.S. defense industrial base contracts, losing certain skills and failing to exploit commercial opportunities, the Japanese increasingly build dual-use capabilities and purchase what the Americans have incentives to discard. This is as true in defense as it is in other sectors. Japan maintains and secures across-the-board manufacturing and design technologies from abroad in a bottom-up strategy; the United States is now contemplating cutting all but top R&D functions in the defense industry on the theory that manufacturing skills are generally fungible.

Consequently, where American ideology drives firms and policymakers to seek the cheapest components regardless of the structural or domestic economic consequences, their counterparts in Japan—operating under a different set of beliefs—are motivated by a concern to obtain, diffuse, and nurture the broadest possible spectrum of skills. This striking variation in basic principles and resulting industrial choices between America and its principal economic competitor ought, we believe, to give U.S. policymakers pause. If Japan is to be our guide, the United States may be undervaluing the knowledge production and diffusion benefits domestic manufacturing networks generate. If so, a public policy concern is to ensure that indigenous production networks—in defense as in other sectors—are not sacrificed in the operation of current American industrial strategic thinking. Instead, it may be necessary to intervene to protect the nation's manufacturing networks, foster more effective collaboration among both prime contractors and their suppliers, and seek much more substantial access to foreign manufacturing networks, especially in Japan.

7.5.2 A Dual-Use Defense Industry Possible, if Not Essential

The postwar instability of domestic demand and the political impossibility of developing arms exports markets has led the Japanese defense industry to describe itself ruefully as "neither dead nor alive" (*ikasanu yō ni, kurosanu yō ni*).[130] By some measures this assessment may be correct. Although the defense industry's share of total industrial production in Japan has increased slightly since 1970, it is still less than 1 percent of total industrial production.[131] In sales, the defense industry in Japan is on the scale of the nation's sushi shops or bakeries.

But these measures greatly understate both latent Japanese defense capabilities and the country's achievements in "embedding" a military production sector within the commercial economy. By relying on the skills of its commercial producers to obtain and master dual-use technologies, as we described in the case of aircraft, Japan has generated dramatic absolute growth in its military sector. One percent of 1970 Japanese GNP is not the same as 1 percent of 1990 Japanese GNP. In any case, if Japanese defense spending is recalculated according to NATO standards (including pensions, aid, and other items that the Japanese exclude in order to stay under the nominal 1 percent ceiling), Japan actually spends 2 percent of its massive GNP on defense.[132] Despite the formal ceiling on defense expenditures that obtained until 1986, defense spending was either the first or second fastest growing item in the national budget throughout the 1980s—a decade during which the total budget more than doubled. Since the mid-1960s defense spending expanded between 5 and 8 percent each year, and actual JDA spending has risen from 300 billion yen to more than 4 trillion yen.[133] By 1984, Japan had the fourth largest naval fleet in the world, and by the late 1980s, its defense budget was third in the world. Thus, by the time Japan slowed down its defense buildup in 1993, it had built

130. Kamata (1979, 205).
131. Japan Defense Agency (1990).
132. Dekle (1989); Tomiyama (1982, 26).
133. Bōeichō . . . Kikakubu (1991, 37).

a formidable defense capability in spite of severe domestic political and international handicaps.

More importantly, unlike U.S. economic policymakers, the Japanese have never believed that silicon chips and potato chips are the same.[134] Differences between sushi and Sidewinders and between bread and ballistic missiles are profound in Japanese thinking, but not for the obvious reason that some build while others destroy. As we have described in the case of aircraft, the Japanese are convinced that advanced technology has a strategic value beyond its immediate application. Guided by this belief, the Japanese try to assess how industries contribute to the national standard of living in general. This has been true in defense as well as commercial sectors, where Japanese procurement decisions have helped to foster domestic networks and skills as well as military readiness.

