United States General Accounting Office

GAO

Report to Congressional Committees

April 1996

TACTICAL AIRCRAFT

Concurrency in Development and Production of F-22 Aircraft Should Be Reduced

GAO/NSIAD-96-59

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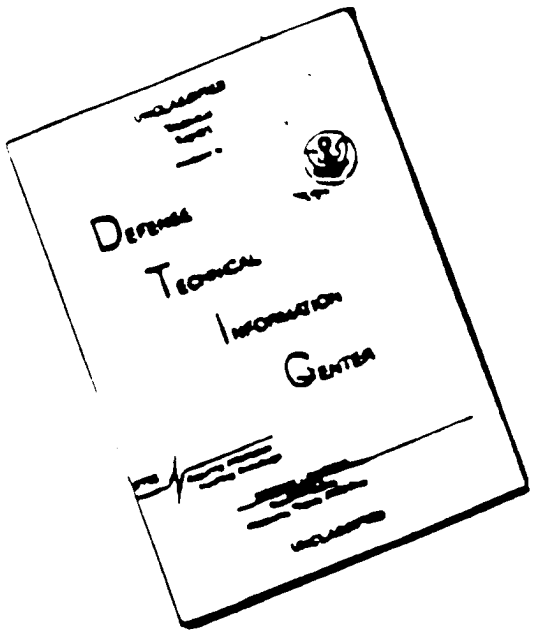

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GAO

United States
General Accounting Office
Washington, D.C. 20548

National Security and
International Affairs Division

B-259204

April 19, 1995

Congressional Committees

As called for by the Senate Armed Services Committee report on the National Defense Authorization Act for Fiscal Year 1995, we assessed the concurrency between the development and production phases of the Air Force's F-22 fighter program and the risk associated with that concurrency.

Background

Concurrency is broadly defined as the overlap between development and production of a system. The stated rationale for concurrency is to introduce systems in a more timely manner or to fulfill an urgent need, to avoid technology obsolescence and/or to maintain an efficient industrial development/production work force. For measuring the degree of concurrency in this report we used a statutorily required guide issued by the Department of Defense (DOD) in April 1990 for assessing concurrency and associated risk in major acquisition programs. Its measure of concurrency is the amount of initial operational testing and evaluation (IOT&E) completed before entering production of a system.

Initial operational tests are field tests intended to demonstrate a system's effectiveness and suitability for military use. IOT&E is a key internal control to ensure that decisionmakers have objective information available on a weapon system's performance and to minimize risks of procuring costly and ineffective systems.

In the late 1980s, the Congress found that DOD was acquiring a large portion of total program quantities, using the low-rate initial production (LRIP) concept, without successfully completing IOT&E. As a result, legislation was enacted in 1989 to limit LRIP quantities for major systems. The law, 10 U.S.C. 2400, defined LRIP as the minimum production quantity needed to provide production representative articles for IOT&E, establish an initial production base, and permit an orderly increase in the production rate sufficient to lead to full-rate production after completion of IOT&E.

In the conference report supporting the National Defense Authorization Act for Fiscal Years 1990 and 1991 (P.L. 101-189), the conferees indicated that LRIP quantities should not total a significant percentage of a total planned procurement. Later, the Federal Acquisition Streamlining Act of

1994 prescribed new controls for LRIP. The act states that the Secretary of Defense must specifically explain to the Congress why any planned LRIP quantities exceed 10 percent of a planned production quantity of a system, as defined at the milestone II or development decision. This provision, however, was not in effect when the F-22 program reached milestone II.

The F-22 passed milestone II in 1991. At that time, the Air Force planned to acquire 648 F-22 operational aircraft at a cost of $86.6 billion. After the Bottom Up Review, completed by DOD in September 1993, the planned quantity of F-22s was reduced to 442 at an estimated cost of $71.6 billion.

We recently reported that aircraft systems, including the T-45 trainer aircraft, B-1B bomber, and the C-17 cargo aircraft, as well as many other smaller systems, entered LRIP before successfully completing any IOT&E.[1] This resulted in the purchase of systems requiring significant and sometimes costly modifications to achieve satisfactory performance, acceptance of less capable systems than planned, and in some cases deployment of substandard systems to combat forces.

The LRIP contract award is scheduled for September 1997. LRIP aircraft are those to be procured during the period of concurrency.

Results in Brief

Although the F-22 program involves considerable risk because it embodies important technological advances that are critical to its operational success, the F-22 program exhibits a high degree of concurrency because the program will enter production well before commencement of IOT&E. This concurrency will permit procurement of a significant quantity of F-22s before many of the technology advances are flight tested and before completion of IOT&E. Historically, there have been numerous examples of the adverse consequences of concurrent development and production, that is, buying weapon systems before they demonstrate, through testing, that they perform as required.

The Air Force plans to procure 80 F-22s under LRIP, or 18 percent of the total planned procurement, at an estimated cost of $12.4 billion, before completing IOT&E. Although the F-22 program entered the engineering and manufacturing development phase before the Federal Acquisition and Streamlining Act was passed, the F-22 LRIP quantities substantially exceed the 10-percent guideline included in the act which requires the Secretary

[1]Weapons Acquisition: Low-Rate Initial Production Used to Buy Weapon Systems Prematurely (GAO/NSIAD-95-18, Nov. 1994).

of Defense to submit a specific explanation to the Congress. The percentage of F-22s to be committed to production before completion of IOT&E is higher than most recent fighter programs.

