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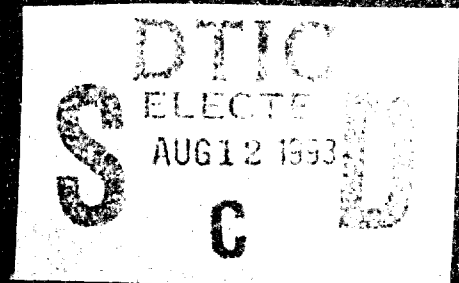
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February 1990

# U.S.-JAPAN CODEVELOPMENT

## Review of the FS-X Program



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National Security and  
International Affairs Division

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February 6, 1990

The Honorable Jeff Bingaman  
The Honorable Alfonse M. D'Amato  
The Honorable Alan J. Dixon  
The Honorable Wendell H. Ford  
The Honorable Jesse A. Helms  
United States Senate

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This is an unclassified version of a classified report that responded to your request to review the Support Fighter (FS-X) codevelopment program between the U.S. government and the government of Japan. We assessed (1) the extent to which the Department of Defense (DOD) coordinated and consulted with the Department of Commerce when negotiating the FS-X agreement, (2) the principal provisions of the government-to-government and commercial licensing agreements, (3) the process for transferring U.S. F-16 technology to Japan, (4) the Japanese composite wing and phased array radar technologies and U.S. requirements for these technologies, and (5) costs and scheduled delivery dates for the FS-X compared to the cost of purchasing an F-16. Between March and May 1989, we briefed your staffs on the status of our work; this report summarizes those briefings and presents the final results of our work.

## Results in Brief

Although the fiscal year 1989 DOD authorization legislation required DOD to consult with Commerce in negotiating such agreements, DOD provided only a cursory briefing on the FS-X agreement to Commerce personnel. As negotiated and concluded, the U.S.-Japan FS-X arrangement involves the joint development of an F-16 derivative fighter aircraft and production of six prototypes. Under the agreement, Japan will receive U.S. design and development assistance, and the United States will receive a 40-percent work share of Japan's estimated \$1.2 billion FS-X development budget. The U.S. government is limiting the release of certain technical data to protect national security and industrial base interests.

The United States will have access to (1) all F-16 derived technologies, including composite wing technologies, at no cost, and (2) solely Japanese-developed FS-X technologies, such as the active phased array radar, at an undetermined price. While DOD did not consider access to the wing and radar technologies to be a key issue in the arrangement, it believed these technologies could be useful to the United States. Available information indicates that the United States is currently superior in composites and phased array radar technologies.

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The codevelopment and production of 130 FS-X aircraft are estimated to cost Japan about twice as much as an off-the-shelf purchase of F-16s from the United States would cost.

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## Consultation and Coordination

In negotiating the FS-X agreement with the government of Japan, DOD did not coordinate with or solicit the views of the Department of Commerce. The National Defense Authorization Act of Fiscal Year 1989, approved September 29, 1988, requires DOD to consider the effects of each Memorandum of Understanding on the U.S. industrial base and to regularly solicit and consider information and recommendations from the Secretary of Commerce. In response to the law, DOD provided a cursory briefing to Commerce on the FS-X program in late October 1988 near the conclusion of the bilateral negotiations.

In early 1989 Members of Congress and the economic agencies, including the Department of Commerce, expressed concern about the equity of the FS-X agreement and technology to be transferred. In response to these concerns, the President commissioned an interagency review in February 1989, co-chaired by Defense and Commerce, to study the arrangement. Based on the results of the review, the U.S. government sought and received from Japan clarifications to the agreement, including a commitment to about a 40-percent work share for the United States if the program enters into a production phase. Procedures are being developed by DOD and Commerce to ensure coordination and consultation on future programs.

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## Benefits to the United States

Although national security interests were said to be of paramount importance in the FS-X program, during the negotiations, DOD recognized U.S. economic and industrial interests as well. The U.S. work share will amount to 40 percent of Japan's estimated \$1.2 billion developmental budget—about \$480 million. Additionally, the United States will obtain cost-free FS-X technology that is derived from U.S.-provided F-16 technology. For example, General Dynamics, the prime U.S. contractor, will obtain from Japan the technology to produce four composite wings for the program. The United States is also guaranteed the option of purchasing technology that is solely developed by the Japanese.

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## F-16 Technology Release

Unlike previous F-16 coproduction agreements, which have released operations, maintenance, and production data, the FS-X program will release certain F-16 design and software data as well. The U.S. government will limit the release of sensitive software source codes for the F-16's avionics systems but will not release source codes for the digital flight control system.<sup>1</sup> In addition, the United States will not release any manufacturing or design data on the engines, which must be purchased from a U.S. manufacturer during the developmental phase of the program.

A joint U.S.-Japanese Technical Steering Committee was established to monitor key aspects of the FS-X program, including the transfer of technology. The Department of Commerce will have a representative on the Committee. The Committee will consider requests from Japan for technical data.

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## Japanese FS-X Technologies

DOD did not pursue the FS-X program with the primary objective of obtaining access to Japanese technology; however, once Japan agreed in principle to codevelop the FS-X, DOD stressed the importance of obtaining access to the new aircraft's technologies. DOD officials emphasized the potential value of the Japanese technology, including composites and airborne radar. DOD believes that the FS-X program sets a precedent for two-way exchanges of military technology.

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## Active Phased Array Radar Technology

Japan is developing an active phased array radar for the FS-X, and DOD is interested in evaluating and possibly acquiring the manufacturing technology used to produce the radar's transmitter/receiver modules. U.S. industry is developing similar radar technology for the next-generation fighter aircraft. The modules are very expensive to produce, and both the United States and Japan are working to develop a manufacturing process that produces affordable, quality modules.

U.S. industry is making considerable progress toward reducing module costs. According to one company's estimates, the module's unit cost has declined from about \$12,000 to about \$8,300 (1985 dollars) over the past 4 years. Anticipated full-rate production costs are estimated to be about \$400 per module by 1997 to 2005. According to U.S. government

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<sup>1</sup>A source code is a series of human-readable statements that describe the operations, functions of a particular computer program. The source code provides access and insight into the methods and analyses used to develop a specific program.

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and industry sources, the United States is ahead of Japan in overall radar development.

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## Composite Technology

Japan is planning to produce composite wings for the FS-X using a process known as co-curing. This process reduces the need for fasteners that hold the wing together. The Japanese approach appears to be high risk because of manufacturing and quality control uncertainties and damage repair problems. The United States expended significant research and development efforts in the 1970s to test and evaluate the basic co-cured composite design that will be used for the FS-X wing. Air Force engineers told us that the designs were rejected for combat aircraft wings, which carry fuel and withstand significant stress.

The U.S. industry's basic knowledge of advanced composites is superior to Japan's. The United States has a demonstrated and proven capability in composite production and application to military aircraft. For example, the U.S. AV-8B has composite wings, but fasteners are used to ensure high confidence in the joints. The United States uses co-curing techniques on structures like tails, which are subject to less stress than wings.

The U.S. trend is toward the use of thermoplastics, a different type of composite material from that proposed for the FS-X. Thermoplastics are more heat resistant than FS-X wing composites. Future U.S. military aircraft will need the more heat resistant materials because of expected performance requirements. The U.S. military requirement for the Japanese composite technology appears to be modest at this time. The Air Force has indicated that the prime use for this technology would be on future versions of the F-16, if the wing proves affordable.

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## Cost

Developing the FS-X will cost Japan more than purchasing F-16s from the United States. According to an Air Force estimate, the most advanced version of the F-16 produced in the United States would cost Japan about \$28.6 million per aircraft (U.S. 1988 dollars), if purchased through foreign military sales procedures. The unit cost of the FS-X is estimated to be about \$61 million (U.S. 1988 dollars).

These matters are discussed in more detail in sections 1 through 7.

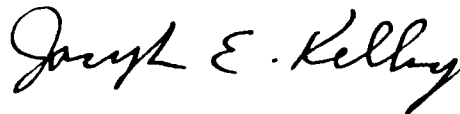
## Agency Comments and Our Evaluation

We obtained written comments on a draft of this report from the Departments of Defense and Commerce (see app. II and III). The Department of State had no comments. DoD agreed with the information and conclusions presented in the report but made technical comments that have been included, as appropriate. Commerce agreed with most of the information presented but reemphasized the success of the interagency review process and noted the administration's concerns about trade, economic, and industrial competitiveness implications of agreements such as the FS-X agreement. Commerce also emphasized that it remains actively involved in reviewing technology release in the program. Finally, Commerce stated that our analysis of the two Japanese technologies—composites and phased array radar—was speculative because it remains to be seen whether or not these technologies will be of value to the United States.

Regarding this last point, we recognized, and noted in our draft report, that some benefits may be derived from these Japanese technologies. Nevertheless, numerous U.S. government and industry aerospace and electronics engineers agreed that the United States maintains an advantage in the overall development and application of these technologies.

Copies of this report are being sent to interested congressional committees; the Secretaries of Defense, State, and Commerce; and other interested parties.

Major contributors to this briefing report are listed in appendix IV. If you have further questions about this report, please call me on (202) 275-4128.