The result has been the creation of a defense sector that appears particularly suited for the post–Cold War world. It might once have been arguable that Japan's defense industry choices were unsuccessful: Japan could hardly have defended itself from potential enemies such as the former USSR or even China without the equipment that the United States produced. But the view that Japan possesses a dysfunctional defense industry is losing favor as the Cold War ends, and clear, long-term military needs are being replaced by fuzzy, highly variable security options and threats. In such a world, the capability to mix and match specific design or production skills to meet military challenges, or to sustain cutting-edge technologies without bankrupting the public treasury, is becoming more valued than the ability to stamp out hundreds of guns, tanks, or fighters in publicly supported defense firms. Analysts are beginning to acknowledge that the absence of specialty aircraft makers, to cite one key element of the defense industry, is an advantage for Japan.[135]

They also have begun to acknowledge the growing confidence of the Japanese to meet national defense needs and to compete with other nations by exploiting the military capacities its commercial firms maintain. After decades of indigenizing, diffusing, and nurturing, Japanese defense production, like Japanese defense technology, is largely indistinguishable from Japanese industry as a whole. As a result, Japan is starting to appreciate that its best commercial producers could easily become the best military producers as well. The chairmen of Honda and Sony each became honorary chairmen of the Japan Defense Technology Association in 1982. As Ibuka Masaru, the chairman of Sony (and a former Naval Air Arsenal researcher) claimed when asked by the head of the Japan Defense Technology Association what targets should be set in order for Japan to achieve an autonomous defense technology base, "[It does

134. This analogy is usually credited to Richard Darman, the chief economic policy advisor to presidents Reagan and Bush.

135. Nihon Kikai . . . Kikin (1991, 7).

not matter what the targets are,] for as long as targets are set for us, we can build anything at all."[136]

Japanese defense capabilities show that military manufacturing can occur in networks of commercial firms, a capability that is now the goal of the United States as defense firms contract and attempt to convert to other purposes. But to have an indigenous defense production base embedded in the commercial economy like the Japanese, a full-spectrum commercial capability is essential. Without an effort to build and sustain lower-tier, sophisticated manufacturing networks in the United States, it will be difficult, if not impossible, to embed American defense capabilities in the commercial economy as the Japanese have done. Each of the pieces of upstream and downstream production must mesh into a seamless network from which defense capabilities precipitate.

Security, the Japanese experience suggests, means more than bombs or missiles. It also means knowledge, and a diverse top-to-bottom manufacturing economy is, in effect, a huge knowledge generator for the whole society. There is a direct relationship between a nation's economic capabilities and its technology and military security. America is only beginning to recognize this relationship much more explicitly in the post–Cold War environment.[137]

7.5.3 Strategic Use of Partners

Japanese firms and the Japanese government have defined their relationships with both domestic and foreign partners in strategic terms, consistent with the security and technology ideology we have described above. One Japanese scholar refers to Japan's international partnering strategy as involving a "two-track" policy: inviting foreign companies into relationships that could transfer technologies or enhance areas of Japanese weakness, while simultaneously building autonomous capabilities to supplant foreign dependencies.[138]

Domestic firms have evolved a system of protocols that ensure stability and shared risk. "Winners" do not "take all," nor do losers come away empty-handed. Relationships among prime contractors and between prime and subcontractors are exceptionally stable and—by U.S. standards—exceptionally interdependent. Prime contractors rely more than ever on the innovations of their subcontractors, and each exists in a complex network of alliances. The final assembly by prime contractors of components and equipment supplied by vendors and subcontractors masks extensive material, supply, and fabrication relationships. As we discussed above, prime defense contractors are directly responsible for only a fraction of Japan's arms and aircraft production.

The indigenization of both prime and subcontractor capabilities in Japan has been a phased process. While the defense industry was buffeted by clear policy shifts first toward and then away from domestic development, it was buttressed

136. Asahi Shimbunsha (1987, 150).
137. See speech by President Clinton at the Westinghouse Electric Corporation, Bethesda, MD, March 11, 1993.
138. Inoguchi (1991, 93).

and stabilized by a consistent technonational ideology. Even if Japan would not develop certain weapons systems due to political and fiscal constraints—such as the PX-L antisubmarine warfare plane that fell victim to Lockheed bribery in the 1970s—it has taken every opportunity to maximize learning from licensing.

At the same time, U.S. firms often obtained more significant revenues from licensing than from selling actual military products. The willingness to pay such premiums must be understood as part of Japanese industry's strategic use of foreign partners. Aircraft and defense technology transfers have been inbound for decades. Foreign partners are selected, not to supply cheap parts, but because they are willing to supply expensive knowledge. International cooperation, the euphemism for foreign licensing, has never been an end in itself; in the twentieth century, as in the nineteenth century, it has been a convenient means of learning the manufacturing processes that underlay the design and production of desired products. Foreign licensing has always been a second choice to domestic development, and it has served to close gaps in Japanese manufacturing technology while enhancing domestic capabilities in military as well as civilian areas. The Japanese strategic use of foreign partners is a major challenge for conventional American practices as well.