F-22 production rates in the LRIP phase of the program are planned to accelerate so that 75 percent of the full-production rate, or 36 aircraft a year, will be achieved under the LRIP phase of the program. We believe the planned rate of acceleration exceeds the amount that is needed to successfully complete the LRIP phase of the program and essentially represents a plan to commit to a full-rate production schedule before IOT&E is completed. Limiting LRIP quantities to about six to eight aircraft a year, or the production rate that can be supported by the first set of tooling, appears to be a more prudent approach, given the high degree of concurrency now incorporated in the program and the potential problems associated with technological advances.

Technology advances and innovations that are critical to the F-22's operational success include an advanced architecture for the integrated avionics system, a propulsion system that will allow cruising at supersonic speeds without the afterburners current fighters need, and low observable (stealth) technologies in an aircraft that is both highly maneuverable and can travel at supersonic speeds.

The need for the F-22, based on our analysis, is not urgent. Our recent report concerning planned replacement of F-15s with F-22s amply demonstrated that the initial operational capability planned for the F-22 could be deferred.[2] Moreover, engine and stealthiness problems already disclosed by DOD, and the potential for avionics and software problems, underscore the need to demonstrate the weapon system's performance through flight testing before significant commitments are made to production.

Concurrency in the F-22 Program

In 1990, DOD performed a statutorily required analysis of the concurrency in acquisition programs partly to define the appropriate measures for evaluating the degree of concurrency and associated risk in programs. The

[2]Tactical Aircraft: F-15 Replacement Is Premature As Currently Planned (GAO/NSIAD-94-118, Mar. 25, 1994).

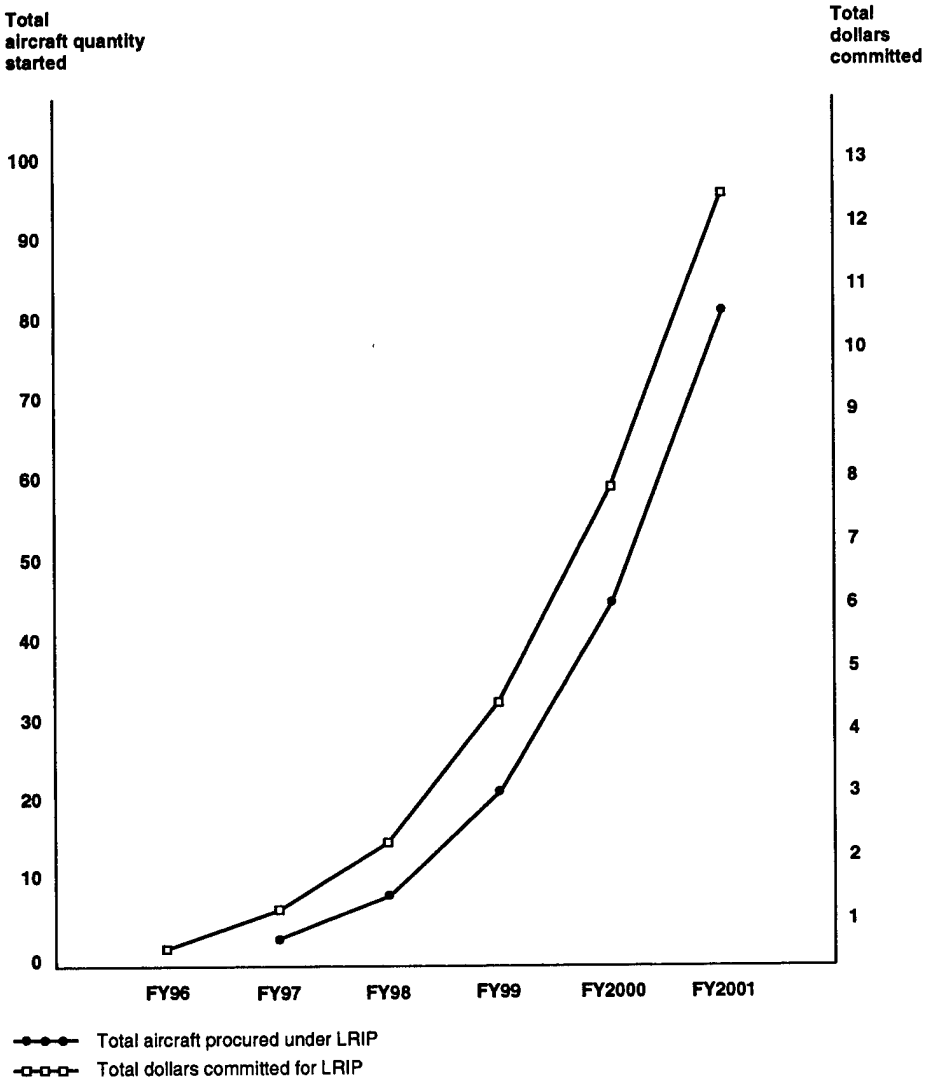
Office of the Secretary of Defense defined a highly concurrent program[3] as one that proceeds into LRIP before significant IOT&E is complete.