Joseph E. Kelley  
Director, Security and  
International Relations Issues

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# Contents

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Letter		1
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Section 1		10
Background	Summary	10
	Japan's FS-X Program Stressed Domestic Development	10
	DOD Considered Japanese Off-The-Shelf Purchase of U.S. Aircraft Unlikely	10
	DOD Position Separated Trade Issues From Defense Issues	11
	DOD Questioned Japan's FS-X Requirements	12
	FS-X Not Pursued With Primary Objective of Obtaining Access to Japanese Technology	12
	DOD's Negotiating Position Stressed Quality and Quantity Work-Share and Technology Flowback	13
<hr/>		
Section 2		15
FS-X Consultation and Coordination	Summary	15
	DOD's Consultation With Commerce Was Minimal	15
	Previous U.S. Attention to Economic Implications of Coproduction Was Inadequate	16
<hr/>		
Section 3		18
Government-To-Government and Commercial Arrangements	Summary	18
	Under the Agreement, Japan Will Take Lead in FS-X Codevelopment Program	18
	United States Will Receive 40 Percent of Development and About 40 Percent of Production Work Share	19
	Technology Flowback Provisions Allow U.S. Access to Japanese Technologies	19
	Program Strives to Maintain Interoperability	19
	Third-Party Sales of U.S.-Origin Technology Are Restricted	20
	Commercial Arrangement Implements Government-To-Government Agreements	20
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Section 4		22
Technology Transfer	Summary	22
	FS-X Involves Greater Release of F-16 Technical Data Than Previous Coproduction Programs	22
	Safeguarding Technology Poses a Challenge	23

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Contents

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---

DOD Has Procedures for Reviewing Technology Release and Is Currently Reviewing Data Lists	23
DOD Plans to Limit Release of Flight Control and Avionics Software	24
Sanitized Fire Control Computer Software Source Codes to Be Released	25
Physical Safeguards Are Planned to Reduce Potential for Inadvertent Disclosures	25
The Technical Steering Committee Will Monitor Technology Flow	26
Commercial Application of FS-X Technology Is Uncertain	26

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Section 5  
Active Phased Array  
Radar Technology

Summary	28
DOD Is Interested in Japanese Radar Module Production Technology	28
U.S. Knowledge of Japanese Radar	28
U.S. Industry Is Making Significant Advances in Reducing Module Cost	30
Benefits to the United States Are Questionable	30

---

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Section 6  
Composite Wing  
Technology

Summary	31
Japan Claims Its Proposed Composite Wing for the FS-X Is 25 Percent Lighter Than a Metal Wing	31
Japanese Wing Has Potential Merits and Disadvantages	32
The United States' Composites Capability Is Excellent and Superior to Japan's	33
The United States Has Produced All Composite Wings but Has Chosen to Employ Fasteners to Increase Confidence	33
The U.S. Requirement for Japanese Technology Is Modest	33

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Section 7  
Cost

Summary	35
Off-The-Shelf Purchase Is More Cost-Effective	35

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Appendixes

Appendix I: Objectives, Scope, and Methodology	36
Appendix II: Comments From Department of Defense	38
Appendix III: Comments From the Department of Commerce	45
Appendix IV: Major Contributors to This Report	50

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**Contents**

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**Abbreviations**

DOD	Department of Defense
FS-X	Support Fighter
JDA	Japan Defense Agency



# Background

## Summary

- Japan's FS-X program stressed domestic development.
- DOD considered Japanese off-the-shelf purchase of U.S. aircraft unlikely.
- DOD position separated trade issues from defense issues.
- DOD questioned Japan's FS-X requirements.
- FS-X not pursued with primary objective of obtaining access to Japanese technology.
- DOD's negotiating position stressed quality and quantity work-share and technology flowback.

## Japan's FS-X Program Stressed Domestic Development

In the late 1970s, the Japan Defense Agency (JDA) began considering replacing its fleet of domestically produced F-1 fighter support aircraft. At about the same time, JDA began funding next-generation fighter studies, primarily to identify requisite technologies. Attention was focused on and funding provided for advanced metallurgy, composite materials, stealth technology, and advanced avionics.

Japan considered various options for its replacement candidate, including an off-the-shelf purchase and domestic development. Advocates of domestic development organized quickly and included JDA's Air Staff Office, private industry, and JDA's research and development arm, the Technical Research and Development Institute. In 1985, the Institute announced that Japan possessed the domestic capability to develop—except for the engine—an advanced fighter for about \$1 billion.

## DOD Considered Japanese Off-The-shelf Purchase of U.S. Aircraft Unlikely

Starting in 1985 DOD, with the Department of State's assistance, took steps to persuade the government of Japan not to develop its own aircraft. DOD preferred that Japan purchase an off-the-shelf U.S. aircraft but recognized that such a purchase was highly unlikely. DOD made several attempts to encourage Japan to buy a U.S. aircraft such as the F-16 or F/A-18. At the same time, DOD recognized that Japan, as a sovereign nation, could not be forced to purchase an aircraft from the United States. In the past, Japan had rejected direct purchase marketing efforts by U.S. airframe manufacturers. Further, Japan had been producing U.S. aircraft under license since the mid-1950s, including most recently the F-15. In February 1989, DOD stated that there has never been any realistic possibility that Japan would buy a U.S. aircraft off the shelf.

The F-1 was produced by Mitsubishi Heavy Industries from 1977 to 1984. It is used by the Japanese Air Self-Defense Force, for ground and ship attack.

Japan considered economic factors that precluded an off-the-shelf purchase. DOD noted that Japan intended to keep its aerospace industry active and ensure continued employment of its engineers. DOD officials believed that from Japan's perspective, it made no sense to buy current U.S. aircraft or even produce them under license due to Japan's investment in the research and development of components such as radar, avionics display systems, and composites. An additional factor was that Japan had obtained considerable manufacturing know-how over the years from various licensed production programs with the United States. Through these programs, however, Japan had not acquired the critical knowledge that is derived from designing and developing a sophisticated military aircraft.

In 1986 DOD established a policy position that offered a compromise, since Japan was not interested in purchasing a U.S. fighter aircraft or producing one under license. The policy suggested that a cooperative venture—codevelopment—between the United States and Japan could be a viable alternative. DOD noted that Japan seemed to be interested in codevelopment if it could retain leadership of the project. The policy statement set the tone for future government and industry discussions with Japan.

## DOD Position Separated Trade Issues From Defense Issues

DOD separated trade and economic issues from national security issues during preliminary FS-X discussions. DOD believed that Japan's pursuit of the domestic development option would blur the distinction between trade and defense and elevate congressional concerns about the program. Further, DOD believed that domestic development would signal Japan's commitment to a program that would not be cost-effective, would have considerable risks associated with the development of a new aircraft, and would lead to potential delays in deployment.

In a series of meetings, high-level U.S. government and Japanese officials discussed the need to keep trade and defense issues separate. These discussions were part of a continuing U.S. effort to encourage Japan to reject domestic development. In August 1987 DOD and JDA agreed to cooperate in the development of the FS-X aircraft and to base the new aircraft on a modified version of an existing U.S. fighter. In October 1987 JDA selected the General Dynamics F-16 as the baseline aircraft for the FS-X.

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## DOD Questioned Japan's FS-X Requirements

DOD analysts considered Japan's FS-X mission requirements too narrow and some of the proposed performance requirements unrealistic. Some DOD officials believed that Japan had developed such performance goals to exclude U.S. aircraft from consideration and justify domestic development. These officials believed that Japan had designed the FS-X in part to accommodate various domestic technologies without adequately analyzing other available options.

After considerable urging, JDA agreed to hear DOD's presentation of its assessment of the threat and mission requirements and to consider U.S. industry proposals for modifying an existing U.S. fighter aircraft to meet Japan's requirements. In April 1987, a DOD team presented its assessment of the threat and operational requirements to JDA. The team advanced DOD's position that an existing or modified U.S. fighter would meet most of the FS-X's mission and operational requirements and at the same time save a considerable amount of time and money.

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## FS-X Not Pursued With Primary Objective of Obtaining Access to Japanese Technology

The United States was primarily concerned with finding a compromise solution for the FS-X that would maintain the overall bilateral security relationship with Japan. According to DOD, its priorities were to (1) ensure that the FS-X maintained interoperability with U.S. forces in the region and (2) maximize the capability Japan received for its defense expenditures. DOD officials recognized, however, that the program would create the opportunity to gain insight into and derive potential benefits from Japanese FS-X-related technologies.

Because acquiring Japanese technology was not paramount, DOD did not extensively review Japan's FS-X-related technologies. In April 1987 a DOD team made a 3-day visit to various Japanese industries to learn more about the technologies identified by Japanese officials as significant for the FS-X. These technologies included the active phased array radar and composites. The team concluded that these technologies were significant and of high quality but not unique. (See sections 5 and 6 for further details about the Japanese radar and composites.)

## DOD's Negotiating Position Stressed Quality and Quantity Work-Share and Technology Flowback

Government-to-government negotiations for the FS-X program began in November 1987. The primary objectives of the U.S. negotiating team were to

- obtain an adequate U.S. development work share, both in quantity and quality (an initial 40- to 60-percent goal was established);
- obtain free and automatic flowback of any technical improvements that Japan made to the baseline aircraft, for example, rights to F-16 derived technology at no cost and access to all Japanese-developed FS-X technology;
- establish a joint DOD-JDA steering group to implement, oversee, and manage the program; and
- obtain provisions for a 30- to 70-percent U.S. production work share (excluding the engine).

In a May 1988 report accompanying the Fiscal Year 1989 Defense Authorization Act, the Senate Armed Services Committee urged DOD to obtain a meaningful work share for U.S. industry and acquire without charge any technological improvements substantially derived from technology provided by the United States. Further, the report stated that the U.S. government should not enter into a memorandum of understanding with the Japanese government on the FS-X/F-16 that simply transferred American technology and jobs to Japan with nothing more than a license fee in return. According to a high-level DOD official, this recommendation reinforced DOD's negotiating position and emphasized the requirement to obtain Japanese technologies.