7.5.4 Reciprocity, Not Protection

Building an indigenous "full-spectrum" commercial economy that will also sustain U.S. defense capabilities is not simply a domestic problem. Rather, as the growing foreign interpenetration of American supply networks demonstrates, it is also a matter of regulating the flow and effects of overseas products and technology into the country. This may involve two seemingly opposite goals. First, to provide the kind of support and nurturing that has stimulated long-term, stable skill development in countries like Japan, U.S. firms may have to be shielded in some fashion from external shocks—including foreign competition—while domestic networks are rebuilt. At the same time, however, to obtain access and indigenize technology from abroad, the United States must avoid naked protectionism that would alienate its foreign partners. In short, the United States will have to develop its own version of the subtle blend of strategic cooperation and domestic technological nurturing the Japanese have practiced for decades.

The threat that American industrial reversals will foster crude protectionism is especially troublesome. Protectionism only ensures that, as Japan's technology highways (and those of other rapidly developing economies) become even more fully articulated, American access will be increasingly difficult and costly. Further, the day has long passed when the United States could expect to control or dominate world technology by retarding the flow of skill and know-how abroad. To do so now would be politically costly and would likely fail. Nor should America *want* to be isolated from overseas technologies, an outcome that would only ensure the nation's eventual obsolescence and generate even more profound commercial and defense consequences.

Instead, the task is to develop a rough parity with other nations in domestic full-spectrum indigenization, diffusion, and nurturing capabilities. There are several policy levers for achieving this goal. One is to spur U.S. firms to partner strategically with foreign producers to obtain technology flow-backs—that is, to obtain and then diffuse technology in the United States just as Japanese and other nations' producers have done with American know-how in the past. Another is to recognize the express connections between technology, knowledge, and national security and leverage America's substantial international contribution to international stability—especially in the Pacific Rim—for reciprocal access to manufacturing networks abroad. If global power increasingly turns on industrial capabilities, the United States will lose its capacity to bargain in the world if it fails to link itself more effectively with foreign economies in ways that assure that state-of-the-art technologies flow into its domestic economy and are exploited.

The Japanese clearly understand the subtleties involved in maintaining an open economy while seeking national advantage. They recognize that their bargaining power with other nations requires nurturing and indigenizing advanced technological capabilities. Restrictions of access to technology routinely accelerate Japanese efforts in both respects: "The United States has recently begun to increase its restrictions on technology transfer, and there has developed an increased severity of the environment hemming in the Japanese aircraft industry. We cannot expect the sorts of easy technology transfer we have experienced until now. So, it has become an indispensable premise that above all else we achieve world levels of autonomous technology by undertaking international joint development."[139] To the Japanese, building future options for accessing international networks while also localizing industrial capabilities is as essential a security task as manufacturing fighters or tanks.

Nurturing without becoming predatory and indigenizing without protectionism is a delicate and difficult task, one made more challenging by the need to insist on reciprocal treatment and access to technology networks—manufacturing associations, consortia, and regional networks—in countries like Japan that have little experience sharing.

Nevertheless, the stakes involved may require that the United States continue to press at every level for reciprocity and access—while pursuing the necessary domestic initiatives—so that at the least a stable balance of technology diffusion and indigenous capabilities with other dominant nations can be achieved. In the post–Cold War era, technology differentials will continue to affect each nation's defense capabilities. But more than in the past, a nation's defense skills will depend on the strength of its commercial economy. If differentials in commercial capabilities are allowed to widen, enriching manufactur-

139. Nihon Kikai . . . Kikin (1991, 2).

ing networks in one nation while they atrophy in another will result in unacceptable national security implications. The crucial task for the United States and Japan is to restructure their historical roles regarding bilateral technology diffusion while maintaining rounds for collaboration rather than conflict. Difficult though this goal might appear in an age of escalating transpacific recriminations, the likely alternatives appear much less attractive.