Using DOD guidelines, concurrency in the F-22 program is high because the F-22 program is scheduled to proceed into LRIP well before any IOT&E is started. Further, considering the new technology advancements being developed for use in the aircraft, the level of concurrency increases the cost, schedule, and technical risks of the program. We found that development flight tests of critical F-22 technology advances are not scheduled to begin until about 1 year after LRIP is scheduled to start and over $2 billion will have been committed to procure F-22 aircraft.

According to the F-22 acquisition plan, the Air Force will commit to LRIP quantities that increase from 4 aircraft a year to 36 a year (an 800-percent increase), totaling 80 aircraft, before completion of IOT&E. Production of 36 aircraft a year under LRIP represents 75 percent of the planned full-production rate. The estimated cost of those 80 aircraft is $12.4 billion. Figure 1 shows the planned schedule of commitments to procurement of F-22 aircraft and the estimated cumulative costs prior to completion of IOT&E.

[3]Definition in Report on Guidelines for Determining the Degree of Risk Appropriate for the Development of Major Defense Acquisitions Systems, and Assessing the Degree of Risk Associated with Various Degrees of Concurrency; and Concurrency in Major Acquisition Programs, April 1990.

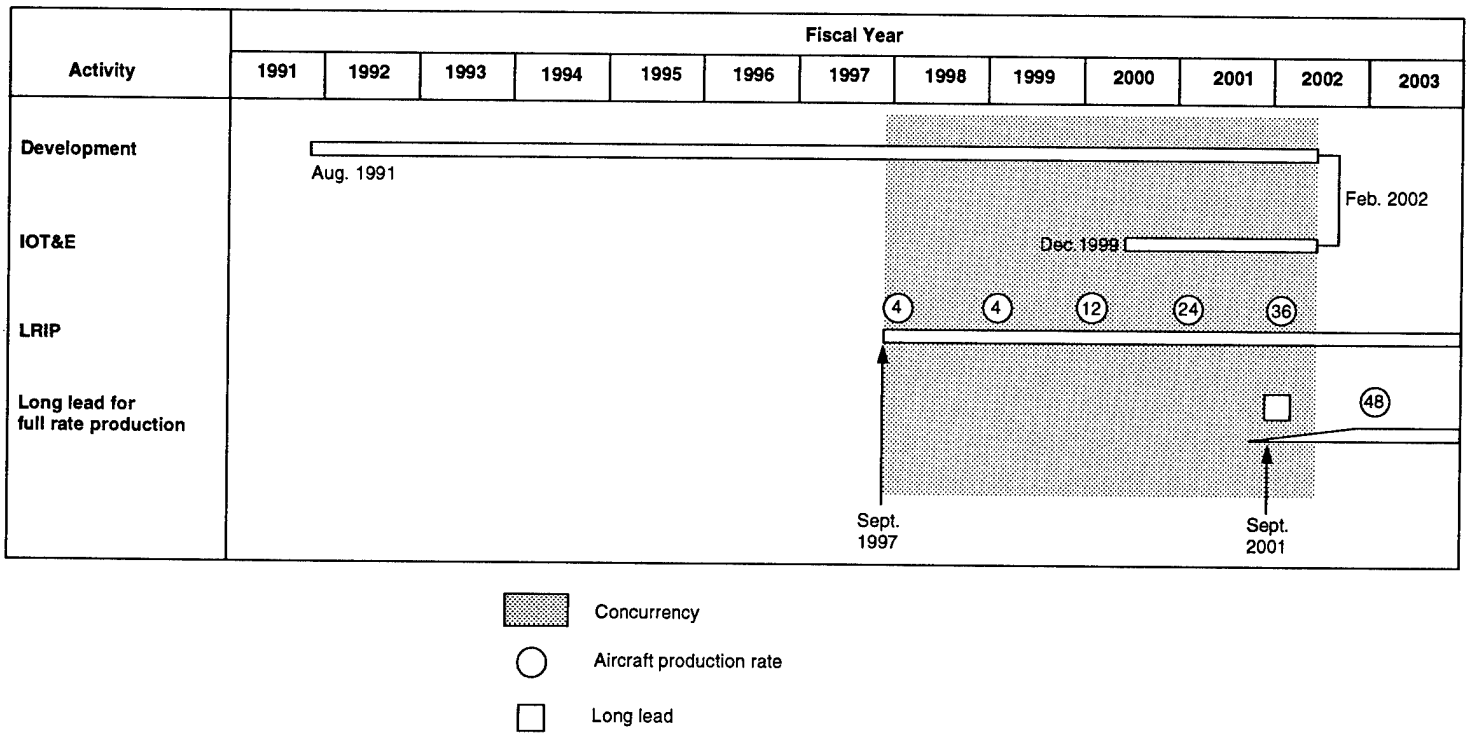
Figure 1: Planned Commitments to Procure F-22 Aircraft and Estimated Cumulative Costs Prior to Completion of IOT&E (dollars in billions)



A first set of hardened tooling is required initially to produce the developmental aircraft for testing. Program office officials told us that the maximum quantity of F-22s that can be produced with the first set of tooling is about 6 to 8 aircraft a year.

The concurrency of development, testing and production in the F-22 program is shown in figure 2, which shows concurrent development and production from September 1997 through February 2002.