Initially, Japan was unwilling to allow General Dynamics to produce any composite wings, citing increased program costs and reduced program efficiency. According to DOD, wing production became the symbol of a meaningful two-way exchange of technology. Additionally, the U.S. Air Force believed that the Japanese co-cured composite technology was the single most important item of technology that would be created during the FS-X program. Without transfer of this technology, the United States would reap few benefits from participating in the program. A high-level DOD official said that our government was prepared to walk away from the program if there was no wing production in the United States. Japan conceded this point and agreed to permit the U.S. contractor to participate in the production of wings.

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**Section I**  
**Background**

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The memorandum of understanding was signed on November 29, 1988. During later discussions, Japan agreed on the overall level of U.S. participation in the development program, including the production of FS-X composite wings.

# FS-X Consultation and Coordination

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## Summary

- DOD's consultation with Commerce was minimal.
- Previous U.S. attention to economic implications of coproduction was inadequate.

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## DOD's Consultation With Commerce Was Minimal

In negotiating the FS-X agreement with the government of Japan, DOD did not coordinate with or solicit the views of the Department of Commerce. Section 824 of the National Defense Authorization Act, Fiscal Year 1989 (P.L. 100-456), September 29, 1988, requires DOD to consider the effects of each government-to-government memorandum of understanding on the U.S. industrial base and to regularly solicit and consider information and recommendations from the Secretary of Commerce.

In response to the law, DOD provided a cursory briefing to Commerce officials in late October 1988 near the conclusion of the bilateral negotiations. In November 1988 DOD denied Commerce's requests for a copy of the memorandum. According to Commerce records, DOD argued that the briefing sufficiently allowed Commerce to comment on the project's effect on the industrial base and therefore satisfied the statutory requirement for consultation. After a series of discussions between DOD and Commerce legal officials, the memorandum was forwarded to Commerce in mid-December 1988.

DOD officials told us that it was inappropriate to initiate full consultation and coordination with Commerce on FS-X because the negotiations were virtually complete by October 1988.

Subsequent to the signing of the memorandum, Members of Congress and the economic agencies, including Commerce, raised questions about the equity of the proposed agreement and the technology to be transferred to Japan. In February 1989, the President commissioned an inter-agency review of the FS-X arrangement, co-chaired by Defense and Commerce, to study the agreement.<sup>1</sup> The review focused on the impact that production of the FS-X would have on the U.S. industrial base and competitiveness and sought to establish interagency procedures for coordination and consultation of defense cooperative agreements.

Based on the review, DOD agreed to notify the Secretary of Commerce of its intent to begin negotiations on a memorandum of understanding prior

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<sup>1</sup>Other members of the interagency review included the Departments of State, Labor, and Energy; the Office of the United States Trade Representative; the Office of Science and Technology Policy; the National Security Council; and the Central Intelligence Agency.

to the opening of discussions with foreign governments. Throughout future negotiations, Commerce will have full access (as an adviser) to negotiations, documents, memorandums of understanding, industry-to-industry agreements, and other relevant documents. Commerce will analyze the impact of the proposed agreement on the industrial base and provide assessments to DOD on a continuing basis. No agreement will be concluded until full consultation with Commerce has been completed. At the time of our review, procedures to implement this process were being developed.

DOD is now providing Commerce with proposed memorandums of understanding for comment. In commenting on our draft report, Commerce stated that it has established a cooperative relationship with DOD on the FS-X program and is reviewing other defense-related cooperative agreements as well.

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## Previous U.S. Attention to Economic Implications of Coproduction Was Inadequate

Prior to the fiscal year 1989 legislative requirement and the subsequent interagency review of the FS-X arrangement, major defense items were transferred without full consultation with the economic agencies. In 1982 we reported that when negotiating a coproduction agreement with Japan on the U.S. F-15 aircraft—and on other military coproduction programs as well—DOD and State separated the U.S. defense and foreign policy interests from the domestic economic, industrial, and labor considerations.<sup>2</sup> DOD and State did not systematically draw upon the available expertise of other federal agencies when considering coproduction requests or when negotiating and implementing these programs. On the other hand, Japan and other countries included such interests in their decisions to coproduce rather than purchase off-the-shelf U.S. aircraft. We stated that it is appropriate for U.S. allies to consider their economic interests when addressing defense issues, but it is just as appropriate for the United States to do the same.

We noted that national security objectives were of prime consideration when the United States entered into coproduction arrangements and did not take exception to these objectives. We expressed the view that DOD and State had too narrow a perspective to adequately address the economic, industrial, trade, and labor interests and concluded that increased interagency and government-industry coordination was needed prior to making coproduction commitments.

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<sup>2</sup>U.S. Military Coproduction Programs Assist Japan in Developing Its Civil Aircraft Industry (ID-82-23, Mar. 18, 1982).

We recommended that the Secretary of State take the lead, in cooperation with DOD and pertinent civilian agencies, to form a clearer and more comprehensive military coproduction policy that would fully recognize the trade and economic implications of these arrangements, as well as the political and military goals to be achieved. We further recommended that these agencies (1) establish procedures to coordinate consideration of allies' requests to coproduce high-technology items; (2) develop, with input from industry, criteria for conducting economic assessments—to include the impact of impending transfers on U.S. industry—before approving and negotiating coproduction agreements; and (3) participate with DOD in determining the releasability of high technology originally denied in memorandums of understanding.

The Departments of Commerce, Treasury, and Labor and the Office of the U.S. Trade Representative generally agreed with our conclusions and recommendations. Although the State Department had some reservations about our analysis of the relationship between coproduction and Japan's civil aircraft industry, it agreed that the U.S. government should more carefully consider the economic implications of coproduction and that greater interagency coordination was needed. DOD agreed with the need for interagency coordination but noted that the existing system provided for careful review of all coproduction requests. DOD stated that a formal mechanism was neither necessary nor desirable.

Our recommendations were not implemented. We believe that had these measures been followed, some of the questions concerning technology transfer and the resultant economic impact on the U.S. industrial base would have been considered and addressed before the FS-X memorandum of understanding was negotiated and signed.

# Government-To-Government and Commercial Arrangements

## Summary

- Under the agreement, Japan will take lead in FS-X codevelopment program.
- United States will receive 40 percent of development and about 40 percent of production work share.
- Technology flowback provisions allow U.S. access to Japanese technologies.
- Program strives to maintain interoperability.
- Third-party sales of U.S.-origin technology are restricted.
- Commercial arrangement implements government-to-government agreements.

## Under the Agreement, Japan Will Take Lead in FS-X Codevelopment Program

The United States and Japan will cooperate to develop the FS-X aircraft. The FS-X is to be based on the F-16 C/D aircraft, will incorporate U.S. and Japanese technology, and will be significantly modified to meet requirements established by JDA. Japan will develop and manufacture the following advanced technology avionics systems: the active phased array radar, the mission computer, the inertial reference system, and the integrated electronic warfare system. Japan will purchase the engines to be installed in the prototype aircraft from a U.S. manufacturer.

U.S. industry, led by General Dynamics, will participate in development of the wing and in the development and integration of the aircraft's avionics systems. Certain integration of systems is reserved solely for U.S. industry because of the sensitivity of the data or techniques involved or due to proprietary rights. In these instances, Japan can either integrate the systems without U.S. assistance or accept U.S. assistance with certain technology transfer restrictions. For example, as discussed in section 4, the United States has determined that source codes for the F-16 flight control computer will not be released to Japan. Japan has the option of accepting this restriction or developing the data on its own.

JDA is responsible for leading the FS-X program. It will have final authority over the aircraft's configuration, scheduling, cost, and other procedures needed to meet system requirements. JDA plans to develop and produce six prototype aircraft—four for flight testing and two for ground testing. JDA will bear all the necessary costs for the FS-X within the amount of its budget authorization, estimated to be \$1.2 billion, and will pay the U.S. government a research and development recoupment charge for each FS-X manufactured. Nothing in the agreement obligates the U.S. government to expend funds.

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## United States Will Receive 40 Percent of Development and About 40 Percent of Production Work Share

Japan agreed that the U.S. work share will reach 40 percent of the entire FS-X development budget. For budgeting purposes, the U.S. work share is \$480 million. The 40 percent remains constant despite any currency fluctuations. The agreement did not make a firm production work share commitment. In an exchange of letters dated April 28, 1989, between the Secretary of State and the Japanese Ambassador to the United States, Japan agreed that if the program entered into production, the United States would receive approximately 40 percent of the value of the total production work.

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## Technology Flowback Provisions Allow U.S. Access to Japanese Technologies

JDA will transfer to the United States, at no cost, technology derived from the F-16. DOD will also have access to non-derived technology, that is, data developed solely by Japan. These technologies can be purchased through established procedures.<sup>1</sup> In the April 28, 1989, exchange of letters, Japan identified four non-derived technologies associated with the project—radar, electronic countermeasures, inertial reference system, and mission computer hardware. If the use of U.S. technology is essential to the development of these Japanese technologies, they will be considered derived and available to the United States at no cost. Further, Japan agreed that the United States will have access to all technology associated with the FS-X that it wishes to obtain.

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## Program Strives to Maintain Interoperability

Japan agreed that the FS-X should achieve, to the degree possible, interoperability with existing U.S. military systems. DOD believes that the FS-X will be interoperable with the F-16 and other U.S. weapon systems; that is, it will use the same ground support equipment, have compatible communications and data link systems, and be capable of in-flight refueling from the same equipment. Certain FS-X components, such as the engines, will be interchangeable with U.S. aircraft. DOD recognizes that the majority of the FS-X structure and the major avionics systems, such as the radar and the mission computer, will be different from those in the F-16.