7.5.5 Regional Implications

Resolving current and potential conflicts attributable to divergent national technology and security ideologies is also essential for Asian stability. Bilateral United States–Japan disputes are merely one instance of more general problems centering on technology sharing and access that are likely to affect U.S.-Asian, Japanese-Asian, and regional relations in the future.

The pattern of American aerospace technology and product exchanges with Japan is strikingly similar to those involving South Korea, Taiwan, and Southeast Asian states. Both Taiwan and Korea have insisted on increased technology development roles for military projects with the United States, starting first with licensing and then codevelopment. They also actively seek to leverage their defense component and manufacturing capabilities to supply the U.S. and global defense and commercial aerospace industries.[140] In 1991, a Taiwanese company mounted a bid, backed in part by government funds, to purchase a stake in McDonnell Douglas's commercial transport (aircraft) operations. Countries as diverse as Singapore and Indonesia have discussed, or are developing, similar licensing and developmental strategies.[141]

The use of licensing and subcontracting to build domestic skills that can facilitate increasingly advanced defense and commercial capabilities exists throughout the world. But unlike Europe, where American and European mutual defense supply network interpenetration and close political collaboration promotes at least the appearance—if not the reality—of reciprocal U.S. technology access, American industrial interaction with Asian nations has generally not produced reciprocal technology flows. As in Japan, U.S. producers are technology suppliers, prime contractors, and component consumers. Should North and Southeast Asian economies substantially penetrate the U.S. defense supply base, or obtain growing shares of the global commercial aerospace business, many of the same tensions that are likely to afflict U.S. and Japanese relations may well recur throughout the region.

Consequently, even though the political and security contexts, and industrial

140. For an excellent review of the Korean defense industry "partnership strategy," which involves the goals of (1) supplying components to U.S. defense firms and using offsets to induce local subcontracting by American primes, (2) exporting components worldwide, and (3) collaborating in weapons technology development, see Office of Technology Assessment (1990, 133–36). A description of Taiwan's indigenization and diffusion efforts, centering on the codevelopment with General Dynamics of a two-engined fighter based on the F-16, the IDF, or Ching Kuo, and government promotion of defense-commercial industry linkages, is also found at 170–74.

141. Ibid., 164–70.

capabilities, of other Asian countries are very different form Japan, the basic issue of ensuring reciprocity and preserving a full-spectrum commercial base to support defense requirements will likely be a dominant concern for the United States in the region. Moreover, should Japanese multinationals increasingly knit the Asian region's industrial base together, purely bilateral U.S. and Japanese technology and security conflicts could well be exported throughout Asia.

Japan must also learn how to offer specific, effective reciprocal technology access to preserve its own interests in Asia. Japan's role in the region is the reverse of its historical position relative to the United States; it is a supplier, not a consumer, of technology and know-how from its Asian partners. As such it has to learn new forms of interaction with its neighbors, for as we have discussed, Japan's technology and security ideology may uneasily accommodate the transfer and sharing of industrial capabilities or opportunities. This possibility has led many Asian countries to question whether their participation in Japanese manufacturing networks could adversely affect their long-term domestic capabilities and thus their security interests. The result has been increasingly contentious efforts to force Japan to transfer technologies or to condition Japanese direct investment on reciprocity and commitments to create local business opportunities.[142]

The close and growing correlation between technology, domestic capabilities, and security may therefore drive conflict and realignment in Asia. This will likely compel America to develop strategies for obtaining reciprocity and preserving its industrial base that go beyond bilateral concerns with Japan. Japan may find that its economic efforts in Asia could be stalled if its commitment to share and develop technologies in a genuine partnership with other nations is widely questioned. Rather than observing the development of a new, Asian regional "bloc" economy, technology and security concerns could well provoke new alliances among the United States, Europe, and Asian states. The successful creation of reciprocal technology networks, or highways, could become the critical factor shaping future Asian political and economic relations. If so, technology and security issues will transcend the U.S.-Japanese bilateral relationship, and will be crucial to the stability and welfare of the Asian region as a whole.

142. A central point of contention between South Korea and Japan, for instance, was technology transfer, and many Korean companies are now canceling tie-ups with Japanese firms that have lasted for years. Singapore reportedly has also begun restricting Japanese investment in semiconductor facilities, absent more extensive technology sharing and transfer. Even in Malaysia, a country often cited as one of the seminal "look East" nations that actively prefer Japanese investment over U.S. or European ties, bilateral conflict over Japanese subcontracting, technology transfers, and local business development has erupted. See, for example, the account of Malaysian-Japanese struggles to develop ventures in automobiles and steel in Machado (1990).