Figure 2: Concurrent Development and Production of the F-22



Low-rate production of the F-22 is scheduled to begin in September 1997. However, IOT&E is not scheduled to take place until December 1999 through February 2002.[4] Thus, the testing is not scheduled to be complete until over 4 years after the start of production and the commitment at an estimated cost of $12.4 billion to procure 80 aircraft[5] (4 preproduction

[4]Dedicated IOT&E, which is the independent operational testing and evaluation made by an Air Force test organization, is not scheduled to start until March 2001.

[5]In addition to the 80 aircraft planned under low-rate production, the Air Force plans to initiate long lead effort on 48 full-rate production aircraft in September 2001.

aircraft and 76 production aircraft), or 18 percent of all 442 aircraft to be procured.

Flight Tests of Critical Technology Not Planned Until Well After Production Start

Although laboratory tests are underway and simulations of the avionics are planned, the Air Force does not plan to flight test several of the critical F-22 technology advances on an F-22 until well after the start of production in September 1997. Flight tests of low observability are not scheduled to begin until September 1998. Although the highest risk element of the F-22 program was reported to be the integrated avionics, the first flight test of an F-22 equipped with a complete integrated avionics system is not scheduled to begin until September 1999, 2 years after the start of production. By the time that testing begins, the Air Force will have already made commitments to procure 20 aircraft and long lead materials for an additional 24.

Plan for F-22 Low-Rate Production Compared With 1994 Congressional Guidelines

For programs entering the engineering and manufacturing phase of the acquisition cycle, the Federal Acquisition Streamlining Act of 1994 requires the Secretary of Defense to explain to the Congress any plans to procure more than 10 percent of the total procurement quantity in the LRIP phase. This provision of the act is not retroactive to the F-22 program.

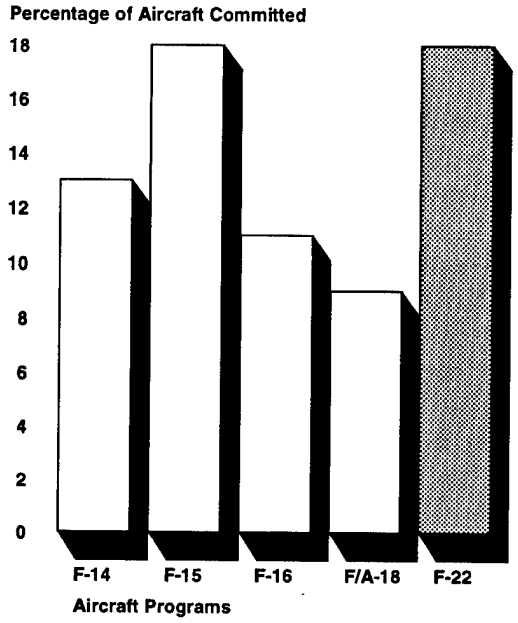
In 1991, when milestone II was approved for the F-22 program, the total aircraft procurement quantity planned was 648. Accordingly, 10 percent would have been 65 aircraft. Currently, 442 aircraft are to be procured, meaning 10 percent would be 44 aircraft. The number of F-22 LRIP aircraft currently planned is 80, exceeding 10 percent, in either case.

Commitments to Production of F-22s Prior to IOT&E Completion Is Higher Than Most Prior Fighter Programs

The Air Force's planned commitment to production of F-22's prior to completion of IOT&E, as a percentage of total production, exceeds the commitments made for recent fighter programs except the F-15, in which the percent is about the same as the F-22. Figure 3 compares the planned percentage of aircraft committed to production before completion of IOT&E for the F-22 and percentages committed for other recent fighter programs.[6]

[6]The total aircraft for the F/A-18 includes aircraft to be procured through fiscal year 1997. Production is complete on all other aircraft.

Figure 3: Aircraft Committed to Production Before Completion of IOT&E as a Percentage of Total Aircraft



Although the actual number of F-22 aircraft to be acquired before completion of IOT&E is lower than in the F-14, F-15, F-16, and F/A-18, the other fighters were acquired before the end of the Cold War when a greater degree of urgency existed for procuring aircraft.

Development Risks With High Technology Systems and Subsystems

The Air Force plans to use advances in technologies and innovations to provide high performance and increased reliability and maintainability for the F-22. The integrated avionics, engine, and stealth characteristics are the primary areas that increase the cost, schedule, and technical risk in the F-22 program. After reviewing the program, the DOD Defense Science Board (DSB) concluded that concurrency was acceptable and risks were readily controllable, but noted that the F-22 program is very ambitious technically. Descriptions of some of the problems that have occurred in the development program are included below. The purpose of these descriptions is to illustrate that there remain important cost, schedule, and technical risks in the F-22 program.

The F-22 Program Office has taken a number of steps to reduce the technical risks of the program, including a 54-month

demonstration/validation phase using an F-22 prototype, and a risk management program for engineering and manufacturing. Some deficiencies associated with the higher risk features of the F-22 have been experienced during ground tests, requiring expensive redesigns.

Avionics and Software Risk

The F-22's integrated avionics are expected to provide unprecedented situational awareness to the pilot. The F-22 is the first aircraft to use integrated avionics, that is, critical systems such as the radar, the weapons management system, and electronic warfare sensors that work as one unit. The key to achieving the necessary performance is the successful development of highly advanced integrated computer processors, known as the common integrated processors, and large amounts of software.