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<sup>1</sup>In November 1983, the government of Japan agreed to permit the export of military technology to the United States. All U.S. requests for Japanese military technology must be addressed through diplomatic channels to a Joint Military Technology Commission. The Commission consists of senior representatives of the various Japanese government agencies and U.S. Embassy officials. According to DOD, few transfers of Japanese military technology have been made under this agreement.

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## Third-Party Sales of U.S.-Origin Technology Are Restricted

Japan agreed that all technical data, information, and documentation provided by U.S. manufacturers or DOD will be used only for development and are prohibited from transfer to a third party without the U.S. government's prior approval. Further, no defense articles or technical data provided or developed from information provided by the United States will be sold or transferred to a third party without prior approval.

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## Commercial Arrangement Implements Government-To- Government Agreements

The memorandum of understanding has been implemented under a commercial license and technical assistance agreement, which was signed on January 12, 1989, by General Dynamics and Mitsubishi Heavy Industries. Mitsubishi will be the prime contractor, and General Dynamics will provide technical assistance and produce certain parts of the FS-X. General Dynamics' work share will be 30 percent of the FS-X development cost. The remaining 10 percent is reserved for other U.S. contractors. Included in General Dynamics' work share is a license fee of \$60 million.

General Dynamics' technical assistance includes (1) explaining the technical data provided under the agreement; (2) providing advice on the design, development, and production of the FS-X; and (3) making recommendations on the effect of changes to the F-16 design. Other tasks include

- leading in the design, development, and manufacture of the aft fuselage and certain hardware and software systems;
- participating (extent still to be determined) in the development of the modified F-16 digital flight control system's hardware and software; and
- designing, developing, and manufacturing the wing's leading edge flaps.

General Dynamics will provide qualified personnel to Mitsubishi for engineering, design, and production support. Both contractors will establish program offices in the United States and Japan to support the technical representatives of their respective companies. General Dynamics officials expect to have as many as 70 people in Japan during the program.

General Dynamics will have an in-depth, fully integrated, and involved role in all significant aspects of the overall FS-X wing project, including design, development, manufacture, and testing. Japanese industry will be the overall project leader. General Dynamics will manufacture 4 of

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**Section 3  
Government-To-Government and  
Commercial Arrangements**

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the 14 co-cured composite wing boxes.<sup>4</sup> The wing boxes manufactured by General Dynamics will be subjected to the same level of testing as the Japanese-manufactured wing boxes to ensure an equivalent level of quality.

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<sup>4</sup>The wing box is the major structural portion of the stationary wing. It includes the internal frame and wing skins, or top and bottom covers.

# Technology Transfer

## Summary

- FS-X involves greater release of F-16 technical data than previous coproduction programs.
- Safeguarding technology poses a challenge.
- DOD has procedures for reviewing technology releases and is currently reviewing data lists.
- DOD plans to limit release of flight control and avionics software.
- Sanitized fire control computer software source codes to be released.
- Physical safeguards are planned to reduce potential for inadvertent disclosures.
- The Technical Steering Committee will monitor technology flow.
- Commercial application of FS-X technology is uncertain.

## FS-X Involves Greater Release of F-16 Technical Data Than Previous Coproduction Programs

The FS-X codevelopment program will involve a greater release of F-16 technical data than previous coproduction agreements. Previous F-16 coproduction programs have released operations, maintenance, and production data to Denmark, the Netherlands, Norway, Belgium, and Turkey. A key distinction between these coproduction programs and the FS-X is that the FS-X will require the release of certain F-16 design data, such as wind tunnel test data, used for wing design and development. The release of the design data is required to enable Japan to develop an aircraft based on the F-16 design. During the interagency review, Commerce and DOD agreed to minimize the release of design data and jointly developed a list of sensitive F-16 technical data to be withheld to protect U.S. national security and industrial competitiveness.

The FS-X program will require the release of certain F-16 software that will help the Japanese incorporate their avionics systems into the aircraft. General Dynamics will provide systems integration assistance to Japan to accomplish this complicated task. For example, General Dynamics will help integrate Japan's mission computer with other avionics systems, such as the radar and inertial navigation system. This integration assistance will require a close working relationship between U.S. and Japanese engineers. According to DOD, the integration process represents a significant departure from other aircraft coproduction programs, which generally involve the foreign country's manufacturing and/or assembling existing U.S.-designed and integrated components.

## Safeguarding Technology Poses a Challenge

Safeguarding the transfer of technology to Japan during the course of the program poses a significant challenge. According to DOD, the volume of data to be provided will be greater than would be transferred under coproduction or direct purchase. The FS-X will use the F-16 Block 40 aircraft as a baseline for development. Some of the F-16 technical data that will be provided to Japan include F-16 production drawings, performance data for the 375 square-foot wing considered for the Agile Falcon (F-16 derivative), engineering changes adopted to enhance the safety of the Block 40 aircraft, and sanitized computer software interface and integration data.

Because of U.S. security and proprietary reasons and because Japan will incorporate many of its own avionics components in the FS-X, numerous items and components will not be included in the F-16 technical data package. Some of the excluded items include radios, landing gear, radar, electronic warfare systems, an inertial navigation system, and a central mission computer. For these items, only data that describes communications between aircraft computer systems, known as interface data, will be provided. Japan has the option of either developing these systems and components or buying them from U.S. vendors.

Engines for the development phase aircraft will be sold as end items. Only integration and cost data needed to select and install engines will be provided. DOD will consider releasing engine production technical data after a production memorandum of understanding is negotiated. DOD will not consider releasing certain technical data for parts of the engine, such as the digital fuel control system and the "hot section" (where combustion occurs).

## DOD Has Procedures for Reviewing Technology Release and Is Currently Reviewing Data Lists

DOD has established procedures for determining the release of military technology and data to foreign countries. Procedures are in place to consider the types of technical data eligible for release based on industrial and security-related criteria. Within DOD, technology release reviews are conducted through a multilayered process that includes the Defense Technology Security Administration, the National Disclosure Policy Committee, and the military services.<sup>1</sup> These organizations established guidelines for controlling the release of F-16 technical data.

<sup>1</sup>The Defense Technology Security Administration reviews the international transfer of defense-related technology, goods, and services, consistent with national security and foreign policy objectives. The National Disclosure Policy Committee formulates and administers specific criteria and conditions that must be satisfied before a decision is made to release classified military information to foreign governments and international organizations.

The Air Force, in coordination with the Defense Technology Security Administration, drafted a Delegation of Disclosure Authority Letter, which provides criteria on what technical data can and cannot be released to Japan in support of the program. A team of Air Force engineers is reviewing the F-16 technical data list—item by item—to determine releasability of specific information. The team is identifying data that must be sanitized to remove sensitive elements prior to release based on military security or industrial base concerns. Selected key data will also be reviewed by technical personnel from the Defense Technology Security Administration prior to its release. Commerce also reviewed the releasability guidelines and will continue to review technology release issues.

## DoD Plans to Limit Release of Flight Control and Avionics Software

The release of F-16 systems integration data has been closely scrutinized by DoD and other executive branch agencies. Specifically, the release of F-16 digital flight control and fire control computer software source codes was given special consideration.

The digital flight control computer software—the fly-by-wire system—enables the F-16 to maintain stability and maneuver quickly and safely. The flight control software is considered state of the art, is unique in its sophistication, and can have direct application to commercial aircraft. DoD has not released digital flight control software source codes to any nation. Japan is no exception. DoD and Commerce agreed that if Japan chose to request U.S. assistance, General Dynamics would develop the flight control software for the FS-X in the United States, and the resulting software object codes<sup>2</sup> would be provided to Japan only as an end item. A limited number of Japanese engineers will be permitted to observe the development and tests of the software for the FS-X so that Mitsubishi Heavy Industries can ensure the validity and readiness of the software for the flight test. DoD plans to withhold source codes during the development stage and, more importantly, to deny hands-on experience and participation in the development process of the software for the digital flight control computer.

After completion of the FS-X flight test program and after a production memorandum of understanding has been negotiated, release of the source codes may be reconsidered to allow Japan to maintain and

<sup>2</sup>The object code is derived from the source code. It consists of a series of numbers (0s and 1s) that a computer reads to perform designated functions and operations. The object code does not provide insight or access into analyses or methods used by software engineers to develop a particular computer program.

update the developed software. At the time of our review, it was uncertain whether or not Japan would agree to these restrictions. If not, Japan will probably develop its own software for the FS-X flight control computer.

## Sanitized Fire Control Computer Software Source Codes to Be Released

DOD will release sanitized F-16 fire control computer software source codes to help Japan develop and integrate its mission control computer into the FS-X. The FS-X mission control computer performs the functions of the F-16 Block 40 fire control computer. The fire control computer is a critical part of the F-16 avionics system. It integrates various on-board systems that enable the pilot to effectively fire weapons at the target. During the February-March 1989 interagency review of the FS-X program, DOD and Commerce disagreed on releasing F-16 fire control computer source codes to Japan. DOD believed certain portions of the source codes should be released, while Commerce maintained that all the source codes should be withheld. DOD's position was accepted by the National Security Council.

In the April 28, 1989, exchange of letters, the United States informed Japan that it will receive access to the source codes necessary to develop the mission control computer. According to DOD, the source codes will be sanitized, giving Japan the "know what" but not the "know why." In other words, the sanitized source codes provide the outcome but not the methods used to arrive at the outcome.

According to General Dynamics, its engineers will work with Japanese engineers during the development and integration of the mission computer. They noted that U.S. contractor assistance will enable Japan to develop the system more quickly, but the United States will gain access to Japanese systems as a result.