Appendix A

Table 7A.1 Major Japanese Foreign Airframe Subcontracting, by Firm and Project, 1991 (including helicopters)

Firm	Aircraft	Components
	1. Mitsubishi Heavy Industries	
Boeing	737	nose landing gear steering actuator; valves
	747	inboard flaps; landing gear door actuator
	757	landing gear door actuators; fuselage longerons; valves
	767	aft fuselage; doors; landing gear actuator valves
McDonnell Douglas	MD-80	wing panels
	DC-10, MD-11	fuselage tail sections
	2. Kawasaki Heavy Industries	
Boeing	707, 727, 737, 747, 767	gearbox; machinery components
	737	inspar ribs; outside flaps
	747	outboard flaps
	767	forward, mid fuselage; cargo doors; flap actuators; wing ribs
McDonnell Douglas	MD-80	flap actuating section fairing covers
	MDX	main reduction gears
KHI/Messerschmitt-Boelkow-Blohm	BK-117	total assemblies; fuselages; main reduction gears
	3. Fuji Heavy Industries	
Boeing	747	rudder, ailerons, and fitting sheets; spoilers
	757	outside flaps
	767	fairings; main landing gear door
McDonnell Douglas	MD-11	outside ailerons
Fokker	F-50	rudders, elevators
	4. Shin Meiwa	
Boeing	757	tail unit components
	767	fuselage structural components
McDonnell Douglas	MD-80	thrust reverser components
	MD-11	engine suspenders
	5. Nihon Kokuki	
Boeing	767	structural components
	6. Teijin Seiki	
Boeing	737	landing gear actuating cylinders/ brake control valves
	747	aileron actuators; nose landing gear steering actuator
	757	aileron actuators; yaw damper

Table 7A.1 (continued)

Firm	Aircraft	Components
	767	spoiler aileron; hydraulic components; yaw damper
McDonnell Douglas	MD-11	elevator actuators
	7. Shimadzu	
Boeing	737	brake control and fuel reverse flow prevention valves
	747	aileron adjustment equipment; spoiler actuators; fuel cut-off valves
	757	aileron adjustment and cargo door actuators; gearbox
	767	gearbox; high-lift device actuators
	8. Kayaba	
Boeing	737	thrust reverser control valves
	757	valves, nose landing gear steering equipment
	767	valves; landing gear hydraulic actuators
	9. Yokohama Rubber	
Boeing	737	water tanks
	747	honeycomb structural core
	757	lavatory modules and fuel tanks
	767	composites
McDonnell Douglas	MD-11	water tanks
	10. Kobe Steel	
Boeing	737, 757, 767	titanium and steel forgings
	11. Furukawa Aluminum	
Boeing	757, 767	aluminum forgings; extrustions
	12. Japan Airline Manufacturing Company	
Boeing	757	galleys; elevators; carbon fiber pipes
	727, 737, 747, 767	galleys
McDonnell Douglas	MD-80	lavatories; cabin attendant seats
	MD-11	lavatories
Airbus	A300/310	lavatories
British Aerospace	BAe 146	galleys
	13. Minebea	
Boeing	747, 757, 767	bearings; motors
	14. Toray Industries	
Airbus	A300/310	interior component materials
	15. Mitsubishi Electric	
Boeing	747, 757	valves; actuators
	767	valves; actuators; instrument display CRTs
	16. Matsushita	
Boeing	737, 747, 757, 767	entertainment systems
McDonnell Douglas	MD-80	entertainment systems
	DC-10	entertainment systems

Table 7A.1 (continued)