Avionics and software integration has been characterized by the DOD Defense Acquisition Board as one of the highest risks to the successful development of the F-22. The risk assessment was prepared for the DOD Defense Acquisition Board to evaluate the readiness of the F-22 to begin the engineering and manufacturing development phase of the acquisition cycle in 1991. This report in June 1991 explained that the estimated 1.3 million single lines of software code needed for the F-22 represented the largest software task ever for an attack/fighter onboard software program. Further, the DSB in 1993 rated the integrated avionics as the highest technical risk in the F-22 program. Program managers for the F-22 agreed in October 1994 that the avionics and software integration are the most risky tasks facing the contractors.

In a separate report, we concluded in 1994 that although the Air Force's planned strategy for the F-22 software was generally sound in concept, some significant features of the strategy were not being followed.[7] For example, the independent verification and validation of software products—part of the quality assurance process—was less rigorous than planned. In addition, the technical risks being encountered with the system/software engineering environment and common integrated processor were not being formally reported to DOD management. Finally, we indicated that the Air Force had begun actions to respond to our concerns.

DOD responded to that report in February 1995, indicating that the quality assurance program is now being complied with as planned. DOD also stated that common automated tools had matured and would support completion

[7]Air Force F-22 Embedded Computers (GAO/AIMD-94-177R, Sept. 23, 1994).

of the software development effort through the engineering and manufacturing development phase of the program. We have not verified the DOD response.

Engine Problems

The F-22's engine has not been flight tested, but has experienced problems during ground tests. The F-22's engine is expected to be the first to provide the ability to fly faster than the speed of sound for an extended period of time without the high fuel consumption characteristic of aircraft that use afterburners to achieve supersonic speeds. It is expected to provide high performance and high fuel efficiency at slower speeds as well.

Problems with performance of the F-22's engine first surfaced after the initial engine ground tests began in December 1992. The contractor is conducting a series of interim tests, with a goal of having a complete engine with a redesigned turbine and other changes qualified for flight by December 1996 if tests now planned for 1995 are successful. If not, F-22 flight tests will be started with an engine that is not fully representative of the current approved configuration.

An Executive Independent Review Team was formed to provide advice on engine development issues, including a turbine problem. The team stated that it did not consider the nature and number of engine problems to be excessive for a highly sophisticated engine at this stage of development. They also stated that the proposed solutions can only be proven by exposing authentic hardware to the full range of realistic testing.

Through November 1994, the Air Force had identified engine problems that may cost as much as $479 million to remedy. The Air Force increased the target cost of the engine development contract by $218 million to design and test solutions to the engine problems. The incorporation of corrective modifications to future production engines is expected to increase production costs by $123 million. The Air Force believes its current program estimate can cover the $341 million increase ($218 million plus $123 million), but the Air Force has identified other potential design changes that may add $138 million to development and production costs. The other potential design changes are not currently part of the planned program.

Problems With Stealthiness

The low observability or stealth characteristics of the F-22 is another risk area. The F-22 is to be the first supersonic, highly maneuverable fighter

that uses low observable technologies to reduce radar, infrared, acoustic and optical signatures of the aircraft, making it difficult for an adversary to detect.

An evaluation of the complete F-22 radar signature using computer models and a scale version of the aircraft concluded that the aircraft's radar signature did not meet the Air Force's operational requirement. Although DOD advised us that these problems were not considered major, design changes, such as reducing the number of aircraft maintenance access panels and fuel drain holes, and reshaping the airframe were evaluated through December 1994 to determine if these changes were successful in reducing the signature. DOD further stated that the contractual specifications are being revised. The estimated development cost to resolve these problems is about $20 million according to the F-22 program office. Additional production costs of about $110 million could also be required, however, program officials told us the total estimated cost ($71.6 billion) of the F-22 program should not be affected.

Other Technical Risks

The DSB, in its review of the F-22 program's concurrency and technical risks, identified a number of other concerns. Examples of concerns mentioned by the DSB include

- control of excess aircraft weight;
- use of new materials and fabrication processes;
- uncertain durability of composite materials in the F-22 application;
- probable inability of the engine to meet performance and durability goals before first flight;
- design of certain low observable features and applicable manufacturing processes;
- very challenging development of electronic warfare system;
- late scheduling of tests relative to increasing production to 12 aircraft a year; and
- the need for a long, evolutionary software development.

Overall, the DSB characterized the F-22 program as very ambitious technically.

Recommendation

We recommend that the Secretary of Defense reduce the degree of concurrency in the program because

- independent testing of technology advances (IOT&E), will not be completed before significant commitments are made to produce F-22s;
- the percentage of planned F-22s to be committed to production before completion of IOT&E is higher than most recent fighter programs; and
- the need for the F-22 is not urgent.

To minimize commitments to production of F-22s until after successful completion of IOT&E, we recommend that the Secretary of Defense limit LRIP quantities to that which can be produced using the first set of hard tooling, about six to eight aircraft a year.

Agency Comments and Our Evaluation

DOD partially agreed with the findings in this report, but disagreed with the recommendations. DOD indicated it believed that the F-22 program had an acceptable degree of concurrency based on the DSB's evaluation that risks associated with premature entry into successively higher rates of production were readily controllable through insistence on meeting certain key events and test criteria already built into the F-22 plan.