## Physical Safeguards Are Planned to Reduce Potential for Inadvertent Disclosures

Physical safeguards are planned to minimize inadvertent disclosures of withheld technical data and know-how. General Dynamics and Mitsubishi Heavy Industries engineers will be located in a separate area of the F-16 plant at Fort Worth, Texas. Contractor engineering teams will be limited to using a reference library of releasable documents and will be required to display distinctive badges.

The U.S. engineers will be given periodic disclosure awareness briefings by Air Force representatives. The U.S. engineers located in Japan will be similarly briefed by the Air Force FS-X liaison officers stationed there.

General Dynamics will prepare a Technology Control Plan that will be approved by DOD. The plan is designed to ensure that unauthorized data or methods are not revealed at the General Dynamics facility in the United States or by contractor personnel in Japan. General Dynamics officials recognized, however, that it would be difficult to guard against inadvertent disclosures because of the close working relationship among the engineers.

## The Technical Steering Committee Will Monitor Technology Flow

A Technical Steering Committee was established to oversee the implementation of the FS-X program. The Committee, which is co-chaired by high-ranking U.S. and Japanese military officers, will have a representative from the Department of Commerce. U.S. membership primarily includes technical/program managers from the F-16 System Project Office.

The Committee will, among other things, monitor the transfer of technical data to Japan. According to high-level DOD officials, the Committee will be the forum for all requests for release of technical data made by Japan during the course of the development program. The requests for consideration will be channeled to the appropriate technical officials at the Air Force's System Project Office and Foreign Disclosure Policy Office. Requests that fall within the guidelines of the Delegation of Disclosure Letter may be approved. Requests that are outside the established guidelines will be staffed by the Air Force Vice Chief of Staff's Disclosure Policy Office and reviewed by Defense and Commerce Department officials. According to DOD officials, this process will elevate releasability issues to better ensure full and complete review and reduce the opportunities for imprudent disclosures.

## Commercial Application of FS-X Technology Is Uncertain

Japan has targeted aerospace as one of its key technologies for the 21st century. U.S. government officials informed us that the skills and knowledge acquired from the FS-X program can generally be applied to other aviation-related programs. Japanese engineers will gain valuable experience in systems integration. Systems integration consists of combining various aircraft components to work with each other to perform mission-related functions. Japan will integrate various avionics components and subsystems into the FS-X. For example, if Japan decides to develop its own digital flight control system, significant integration skills will be acquired and applied to complete the task. DOD and civilian agency officials stated that Japan has had limited experience in systems

integration, and these officials consider it an art learned only through the "school of hard knocks."

The extent to which these systems integration-related skills are directly transferrable to commercial aircraft development is uncertain. Information available to us indicates that no individual project in the series of U.S.-Japan coproduction programs over the past 30 years gives Japan the technological keys to bridge the competitive gap. However, the cumulative knowledge gained from a broad range of successful joint ventures between the United States and Japan may reduce the time and expense it will take Japanese firms to catch up and become meaningful competitors in the aerospace/aircraft manufacturing industry.

# Active Phased Array Radar Technology

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## Summary

- DOD is interested in acquiring Japanese radar module production technology.
- U.S. knowledge of Japanese radar.
- U.S. industry is making significant advances in reducing module cost.
- Benefits to the United States are questionable.

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## DOD Is Interested in Japanese Radar Module Production Technology

As part of the FS-X program, Japan has been developing an active phased array radar that uses elements called transmitter/receiver modules located in the radar's antenna.<sup>1</sup> These modules can improve range, increase the number of targets tracked simultaneously, reject jamming, and enhance reliability. The critical challenge is to develop manufacturing processes to produce efficient, quality modules that are affordable. There are about 2,000 modules in a radar antenna, and each module currently costs U.S. industry about \$8,300 (fiscal year 1985 dollars) to produce. Thus, the cost of a single antenna would be about \$16.6 million. U.S. companies are currently developing active phased array radars and modules for advanced fighter aircraft—the Advanced Tactical Fighter and the Advanced Tactical Aircraft. U.S. industry's goal is to reduce module costs to about \$400 per module.

The active phased array radar technology is well known. The ability to reduce the size of the modules and produce them at affordable costs is a significant task that remains to be accomplished. DOD would like to acquire from Japan the manufacturing technology for the radar's modules. The government-to-government agreement enables the United States to evaluate and purchase the radar technology that will be developed by Japan under the program. The United States does not know what the cost of procuring the technology will be at this time.

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## U.S. Knowledge of Japanese Radar

DOD's efforts to obtain adequate data to assess performance of the Japanese radar, including test and evaluation results, have been largely unsuccessful. In April 1987, a DOD team visited the Mitsubishi Electric Corporation's facility, which is producing the transmitter/receiver modules. The team saw the modules and described them as impressive, although DOD did not have a radar specialist there. Part of the team also visited the facility where the entire radar was being flight-tested.

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<sup>1</sup>Transmitter/receiver modules are comprised of circuits using gallium arsenide semi-conductor chips. Although the production of gallium arsenide materials and devices is still maturing, their use can surpass conventional silicon devices in speed, power, efficiency, and resistance to radiation effects. Both the United States and Japan are using gallium arsenide technology in the development of their active phased array radar's modules.

expecting to see the radar. According to the DOD team leader, the Japanese refused the team permission to view the radar due to performance problems. The team requested test and evaluation data on the radar, but Japanese officials refused to release this information as well.

In January 1988 DOD attempted to obtain additional information about Japanese radar technology to assess its potential benefits. Detailed technical questions were submitted prior to the trip, but little information was provided. A DOD technician was not permitted to see the radar and was told by Japanese industry officials that the information was proprietary, classified, and not releasable.

In March 1989 the Air Force's Wright Research and Development Center described Japan's radar as a "quick development aimed at drawing even with the U.S. technology base." The Center stated that Japan appeared to have less radar experience than the United States and lacked vital knowledge in terms of defining module performance. U.S. industry representatives had told the Center that they had not witnessed any new Japanese radar technology, only good engineering. In their view it was unlikely that any significant technology flow from Japan would result from the FS-X agreement. U.S. government and industry officials explained that the size of the modules must be reduced to fit in the nose of high performance interceptor aircraft. The Center noted, for example, that Japan's modules were about 6 inches long, which resembled U.S. industry development in about 1983. In 1988, one U.S. company's demonstration/evaluation modules were about 2-1/2 inches long.

An official from the Center's Electronic Technology Laboratory received information from a knowledgeable U.S. industry representative who had observed the Mitsubishi Electric Corporation's production facility and had discussions with its officials in March 1989. The industry representative stated that Japan did not have a phased array radar module production facility similar to anything in the United States. He observed that the Japanese facility was of "soldering iron vintage." Mitsubishi established a cost goal of \$1,250 per module for the array and a maximum production rate, with a relatively low level of automation, of only 1,000 modules per month. Mitsubishi officials admitted to the U.S. industry official that their prior claims of the radar's successful development were "all hype" and that their concern was that if they did not make these claims, their own government would likely purchase an array from the United States.

These observations parallel other U.S. government reports, which state that Japan is having difficulty reducing the overall costs of the radar. Indications are that high costs may limit the number of modules in each Japanese radar; limiting the number of modules will reduce the radar's capabilities. This information also contrasts sharply with earlier, optimistic claims of the Japanese government and industry.

### **U.S Industry Is Making Significant Advances in Reducing Module Cost**

From our discussions with U.S. industry officials and observations of module production facilities, we concluded that the United States is making significant advances in reducing the cost of the modules. Officials from various U.S. companies said that the key will be to reduce the modules' cost through high-volume production. According to one company's estimates, the unit cost of the modules has been reduced from about \$12,000 to about \$8,300 over the past 4 years, a decrease of 31 percent. The companies anticipate that the cost will continue to decline steadily as production increases. For example, by 1992, the unit cost should be about \$3,100. Anticipated full-rate production costs are about \$400 per module by 1997 to 2005 for about 2.3 million modules. This cost is generally accepted by U.S. industry as the cost that would make the antenna and radar affordable. These cost figures are in fiscal year 1985 dollars.

### **Benefits to the United States Are Questionable**

According to DOD, Japan has become a world leader in the design and manufacture of consumer electronics. Its ability to apply new designs to production is well developed. If Japan's knowledge of manufacturing technology is applied to the transmitter/receiver module production, significant advances are likely. Further, the Wright Research Development Center's Deputy Director said it would be wrong to assume that the United States is significantly ahead of Japan. He stated that the Japanese are extremely skilled and have a proven capability in electronics. He stressed the importance of obtaining access to their module technology to evaluate the manufacturing process.

Available information indicates that the United States is ahead of Japan in developing the manufacturing technology necessary to reduce the costs of the radar's transmitter/receiver modules. As a result, the Japanese radar and associated manufacturing processes are of questionable value to the United States in the near term.

# Composite Wing Technology

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## Summary

- Japan claims its proposed composite wing for the FS-X is 25 percent lighter than a metal wing.
- Japanese wing has potential merits and disadvantages.
- The United States' composites capability is excellent and superior to Japan's.
- The United States has produced all composite wings but has chosen to employ fasteners to increase confidence.
- The U.S. requirement for Japanese technology is modest.

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## Japan Claims Its Proposed Composite Wing for the FS-X Is 25 Percent Lighter Than a Metal Wing

Japan is offering critical composites technology related to the wing structure, called the wing box. Japan proposes to make the long stiffening pieces (spars) and the short cross pieces (ribs) out of strong plastics called composites. The strength of the composites comes from the stringy filaments made of carbon fibers, which are held in place with an epoxy glue.