Firm	Aircraft	Components
Airbus	A300/310	entertainment systems; interior component materials
British Aerospace	BAe 146	cabin entertainment
	17. Daido Steel	
Boeing	767	steel sheets
	18. Sumitomo Precision	
Boeing	757, 767	nose landing gear actuating components
Airbus	A300/340	landing gear actuating equipment
Fokker	F-50	heat exchangers and air coolers
	19. Koito Manufacturing	
Boeing	737, 757, 767	reading lights
	737, 747, 757, 767	seats
	20. Tokyo Aircraft Instruments	
Boeing	737	gyro horizons
	757, 767	spare altimeters
	21. Shinko Electric	
Boeing	747, 757, 767	cargo and general motors
	22. Tenryu Industries	
Boeing	727, 737, 747, 767	seats
	23. Japan Aviation Electronics	
Boeing	737	accelerometer
	757, 767	accelerometers; flight panel displays; air data inertial reference system
	24. Toshiba	
Boeing	767	instrument display CRTs
	25. Sony	
Boeing	767	cabin video systems
	Summary: First-Tier Subcontractors	
Boeing	737 = 13	
	747 = 13	
	757 = 18	
	767 = 24	
McDonnell Douglas	MD-80 = 5	
	DC-10 = 2	
	MD-11 = 6	
Airbus	A300/A310 = 3	
	A300/A340 = 1	

Sources: Kukita (1990, 58); *Aerospace Japan Weekly,* August 26, 1991.

Appendix B

Table 7A.2 Spinoffs from Midpostwar Japanese Military Projects, Aircraft Industry

Technology	Spillover Effects
Production Control Technologies	
Quality control methods used for F-86 and T-33	Improved techniques of process control, inspections, vendor control, etc.
Zero defects campaign	Had impacts on a wide range of civilian industries
Reliability management techniques	Became a major turning point for improving the quality of electronics products
Comprehensive transportation production system	Improved production systems operation and design
Design Technologies	
Large-scale helicopters	Improved the designing of speed governors for ships and transmissions
F-104 hydraulic system	Improved high-pressure pipes and coupling for commecial vehicles
Ink recorder	Helped development of ink-recorder oscillographs for microquality measurement
Antivibration, antishock products	Became available for general electronics control systems
Tantalum condenser commission development	Enabled Japanese domestic test of condenser
Test/production of gyroscopes	Contributed to the development of precision equipment
Ground-air telemeter transponder	Contributed to the development of communication microwave technologies
Designing of aircraft heat exchangers	Contributed to the development/mass production of car heaters that use exhaust gas
Jet-engine bearing manufacturing technology	Contributed to the development of durable railcar bearing
Application of aircraft gas turbine to ships	Expanded the applicability to electric generators and ships
Aircraft measuring equipment technology	Enhanced the quality of general high-class measuring equipment
Ceramic brake lining for F-104	Applied the lining technology to buses and other general vehicles
Connector technology	Applied to railcars
Shield beam lamp	Applied its major characteristics—high illumination, small size, light weight, and durability—to general-purpose products
High-pressure oil filters	Contributed to the improvement of filters for automobiles and machine tools
High-pressure hose for F-104	Improved the quality of general-purpose hoses
High-temperature fuel	Contributed to the improvement of tank tester techniques for designing large-scale, high-pressure test chambers

Table 7A.2 (continued)

Technology	Spillover Effects
Manufacturing bolts for F-104 engines (J-79)	Improved the quality of bolts for automobiles
Manufacturing self-locking nuts for aircraft	Improved the quality of self-locking nuts (especially ones with nylon) for automobiles
Domestic production of navigation equipment and gyroscopes	Improved the inertial navigation technology
Domestic production of simulators	Applied to simulators for other areas (e.g., railway, automobile)
Hydraulics controller technology	Improved overall hydraulics control
Information-processing technology	Applied to other information-processing equipment to be used to process radar information
Information-display technology	Applied to other equipment to display symbolized signals
Manufacturing Technologies	
Divided-sleeve technology used for F-104's valve	Improved the quality of precision servovalves for general-purpose soil-pressure equipment
Speed limit assurance testing of T-1A	Applied to range of other transportation test and measuring equipment
Domestic production of aircraft material	Improved overall materials technology
High-pressure technology used for F-104's hydraulic	Improved the hydraulics technology for industrial products equipment such as plunger pump motors
Automatic wiring test technology	Applied computer-aided test technology to other equipment
Module technology	Applied module assembly/manufcturing technology to other equipment
Wiring identification	Applied baking method to other technologies and antiheat wirings
Electrolytic manufacturing method for turbine rotor for air gas hard processing turbine	Applied to the molding of general-hydraulic equipment material
Welding technology for rocket chambers	Achieved JIS 2-class technology and improved the overall quality of welding
Adhesive technology including honeycomb structure	Applied to general-purpose equipment such as stable panel and bus door
Aluminum welding technology	Applied to the manufacture of general-purpose heat exchangers
Prevention of bacteria corrosion of metal products	Improved the technology to prevent bacteria corrosion of metal products
Adhesive technology for aircraft copper, antiheat alloy, and ultra-heat shields	Applied adhensive technologies for antiheat alloys to automatic generation and magneto-hydro dynamics generation
Jet engine parts processing technology	Applied cutting and molding technologies in other industries
Jet engine parts forging technology	Applied to industrial gas turbine parts