The record shows, however, that DOD has often been unwilling or unable to curtail production of other systems after it starts, despite discovery of significant problems in development or operational tests. We believe the degree of concurrency in the program should be addressed now, because (1) independent testing of important technology advances is not planned until after commitments are made to produce F-22s, (2) program concurrency is high according to DOD's prescribed measure, and (3) the need for the F-22 is not urgent.

DOD disagreed with (1) our use of the completion of IOT&E as a measure of concurrency and risk in the program, (2) our positions on the level of risk in the F-22 program, and (3) the comparison of the F-22 to prior fighter programs using the percentage of planned aircraft procured during LRIP as a measurement.

We first applied DOD's own guidance for measuring the degree of concurrency in the program, that is, the amount of IOT&E completed prior to entering productions. We also used other metrics, such as the percent of the total program committed to production before completion of IOT&E. Further, DOD's comments appear to discount the risks in the program identified by the DSB. Our comparison of the F-22 to recent fighter programs, although not the same as comparisons made by the DSB,

provides an important historical perspective that DOD's planned LRIP meets or exceeds the fighter programs undertaken during the Cold War.

Scope and Methodology

In conducting our work, we obtained information and interviewed officials from the Office of the Secretary of Defense, DSB, and Air Force Headquarters, Washington, D.C.; F-22 System Program Office, Wright-Patterson Air Force Base, Ohio; the Air Force Air Combat Command, Langley Air Force Base, Virginia; and the Air Force Operational Test and Evaluation Center, Kirtland Air Force Base, New Mexico.

We interviewed officials in charge of program management, the operation of tactical fighter aircraft, risk assessment and the operational testing of Air Force weapon systems. We reviewed documents, including program office briefings, program schedules, test plans and reports, technology risk assessments, requirements documents and cost reports. We used these interviews and documents to determine the program management philosophy, the amount of program concurrency, the planned flight testing of F-22 technologies, program technology requirements and program risk assessments.

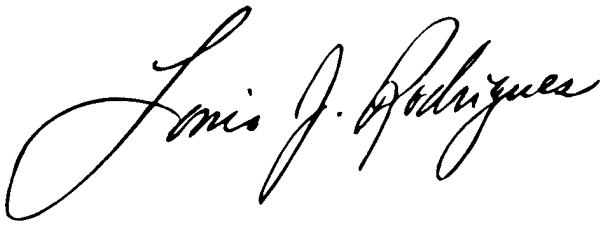
We also reviewed DOD instructions, Air Force regulations, Office of Secretary of Defense guidance, publications from the Defense Systems Management College, our prior reports, a report of another audit organization, congressional reports, an Institute for Defense Analyses report, a DSB report, a report prepared for the Defense Acquisition Board, executive summaries, and monthly program reports.

In addition, we interviewed officials from the Air Force's Air Combat Command and examined the F-22 System Operational Requirements Document, Statements of Need, and the Mission Element Need Statement for new fighter aircraft.

We performed our work from August 1994 through February 1995 in accordance with generally accepted government auditing standards.

We are sending copies of this report to the Secretaries of Defense and the Air Force and the Director of the Office of Management and Budget. Copies will also be made available to others on request.

Please contact me on (202) 512-4841 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix II.



Louis J. Rodrigues
Director, Systems Development
and Production Issues

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Subcommittee on National Security
Committee on Appropriations
House of Representatives

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Abbreviations

DOD	Department of Defense
DSB	Defense Science Board
IOT&E	initial operational testing and evaluation
LRIP	low-rate initial production

Comments From the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000

ACQUISITION AND TECHNOLOGY

FEB 24 1995

Mr. Louis J. Rodrigues
Director, Systems Development and
Production Issues
National Security and International
Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Rodrigues:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, entitled "TACTICAL AIRCRAFT: Concurrency in Development and Production of F-22 Aircraft Should be Reduced," dated January 18, 1995 (GAO Code 707023/OSD Case 9847). The DoD partially concurs with the report findings, but nonconcurs with the recommendations.

Language contained in the Senate Armed Services Committee report on the National Defense Authorization Act for FY 1995, Report 102-212, requested the Secretary of Defense and the GAO to independently assess the concurrency and risk in the F-22 program. The Department convened a Defense Science Board (DSB) Task Force to perform an independent assessment as a part of the DoD overall evaluation. The DSB conducted an assessment of a number of concurrency metrics and compared them to the current DoD guidelines. The DSB also reviewed the current technical status of the program in order to determine the risk, based upon the progress to date and the contractual objectives.

See comment 1.

Although both the DSB and the GAO should have had essentially the same data base to evaluate, the conclusions reached by the DSB differ from those of the GAO. There appear to be three main reasons for this difference: (1) the degree of relevance the GAO attached to the completion of dedicated Initial Operational Test and Evaluation (IOT&E) as a measure of concurrency and/or risk in a program; (2) the GAO position on the level of risk in the F-22 program; and (3) the very narrow metric the GAO chose in its comparison of F-22 concurrency with prior fighter development programs.

One of the key points of the April 17, 1990, DoD report prepared in compliance with Section 801 of the National

Defense Authorization Act for Fiscal Years 1990 and 1991 is the importance of continually assessing the risks associated with the level of concurrency planned for a program to assure a proper balance with other program parameters. The report even provides the guidelines for achieving a proper balance between concurrency and risk.