The top and bottom layers of the wing (skins) will also be of composites but will be made in a different way from the spars and ribs. The skins will have thin composite "cloth," or tape, laid in arranged directions with varying thicknesses. In some places there will be up to 160 layers. Composite wing skins are built up, as contrasted with metal wings, which are cut down from a thick piece of metal.

According to DOD and industry officials, the FS-X wing spars, ribs, and bottom skin will not be fastened together with bolts. Rather, the spars and ribs will be carefully placed on the bottom skin. All of the parts contain epoxy and are held in position with special tooling. The structure will be inserted into an oven (autoclave), where the pieces will become bonded. This process is called co-curing; the epoxy becomes hard and stiff. This composite is termed a thermoset. The upper skin also has to be cured, either alone or in conjunction with the structure. If cured alone, the upper skin would need to be fastened to the structure. With this design, the Japanese hope to save 25 percent in weight compared to a new, all-metal wing.

DOD and U.S. industry officials do not have good information as to whether or not the Japanese can produce the wing as planned. Through its participation in the FS-X program, General Dynamics will be able to evaluate and verify the Japanese design and capability.

DOD noted that the Japanese co-cured composites technology had never been demonstrated on a full-size, wet (fuel inside), contoured wing box.

JDA admitted that the co-cured composite wing technology was not mature and that Japanese industry could not manufacture the proposed FS-X wing. JDA believes that the technology will become mature enough to be incorporated into the FS-X wing within 2 years. Although Japan coproduces significant parts of the F-15, the aircraft has very little in the way of composites and does not have a composite wing. Japan did some research and development on the 7J7 tail under contract to Boeing. Boeing planned the 7J7 as its next generation civil airliner. The tail was to be a large structure made from composites, but Boeing postponed the 7J7 program because of changing commercial demand.

U.S. personnel have seen an FS-X wing specimen. U.S. government and industry officials do not know exactly what composites will be used or how the Japanese plan to tool for the production operation. Further, the Japanese have not made data on design, manufacture, and testing available to the United States. This data would permit evaluation of the wing or specimen.

According to U.S. government and industry design engineers, the Japanese approach is high risk. The United States expended significant research and development effort in the 1970s to test the basic co-cured composite designs now being considered by Japan for the FS-X wing. According to Air Force engineers, the design—tested on small structures—was rejected because of manufacturing and quality control problems.

## Japanese Wing Has Potential Merits and Disadvantages

The proposed Japanese design has both advantages and shortcomings. If Japan is successful, the composite wing may have advantages over metal wings: perhaps better performance in terms of reduced weight and increased durability, perhaps lower costs in the long run considering there could be fewer parts. One of the merits of co-curing is the avoidance of problems and complexities associated with drilling many holes and using expensive fasteners. Co-curing also overcomes the problem of leaks that can occur when fasteners are used. There are potential problems: it is difficult to maintain quality control with respect to the bonds over a long production run, tooling for production at low cost is very complex, and production inspection of small corners and large areas requires innovative procedures. Additionally, access to fuel control equipment is restricted, and damage repair may be limited.

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## The United States' Composites Capability Is Excellent and Superior to Japan's

Available evidence indicates that the U.S. industry's basic knowledge of advanced composites for aerospace is excellent and superior to Japan's. The United States has many suppliers and fabricators and is skilled in aircraft applications. While fundamental principles of composites are available worldwide in handbooks, there are many "tricks to the trade," especially for manufacturing. These tend to be company proprietary. There are varying levels of maturity in the U.S. industry. The consensus among industry experts is that General Dynamics is behind some other U.S. aircraft manufacturers in composites technology because the F-16 aircraft has few composite components.

The United States has a demonstrated and proven capability in the production of composites. Industry has co-cured many parts of aircraft, especially "secondary" structures such as rudders and ailerons. The United States currently produces composite rib/spar/skin secondary structures for fighters and has co-cured the large AV-8B horizontal tail, a primary structure. The United States has manufactured large skins for aircraft tails and for combat aircraft wings. The Marines have extensive fleet experience with the AV-8B under high stress. That aircraft has wavy spars and a wet wing like those proposed by Japan.

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## The United States Has Produced All Composite Wings but Has Chosen to Employ Fasteners to Increase Confidence

The biggest difference between the U.S. work and that planned for the FS-X lies in co-curing the substructure to the bottom skin. For example, while the AV-8B has composite spars and ribs, they are fastened to the bottom and top skins. This practice is currently preferred to ensure high confidence in the joints. While secondary structures and tails have been co-cured, wings of combat aircraft require a substantially different consideration. The latter must withstand far more stress (g's) and carry fuel. The X-29 and the A-6, which have composite skins, were designed with some metal substructure because of their loads.

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## The U.S. Requirement for Japanese Technology Is Modest

The U.S. requirements for Japanese composite technology for military aircraft and civilian aircraft may be different. In the case of military aircraft, there is always a requirement if the wing can be made lighter and cheaper, and the trend is toward increased use of composites. The U.S. Air Force has indicated that the prime use for co-cured thermoset wings would be future versions of the F-16, if the wing proves affordable. The Japanese co-cured thermoset technology may not be in much demand for the next generation of fighters, partly because the flight schedules for the Air Force's prototype Advanced Tactical Fighter and the Navy's Advanced Tactical Aircraft are ahead of the FS-X and partly

because the Air Force's performance requirements may pose problems for thermosets.

To meet the higher temperature requirements for future aircraft, the U.S. trend is toward the use of thermoplastics. This material is formed under pressure in warm molds and becomes hard when cooled. Autoclaves are not used to set the composites. According to industry experts, thermoplastics currently have very high costs but will have some future application.

Composite requirements for civilian airliners are more difficult to assess, since there are many aircraft customers. It is not likely that the Japanese composite technology would be applied to current airliners like the MD-80 and the B-757/767, since they are already being produced at a high rate. By the year 2000, composites may be useful in airliners like the MD-91X and the B-7J7 propfan (for example, the tails) if the costs are low. Thermoset composites are not expected to be widely used for the next generation of supersonic aircraft replacing the Concorde due to the high temperatures at high speed. For the same reason, the thermosets would not be applicable to the future hypersonic aircraft, of which the X-30 is a technical demonstration experiment program.

# Cost

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## Summary

- Off-the-shelf purchase is more cost-effective.

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## Off-The-Shelf Purchase Is More Cost-Effective

Developing the FS-X will cost Japan more than purchasing F-16s from the United States would cost. The Air Force has estimated that it would cost the Japanese about \$28.6 million (U.S. 1988 dollars) to purchase each F-16 Block 50 (most advanced version) from the United States through foreign military sales procedures. Under these procedures, the total unit flyaway cost of the F-16 is about \$17.2 million per aircraft. This includes a research and development recoupment charge of about \$1.2 million. Additional support costs of about \$11 million are factored into the estimate. These support costs include spares, maintenance, and training. According to the U.S. Air Force, Japan would probably require this level of support for the aircraft.

This cost estimate does not include any modifications that the Japanese would want to meet performance requirements similar to those for the FS-X. Most foreign countries like to have special modifications, which add to the cost of the aircraft. (This estimate is like buying a car with no options.) According to the Air Force, initial F-16 deliveries could occur about 36 to 42 months after a government-to-government agreement is signed. According to the contractor, delivery of all 130 aircraft would take about 2 years.

According to DOD, Japan's estimates of total FS-X program costs are preliminary and subject to change as the program develops. These early cost estimates include \$1.2 billion for the development phase and about \$5 billion for the production phase. General Dynamics has roughly estimated the FS-X unit cost to be about \$61 million (U.S. 1988 dollars). The procurement cost for each aircraft is anticipated to be about \$46 million, and the unit estimate for development, potential flight test, and program growth is about \$15 million per aircraft.

# Objectives, Scope, and Methodology

In letters dated January 30, 1989, and March 21, 1989, Senators Jesse Helms, Jeff Bingaman, Alan Dixon, Wendell Ford, and Alfonse D'Amato expressed concern about the proposed FS-X codevelopment program between the U.S. government and the government of Japan. They were concerned that the program signaled a greater Japanese interest in obtaining research and development experience rather than in providing effectively and efficiently for their own defense.

In response to the Senators' requests, we assessed (1) the extent to which DOD coordinated and consulted with the Department of Commerce when negotiating the FS-X agreement, (2) the principal provisions of the government-to-government and commercial licensing agreements, (3) the process for transferring U.S. F-16 technology to Japan, (4) Japanese composite wing and phased array radar technologies and U.S. requirements for these technologies, and (5) costs and scheduled delivery dates for the FS-X compared to the purchase of an F-16.

In doing our work, we obtained information from various U.S. government and industry sources. We primarily reviewed program files and had extensive discussions with DOD and U.S. Air Force program and technical officials in Washington, D.C., and the F-16 System Project Office, Dayton, Ohio. From these records and discussions, we obtained background information, including the negotiating history; assessed F-16 technology releasability issues and procedures; analyzed cost data; and reviewed the government-to-government and commercial licensing agreements.

To assess the technology issues, we met with structural, design, and electronics engineers at the Air Force's Wright Research and Development Center, Dayton, Ohio. We also met with industry representatives from Hughes Aircraft Corporation, Westinghouse Electric Corporation, Texas Instruments, Inc., McDonnell Aircraft, and General Dynamics Corporation. In addition, we contacted numerous other industry technical officials to further assess U.S. capabilities and obtain information, to the extent available, about Japanese capabilities.

We also met with officials from the Departments of State, Commerce, Energy, Labor, and the National Aeronautics and Space Administration to obtain information on the consultation process and other general background information on the FS-X.