Table 7A.2 (continued)

Technology	Spillover Effects
Aircraft parts electron discharge method (EDM)	Applied to industrial gas turbine parts processing technologies
Precision grinding, polishing, and processing technologies	Applied to special processing treatment of industrial products to reduce engineering tasks
Improved hydraulic technologies	Applied to the installation of industrial oil-pressure control chambers and to cylinders
Metal-plating technology	Contributed anticorrosion and high degrees of precision to the development of special metal-plating technologies for industrial products
Welding technology	Applied high-reliability spot-welding to industrial products
Heat treatment technology	Improved stability in heat treatment for industrial products
J-58 engine ignition system	Applied to antivibration, antishock treatment by reducing size and weight
Technology for plating nickel onto aluminum plate used for J-79 ignition	Applied to other industrial products in reducing size and weight of parts
Military dual-side-printed circuit board	Manufactured through-hole, circuit boards commercially
Special CRT technology	Contributed to the enhancement of high-definition CRT technology
Other Technologies	
Explosive forming technology ued for F-104 fuselage parts	Applied forming technology for metal processing, leading to the widespread use of large-scale presses
Duct hose used for F-104	Applied to the auto industry
O-rings for aircraft	Applied to the general-purpose oil-pressure equipment in other industries
Disk brakes for jet aircraft	Used in automobiles and rapid railways
Plastic tooling introduced for F-86	Used for automobiles and engine turbine blades
Anodizing process developed for F-86	Increased durability and reduced weight for other machine parts
Reinforced plastic developed for F-104	Used in YS-11 and MU-2, as well as in buses, automobiles, and general-purpose machinery
F-104 chemical milling technology	Applied to other machinery processing to cut costs
Jet engine bearing technology	Used for bullet trains
Mentor Trainer oil cooler technology	Improved heat exchangers such as general-purpose radiators, car coolers, and car heaters

Sources: Keidanren Bōei Seisan Iinkai (1965, 285); Bōei Kiki Sangyō Jittai Chōsa Iinkai (1968, 81–84).

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Comment Gregory W. Noble

This study of the Japanese aircraft industry by David Friedman and Richard Samuels, with its emphasis on the success of Japan's "bottom-up" strategy of concentrating on producing materials and composites in dual-use plants, is nothing if not provocative. It directly contradicts conventional wisdom about the weakness of the Japanese aerospace industry. Especially arresting is the description of the deepening relationship between Boeing and its Japanese suppliers. Backed by impressive technical skills and the buying power of Japanese airlines, Japanese suppliers have increased their share of value-added in each generation of Boeing aircraft and now dominate Boeing's foreign procurement, the authors say. Nor, they argue, is the Japanese role confined to standard parts: Japanese suppliers have been integrated into the design and engineering of the forthcoming 777. The material on subcontracting and small-firm networks also addresses a gaping hole in the existing literature on aerospace in both countries. If the authors are right, the American aerospace industry faces serious challenges from Japan just as Airbus is consolidating its position as chief rival to Boeing. Given the economic, technological, and symbolic importance of aerospace, intensified political struggle among the advanced industrial countries could be in the offing.

Friedman and Samuels posit three elements in Japan's aircraft industry, and in technology policy more broadly: (1) indigenization—the active acquisition of every type of technology rather than simple acceptance of some fixed position in the international division of labor; (2) diffusion—active dispersion of technology throughout assembler-supplier networks, across civilian and military products, and among prime contractors, particularly through repeated cooperative projects; and (3) nurturing—a combination of promotion and insurance against instability.