See comment 2.

While the GAO stated that the concurrency guidelines outlined in the April 1990 report were used in its assessment to establish the degree of concurrency in the F-22 program, the GAO did not acknowledge that the F-22 program meets most, if not all, of the risk/concurrency guidelines established in the report for maintaining the proper balance between concurrency and risk in development. The GAO focused almost exclusively on the number of aircraft committed to production prior to completion of dedicated IOT&E as its sole metric for judging concurrency and risk in the program.

See comment 1.

In assessing concurrency and risk for the F-22, the focus is more properly directed at the efficiencies and economies associated with the production ramp-up rate decision. Under the planned F-22 development plan, the DSB concluded that the F-22 will have passed the critical tests on all the major systems and subsystems prior to the ramp-up decision. If the tests are not passed, the DSB observed that production can be constrained.

The detailed DoD comments on the report findings and recommendations are provided in the enclosure. The DoD appreciates the opportunity to comment on the draft report.

Sincerely,

for George R. Schneiter
Director
Strategic & Tactical Systems

Enclosure

GAO DRAFT REPORT - DATED JANUARY 18, 1995
GAO Code 707023/OSD CASE 9847

"TACTICAL AIRCRAFT: CONCURRENCY IN DEVELOPMENT AND PRODUCTION OF F-22 AIRCRAFT SHOULD BE REDUCED"

DEPARTMENT OF DEFENSE COMMENTS

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FINDINGS

FINDING A: Status of the F-22 Low Rate Initial Production Program. The GAO used a statutorily required DoD guide, dated April 1990, to measure the degree of concurrency in the F-22 program. The GAO indicated that the measure of concurrency is the amount of initial operational test and evaluation (IOT&E) completed before a system enters production. The GAO explained that initial operational tests are intended to demonstrate the system's effectiveness and suitability for military use. The GAO observed that the purchase of long lead materials to support the initiation of F-22 low rate initial production (LRIP) is planned for August 1996, and the LRIP contract award is scheduled for September 1997. The GAO explained that LRIP aircraft are those aircraft procured during the period of concurrency.

The GAO observed that, in the FY 1990-1991 National Defense Authorization Act, the conferees indicated that LRIP quantities should not total a significant percentage of the total planned procurement for a particular weapon system. The GAO also observed that the Federal Acquisition Streamlining Act of 1994 prescribed new controls for LRIP, and requires the Secretary of Defense to explain to the Congress why any planned LRIP quantities exceed 10 percent of the planned production quantity as defined at the Milestone II or development decision. The GAO found that the DoD plans to procure 442 F-22 aircraft and that the number of LRIP aircraft currently planned is 80, which exceeds the 10 percent (or 44 aircraft) specified in the Act. However, the GAO acknowledged that the Act was not in effect when the F-22 program reached Milestone II and is not retroactive to the program.

The GAO also found that the DoD planned production commitment of the F-22 prior to completion of IOT&E, as a percentage of total production, exceeds the commitments made for prior fighter programs, except the F-15, which was about the same as the F-22. However, the GAO asserted that the

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Now on pp. 1-3 and 7-8.

prior fighter programs, including the F-14, F-15, F-16, and F/A-18, were acquired during the Cold War when a greater degree of urgency existed for procuring aircraft. (pp. 1-3, pp. 12-14/GAO Draft Report)

DOD RESPONSE: Partially concur. The DoD agrees that the currently planned LRIP quantities for the F-22 exceed the 10 percent guideline called for in the Federal Acquisition Streamlining Act of 1994. However, as the GAO has pointed out, the F-22 Milestone II decision was completed prior to the enactment of that guideline. In the case of the F-22, rather than focus on an arbitrary guideline that varies with production quantities, and does not even apply, the most important consideration should be whether the proposed ramp-up rate for the aircraft makes sense and is economically sound. The Defense Science Board (DSB) concluded that the F-22 will have passed its critical tests prior to the ramp-up, and, if it has not, the production can be constrained until the tests have been passed.

See comment 3.

The data base on prior fighter aircraft programs shows that the number of aircraft procured prior to Milestone III (full-rate production) by the F-16, F/A-18, and F-15 programs is in line with the planned F-22 procurement. A comparison of the most recent fighter aircraft development programs shows that the DoD committed to production of 92 F-15s, 107 F-16s, and 113 F/A-18s by Milestone IIIB. The F-22 program will commit to 80 aircraft prior to the same milestone.

See comment 4.

The important issue is the balance in the development and production programs. In that respect, the F-22 program employs most, if not all, of the risk/concurrency guidelines called for in the April 17, 1990, report for maintaining a proper balance between concurrency and risk in a program. Unlike prior fighter developments, the program is an event-driven program that explicitly links milestone decisions to demonstrated accomplishments. As the DSB discovered during its assessment of the F-22 program, appropriate testing is accomplished prior to any significant commitment of production resources.

See comment 3.