Due to the continuing bilateral negotiations to clarify certain aspects of the program, we did not visit Japan to obtain the views of appropriate

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**Appendix I**  
**Objectives, Scope, and Methodology**

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government and industry officials. Further, we did not specifically assess the commercial application of the FS-X codevelopment program. In our discussions with U.S. government and industry officials, we did, however, solicit their views on the issue.

We conducted our review between February and May 1989 in accordance with generally accepted government auditing standards.

# Comments From Department of Defense

Note GAO comments supplementing those in the report text appear at the end of this appendix

GAO DRAFT REPORT - DATED AUGUST 29, 1989  
(GAO CODE 463776) OSD CASE 8000-G

"U.S.-JAPAN CODEVELOPMENT: REVIEW OF THE FS-X PROGRAM"

DEPARTMENT OF DEFENSE COMMENTS

\* \* \* \* \*

## FINDINGS

**FINDING A: The DOD Encouraged Japan to Purchase an Off-the-Shelf U.S. Fighter.** The GAO reported that, in the late 1970s, Japan began to consider replacement of its domestically produced fighter. The GAO reported that the Japanese Technical Research and Development Institute, the department responsible for R&D within the Japan Defense Agency, believed that Japan had the domestic capability to develop the new fighter--except for the engines. The GAO observed that Japan considered economic factors such as employment in its aerospace industry and the knowledge gained from various licensed production programs with the U.S. The GAO also observed that, while DOD made several attempts to encourage Japan to buy a U.S. fighter off-the-shelf, it generally assumed that there was not any realistic possibility of this occurring. The GAO reported that, ultimately, as a compromise between U.S. and Japanese interests, DOD proposed a cooperative venture between the two countries. The GAO noted that, in August 1987, the DOD and the Japan Defense Agency agreed to cooperate on the development of the FS-X aircraft--to be based on a modified version of an existing U.S. fighter. The GAO found that DOD analysts influenced Japan to consider broader requirements for the aircraft than Japan had initially defined--and also convinced Japanese officials that an existing or modified U.S. fighter could meet most of these requirements.  
(pp. 11-16/GAO Draft Report)

**DOD Response:** concur.

**FINDING B: The DOD Consultation with Commerce was Minimal.** The GAO reported that the DOD and the Department of State did not solicit the views of the Department of Commerce or other economic policy-making agencies in negotiating the agreement--despite the requirement to do so in the Defense Authorization Act for Fiscal Year 1989. However, the GAO did note that, in

Enclosure

Now on pp 8-10

October 1988, the DOD did provide a cursory briefing to Commerce. The GAO reported that, subsequently, in February 1989, the President commissioned an interagency review to study the agreement--which was co-chaired by DOD and Commerce. The GAO found, based on the review, the U.S. Government sought and received clarifications to the agreement, including the stipulation that the U.S. would receive approximately 40 percent of the workshare if the FS-X goes into production. The GAO reported that, for future agreements, the DOD agreed to (1) notify Commerce prior to initiating discussions on a Memorandum of Understanding with a foreign government, (2) provide full access (as an advisor) to negotiations and to relevant documents, and (3) not to conclude agreements until consultation with Commerce was completed.  
(p. 1, p. 3, pp. 20-24/GAO Draft Report)

Now on pp 1-2 13-14

DOD Response: Concur.

**FINDING C: The DOD Primary Reasons for Concluding the FS-X Agreement with Japan was not Access to Japanese Technology.** The GAO reported the U.S. was primarily concerned with finding a solution that would maintain the overall bilateral security relationship with Japan. The GAO found that the highest U.S. priorities were (1) to ensure that the FS-X maintained interoperability with U.S. forces in the region and (2) to maximize the capability that Japan received from its defense expenditures. In the government-to-government negotiations, the GAO noted the U.S. team's primary objectives were (1) to obtain an adequate development and production workshare and (2) to establish a joint DOD/Japan Defense Agency steering group to manage the program. The GAO noted that, while access to Japanese technology was not a primary consideration, DOD realized that the FS-X program provided an opportunity to gain insight and access to Japanese FS-X related technologies. The GAO noted that the agreement established that the U.S. workshare shall reach 40 percent of the entire FS-X development budget--and an April 28, 1989, exchange of letters stated that, if the program entered production, the U.S. would receive approximately 40 percent of the total production workshare. The GAO also found that, under the Memorandum of Understanding, the Japanese Defense Agency will seek interoperability with similar U.S. Air Force systems. The GAO noted that DOD believes that the FS-X will be interoperable with the F-16 and other U.S. weapon systems.  
(p. 2, pp. 16-18, pp. 27-30/GAO Draft Report)

Now on pp 1, 10-11 17-18

DOD Response: Concur.

**FINDING D: Sensitive U.S. Technologies and Capabilities will not be Transferred to Japan.** The GAO reported that, unlike previous F-16 coproduction agreements which have made available operations, maintenance, and production data, the FS-X program will also release certain F-16 design and software data that was not previously released. However, the GAO found that, in order to protect U.S. national security and industrial competitiveness, during the interagency review the DOD and the Department of Commerce agreed to minimize the transfer of F-16 design data and other sensitive technical data to Japan. The GAO reported that the U.S. will not release any manufacturing or design data for the engines--although the DOD will consider providing some engine production technical data after a production Memorandum of Understanding is negotiated. The GAO also found that numerous items and components will not be included in the F-16 technical data package. The GAO reported that the release of the F-16 digital flight control and fire control computer software source codes were given special consideration by the DOD and other Executive Branch Agencies. The GAO observed that the former is state-of-the-art and could have application to commercial aircraft, and that Commerce believed that the later would greatly aid Japan in system integration of fighter aircraft. The GAO found that, because the integration of Japanese avionics into the aircraft requires the release of certain F-16 fire control computer software source codes, the U.S. Government decided that sanitized fire control computer source codes would be transferred to Japan--but, due to its commercial applicability, that the F-16 digital flight control software source codes would not be transferred. The GAO also noted that, after a production Memorandum of Understanding is negotiated, transfer of the digital flight control computer software source codes may be reconsidered.

The GAO also reported that a joint U.S.-Japanese Technical Steering Committee has been established, with a Department of Commerce representative as a member, to monitor key aspects of the program, including technology transfer. In addition, the GAO found that DOD technology transfer/release reviews are conducted through a multi-layered process. The GAO also noted that, for U.S. industry, physical safeguards are planned which will minimize inadvertent disclosures; but, General Dynamics recognizes that it will be difficult to prevent all such disclosures because of the close working relationships between U.S. and Japanese engineers.

The GAO reported that under the terms of the agreement, all technical data, information, and documentation provided by U.S. manufacturers or the DOD will be used only for development of the FS-X and are prohibited from transfer to a third party without the U.S. Government's prior approval.

Finally, the GAO reported that Japan has targeted aerospace as one of its key technologies for the 21st century. The GAO concluded that the Japanese will gain some aviation systems integration skills from the program; however, the extent to which the systems integrated-related skills are directly transferrable to commercial aircraft development is uncertain. The GAO concluded that, over time, the cumulative knowledge gained during a broad range of successful joint ventures with the U.S. may reduce the time and expense required for Japan's aircraft industry to become meaningful competitors to U.S. industry.

(pp. 4-5, pp. 32-41/GAO Draft Report)

DOD Response: Concur.

**FINDING E: The U.S. will Gain Access to Japanese Technology.**

The GAO reported that, while the U.S. did not pursue the FS-X program with the primary objective of obtaining access to Japanese technology, once Japan agreed in principle to the program, the DOD stressed the importance of obtaining access to the new aircraft's technologies. In addition, the GAO pointed out that it is the DOD position that the program sets a precedent for two-way exchanges of military technology between the U.S. and Japan. The GAO noted the agreement provides that the U.S. will have access (1) to all F-16 derived technologies, including composite wing technologies, at no cost, and (2) to solely Japanese-developed FS-X technologies, such as the active phased array radar, at an undetermined price.

**Phased Array Radar.** The GAO reported that Japan is developing an active phased array for the FS-X, and that the DOD is interested in evaluating and possibly acquiring the manufacturing technology used to produce the radar's transmitter/receiver modules. The GAO found both the U.S. and Japan are working to develop a manufacturing process that produces affordable, quality modules--with the U.S. industry making considerable progress. The GAO observed, however, that to date, the DOD efforts to obtain adequate data to access performance of the Japanese radar, including test and evaluation results, have been largely unsuccessful. The GAO reported that, based on the limited information available, current Japanese module technology is comparable to where U.S. industry's technology was in about 1983. The GAO further observed that, according to the DOD, Japan's ability to transition new designs into production is well developed and if Japan's knowledge of manufacturing technology is applied to the transmitter/receiver module production, significant advances are likely. Based on the available information, the GAO concluded that the U.S. is ahead of Japan in

Now on pp 3. 20-25

developing the manufacturing technology necessary to reduce the costs of the radar's transmitter/receiver modules. As a result, the GAO also concluded that the Japanese radar and associated manufacturing processes are of questionable value to the U.S. in the near-term.

**Composite Wings.** The GAO also reported that Japan is planning to produce composite wings for the FS-X using a process known as co-curing. The GAO observed that the Japanese approach appears to be high risk because of manufacturing and quality control uncertainties and damage repair problems. The GAO found that U.S. industry's basic knowledge of advanced composites is superior to that of Japan. Furthermore, the GAO found that future U.S. military aircraft will need more heat resistant materials to meet expected performance requirements and noted that thermoplastics are more heat resistant than the composites used for the FS-X wing. The GAO reported that the U.S. Air Force indicated that the prime use for the FS-X composite wing technology would be on future versions of the F-16, if it proves to be affordable. The GAO further noted that the Japanese have not yet released co-cured composite wing design, manufacture, and testing data to the U.S. The GAO concluded that, based on available evidence, the U.S. industry's basic knowledge of advanced composites for aerospace is excellent and superior to Japan--and the U.S. military requirements for the Japanese composite technology appears to be modest at this time.