If the approach is new and provocative, and some of the data are striking, the analysis is not yet complete, and the evidence not yet sufficiently comparative. First, the paper is remarkably lacking in politics. Much could be done in this area. For example, it is possible that the balance of diffusion and nurturing,

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and the support for supplier networks, follows from the electoral system and patterns of political contributions in Japan: prime contractors in the aerospace industry, like large Japanese firms more generally, supply contributions on a prorated basis to the party headquarters and faction leaders of the Liberal Democratic party (LDP), while smaller producers give votes and money to individual LDP members (Curtis 1988, 176–87). Perhaps this two-tiered pattern of political intervention in Japanese technology policy has served to promote competition and innovation, and not simply rent seeking and protectionism.

Second, the discussion of ideology is sketchy. Do we actually need to look beyond specific institutions and the incentives they create? Perhaps ideology can be conceptualized as a kind of platform binding together a coalition of diverse interests. If so, closer attention to the patterns of overlap and competition among those interests is in order.

Third, the comparative evidence is not always complete and convincing. Technology spillover from military aircraft to the civilian sector in Japan may have been significant in the 1950s and early 1960s, but that was true in the United States as well. As the authors note, the picture for recent years is cloudy, because the political sensitivity of the industry has blocked more recent efforts to assess the contribution of military aircraft production to the civilian economy. On the American side, the authors stress the relative weakness of diffusion policies, but possible counterexamples exist and their effectiveness could be explored: NASA in the 1960s, the Defense Advanced Research Project Agency (DARPA), and the diffusion requirements in Department of Defense procurement regulations. A preliminary glance at the literature suggests that a possible difference is Japan's emphasis on including subcontractors and not simply primes. Similarly, the authors stress that Japanese aerospace firms are efficient and flexible partly because they mix military and civilian production—but is that a cause, or an effect of some other difference in strategy or organization? Grumman tried to move into bus production, as Kawasaki had done so successfully in Japan, but it could not compete in the civilian market. Why the difference? Finally, many first-tier subcontractors in both Japan and the United States mix civilian and military production, yet by the authors' account the Japanese subs are rapidly displacing American producers of aerospace materials and components. Why?

Even if the Japanese industry is organized differently, it is not always clear from this account exactly how it functions. If every major postwar aircraft project has been organized cooperatively, why has the result not been inefficiency and stagnation, as some foreign critics suggest (Mowery and Rosenberg 1985, 19)? If diffusion is critical, why do firms with proprietary technology not block efforts to diffuse their knowledge and skills to competitors—and to the extent that it does occur, why does diffusion not undermine the incentive to innovate? And just how do the crucial vertical regional producer associations (*kumiai*) and horizontal cooperation associations of subcontractors (*kyoryoku-kai*) actually work (Doner 1992)?

Finally, the paper takes little note of the international context. Cold War alliances made the United States willing to defend Japan and to supply it with advanced technology. The Japanese industry did not have to undertake serious defense production and was able to treat each military project as an exercise in technology acquisition and development. The American industry, in contrast, was shaped by the need to develop effective weapons and by an obsession with leading-edge technology, to offset the Soviet advantage in numbers, and with secrecy, to prevent the loss of that technological edge. The contrasting positions of the two countries in the postwar security system thus go a long way toward explaining why they adopted different industrial strategies in aerospace, particularly the greater distance between military and civilian production in the United States.

These reservations notwithstanding, the basic thrust of the article rings true: Japan's position in supplying advanced materials and parts is extremely strong, and Japan has poured tremendous effort into the acquisition and dissemination of technology; the United States has fallen behind in both areas and often fails to recognize the problem. In the FS-X case, for example, the United States was attentive to the short-term economic interests of the prime defense contractors, but paid little attention to identifying and acquiring Japanese technology, and knew little about the capabilities of American subcontractors (Noble 1992). Judging from the evidence in this paper, little progress has been made since the signing of the FS-X agreement. In the case of the space station (and the superconducting supercollider), Japan seems unwilling to support U.S. projects financially without greater opportunities to acquire technology in return.

Aerospace is, to be sure, an unusual industry: barriers to entry are almost uniquely forbidding, governmental subsidies and politicized procurement play crucial roles in the competitive struggle, and in Japan cooperative production has been the norm. Nevertheless, the broader theme of Japan's obsession with the acquisition and diffusion of technology and skills can be seen across the industrial spectrum.

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