(p.2, pp. 5-7, pp. 16-19, pp. 25-32, pp. 42-54/GAO Draft Report)

**DOD Response:** Even though the GAO concluded that the value of the FS-X radar is "questionable" and the value of the FS-X composite wing is "modest," one would have to assume that a technically advanced country like Japan has something to offer the U.S. in these areas. Both the DOD and General Dynamics also believe that, during the course of the program, there will be other Japanese technologies which will be of benefit to the U.S.

**FINDING F: It would be Cheaper for Japan to Purchase U.S. Manufactured F-16 Aircraft than to Develop the FS-X.** The GAO reported that developing the FS-X will cost Japan more than purchasing F-16s from the U.S. The GAO observed that, according to a U.S. Air Force estimate, the most advanced version of the F-16 produced in the U.S. would cost Japan about \$28.6 million per aircraft (in U.S. 1988 dollars)--assuming that it were purchased through Foreign Military Sales procedures. From limited information obtained during its review, the GAO

Now on pp 1. 3-4. 10. 26-32

Appendix II  
Comments From Department of Defense

6

estimated that the unit cost of the FS-X will be about \$61 million (in U.S. 1988 dollars).  
(p. 8, pp. 55-57/GAO Draft Report)

DOD Response: Concur.

Now on pp. 2, 4, 33.

# Comments From the Department of Commerce



UNITED STATES DEPARTMENT OF COMMERCE  
Bureau of Export Administration  
Washington, D.C. 20230

**UNCLASSIFIED**

December 28, 1989

Mr. Frank C. Conahan  
Assistant Comptroller General  
National Security and International Affairs Division  
United States General Accounting Office  
Washington, D.C. 20548

Dear Mr. Conahan:

Following is an unclassified version of the official October 3, 1989 classified Commerce comments to the draft GAO report. Please utilize this unclassified version in the formulation of the final report.

(U) Thank you for your letter requesting the Department's comments on the draft General Accounting Office report entitled "U.S. - JAPAN CO-DEVELOPMENT: Review of the FS-X Program."

(U) I would like to compliment you and your staff for producing a comprehensive and generally well-balanced draft report which reflects a thorough review of the FS-X Memorandum of Understanding. While we believe the report presents an accurate portrayal of the negotiation and subsequent interagency review of the FS-X Fighter Co-development agreement between the United States and Japan, we do have a number of comments on the draft report.

(U) First, we believe that the subsection entitled "INADEQUATE U.S. ATTENTION DEVOTED TO ECONOMIC IMPLICATIONS OF COPRODUCTION" (see pages 22-24) does not present a balanced view of the Administration's actions in reviewing the FS-X agreement. It is not true, as the tone of this section suggests, that no analysis of the technology transfer or industrial impacts of the FS-X agreement was performed. During the interagency review of the agreement, a very detailed analysis of the technology transfer and industrial competitiveness impacts of the FS-X program was jointly performed by Defense and Commerce with full supporting participation from other civilian agencies including NASA, USTR, Treasury, the Departments of Energy and Labor, and the Office of the Science Advisor to the President.

(U) As a result of this process, Defense and Commerce agreed to an extensive list of technologies that would be withheld from the Japanese to protect U.S. national security interests and protect the U.S. defense industrial base. The Presidentially-mandated

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Now on pp. 14-15.  
See pp. 5, 14, and  
comment 1

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-2-

review process did address technology transfer and industrial competitiveness concerns, and had a material effect in placing limits on the scope of technology transfer.

See p 5

(U) We believe this section of the draft report would be more balanced if it stated that since the earliest days of 1989, the trade, economic, and industrial competitiveness implications of defense cooperation agreements such as the FS-X have been a central concern of the Administration.

See p 14 and comment 2

(U) Defense and Commerce have established a cooperative working relationship on the FS-X program, and are now jointly reviewing defense cooperation memoranda of understanding. Commerce is also participating in the formulation of the U.S. negotiating position for programs such as the FX Korean Fighter Program.

Now on pp 21-22.

(U) Our second comment relates to the subsection entitled "DOD HAS PROCEDURE FOR REVIEWING TECHNOLOGY RELEASE AND IS CURRENTLY REVIEWING TECHNOLOGY RELEASE AND IS CURRENTLY REVIEWING DATA LISTS" (see pages 34-35). This section fails to mention that Defense has fully involved Commerce in overseeing technology transfer to Japan in the FS-X program, in keeping with the intent of Section 825 of the Defense Authorization Act of 1988. At the request of Defense, Commerce fully reviewed the Delegation of Disclosure Authority Letter, a comprehensive technical document which identifies which specific technologies can and cannot be disclosed to the Japanese under the FS-X program. This document defines allowable technology transfer under the FS-X program, and is the guiding policy document for the team of Air Force engineers who do the day-to-day work of technical information release to the Japanese. We believe the draft report would be more balanced if it mentioned the fact that Commerce is fully involved in reviewing technology release under the FS-X program.

See p 22 and comment 3.

(U) Our next comment relates to a technical point presented in the subsection of your draft report entitled "COMMERCIAL APPLICATION OF FS-X TECHNOLOGY IS UNCERTAIN" (see page 40). This subsection states: "U.S. government officials informed us that the skills and knowledge acquired from the FS-X program can generally be applied to other aviation-related programs. Japanese engineers will gain valuable experience in systems integration. DOD and civilian agency officials stated Japan has had limited experience in systems integration and these officials consider it an art learned only through the "school of hard knocks". This paragraph is misleading.

Now on pp 24-25

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-3-

(U) The FS-X program systems integration of the digital flight control system to the airframe of the FS-X will be performed by the U.S. contractor, General Dynamics, unless the Japanese decide to independently develop their own digital flight control system. The Delegation of Disclosure Authority Letter governing technology transfer from the United States to Japan specifically prohibits the transfer of digital flight control computer hardware.

See p 24 and comment 4.

(U) Therefore, the Japanese will not gain any significant systems integration knowledge or experience from the digital flight control computer. The systems integration experience gained by the Japanese in the program will be limited to either unsophisticated systems, or to those such as the mission control computer (i.e., fire control computer), which have no direct commercial application. We believe, therefore, that this subsection of the draft report should be revised to reflect this substantive correction.

Now on pp 26-28 and 29-32

(U) The Department's comments on Section 5 of your draft report ACTIVE PHASED ARRAY RADAR TECHNOLOGY" (See pages 42-47) and Section 6, "COMPOSITE WING TECHNOLOGY" (See pages 48-54), are necessarily broad, because we believe the analyses presented in these sections are speculative. It remains to be seen whether or not Japanese technologies will be of value to the United States. No one as yet detailed specific knowledge of the state of development of Japanese phased array radar and composite wing technologies. We believe, therefore, that these sections should be revised to clearly state that assessment of Japanese phased array radar and wing technologies at this point in time is by nature an exercise in speculation.

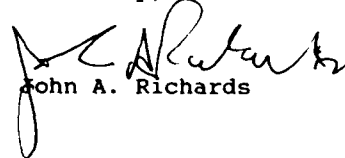
See p 5 and comment 6

(U) Our final comment is that the draft report does not mention the fact that the U.S. Government will receive a research and development recoupment cost fee. This benefit of the program to the U.S. taxpayer should be referenced in the discussion of program costs and U.S. workshare.

See p 16 and comment 5

(U) We appreciate this opportunity to comment on the draft report.

Sincerely,



John A. Richards

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The following are GAO's comments on the letter dated December 28, 1989, from the Department of Commerce.

## GAO Comments

1. Although this section of the draft report was intended to provide a historical perspective on the matter, we have revised the language to clarify and reiterate that coordination among the executive branch agencies did occur in early 1989. As we have noted in our report, however, the coordination resulted only after considerable pressure was applied by members of Congress and executive branch agencies, including Commerce. The interagency review of the FS-X arrangement was ultimately commissioned by the President of the United States. The objectives of the interagency study are discussed in the report.
2. We note that a cooperative relationship now exists between DOD and Commerce.
3. We revised the report to reflect Commerce's role in reviewing the Delegation of Disclosure Letter and noted that Commerce will continue to monitor and review technology release issues.
4. We have modified the example of how Japanese engineers might obtain systems integration experience. If Japan decides to develop its own digital flight control system, there may be direct commercial application. This is why the U.S. government will withhold source codes and will require the U.S. contractor to develop the data with minimal Japanese participation. The FS-X program will enable Japanese industry to build and integrate a sophisticated military aircraft. The extent to which specific systems integration skills acquired will be directly absorbed, assimilated, and transferred into commercial aircraft development is uncertain and impossible to quantify.
5. We have revised the report to reflect that the U.S. government will receive a research and development recoupment fee for each FS-X aircraft manufactured.
6. Our assessment of the two Japanese technologies—composites and phased array radar—is based on numerous discussions with U.S. government and industry aerospace, structural, design, and electronics engineers. We also reviewed documentary evidence that was available from various U.S. government and industry sources. This information indicates that the United States is ahead of Japan in the development and overall application of these two advanced technologies. The potential

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**Appendix III  
Comments From the Department  
of Commerce**

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application and usefulness of these technologies will be determined once they have been made available to the United States for testing and evaluation.

# Major Contributors to This Report

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