FINDING B: Concurrency in the F-22 Program Is High. Using DoD guidelines, the GAO concluded that concurrency in the F-22 program is high, because the F-22 program is scheduled to proceed into LRIP well before any IOT&E is started. Further, considering the new technology advancements being developed for use in the aircraft, the GAO concluded that the level of concurrency increases the cost,

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schedule, and technical risks of the program. The GAO found that development flight tests of critical F-22 technology advances are not scheduled to begin until about one year after LRIP is scheduled to start and substantial commitments are made to procure F-22 aircraft. For example, the GAO found that the Air Force will have committed to procure 8 aircraft and long lead materials for an additional 12 aircraft before testing the basic avionics. The GAO also found that the first flight test of an F-22 equipped with a complete integrated avionics system--the highest risk element of the F-22 program--is not scheduled until more than 3 years after production activities start. The GAO concluded that, by that time, the Air Force will have already made commitments to procure 20 aircraft and long lead materials for an additional 24 aircraft.

The GAO also observed that LRIP of the F-22 is scheduled to begin in September 1997. However, the GAO noted that IOT&E is not scheduled to take place until December 1999 through February 2002. The GAO found that, according to the F-22 acquisition plan, the Air Force will commit to LRIP quantities that increase from 4 aircraft per year to 36 per year (a 800 percent increase), totaling 80 aircraft at a estimated cost of $12.4 billion, before completion of IOT&E. The GAO concluded that production of 36 aircraft per year under LRIP represents 75 percent of the planned full production rate. The GAO further concluded that the F-22 operational test schedule is still tentative, because the Director, Operational Test and Evaluation, Office of the Secretary of Defense, disapproved the F-22 Test and Evaluation Master Plan (TEMP) on March 31, 1994. According to the GAO, the Director stated that the plan was not adequate to determine the F-22's operational effectiveness and suitability for combat and called for the Air Force to submit a revised test plan in February 1995. (pp. 6-12/GAO Draft Report)

Now on pp. 4-8.

DOD RESPONSE: Nonconcur. With regard to concurrency, the April 17, 1990, DoD report to the Congress presented guidelines for determining the degree of concurrency that is appropriate for major defense acquisition programs. The report states at the outset that..."concurrency, per se, is not necessarily an undesirable program feature. Total avoidance of concurrency would lead to a series of time consuming and costly gaps in a program as it evolves from development to full-scale production. The appropriate amount of concurrency to build into a program is a matter of *judgment* involving trade-offs among *risk, cost and schedule* to achieve a specified level of performance." Recognition of the appropriateness of concurrency to major acquisition

See comment 5.

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programs is an essential element of the assessment which the GAO apparently ignored.

See comment 6.

The DSB concluded that the concurrency in the F-22 program was conservative compared with other tactical fighters. The DSB conclusions were based on examination of a very broad data base, which included data originally prepared by the Institute for Defense Analyses (IDA) in support of the independent risk assessment of the F-22 by the DoD prior to the Milestone II decision in June 1991 (and updated in 1994 based on the program re-phasing); F-22 data from Lockheed Premise Modification to Master Schedule, No. 17, dated November 16, 1994; RAND project memorandum "Use of Flight Test Results in Support of F-22 Production Decision," dated November 1994; and other concurrency metrics. The metrics examined by the DSB included: (1) Cumulative Production Commitments (number of aircraft) vs. Proportion of Development Test and Evaluation (DT&E) Flight Testing Completed; (2) Cumulative Production Commitments (value of aircraft in millions of dollars) vs. Proportion of DT&E Flight Test Completed; (3) Key Periods of Development for Fighter/Attack Aircraft; (4) Flight Test Data Comparisons; (5) Major Problem Occurrence vs. Percentage of Flight Test Accomplished; (6) Production Start vs. Completion of IOT&E; and (7) Aircraft Procured Prior to Completion of IOT&E. The GAO report focused on a very narrow data base that did not adequately consider a range of potential concurrency metrics.

See comment 7.

It is not appropriate to focus on completion of dedicated IOT&E as the key element in determining whether production ramp-up for the F-22 is properly timed. There are two principal reasons. First, the purpose of OT&E is not to uncover major developmental problems. The RAND study showed that critical problems are generally uncovered in the first 10-20 percent of developmental testing. The purpose of OT&E is to confirm that line pilots and maintenance personnel can use the system to achieve the operational objective for which it is designed. Second, the OT&E community (the Director of Operational Test and Evaluation (DOT&E), and the Air Force Operational Test and Evaluation Center) will be involved throughout the acquisition process, not just during dedicated IOT&E. The DOT&E is already engaged in monitoring F-22 progress and will provide on-going operational assessments through its Annual Report to Congress. Additionally, the Air Force will generate, and the DOT&E will approve, a formal Early Operational Assessment in support of the 1998 LRIP decision. All testing, to include ground testing of subsystems and flight testing of delivered aircraft, will be considered in that assessment. Note that

seven of nine F-22 development aircraft will be flying by the time the report is completed, and significant avionics testing will have been completed in both the Flying Test Bed and the F-22s.

The DSB identified the key events for each critical technology advance/subsystem, and examined the current status and planned milestones for each. The data showed that for each technical area, several key test events will be completed prior to Lot 2 long-lead and contract award. That is consistent with the event-driven strategy for the program. The DSB concluded that those test milestones were appropriate for judging readiness for production ramp-up. The DSB further stated that given the amount and duration of testing (in the F-22 program), it seemed unlikely that keying the start of production ramp-up to completion of dedicated IOT&E testing would substantially reduce technical risk.

The GAO implication that disapproval of the F-22 TEMP was related to concurrency issues is misleading. The fact that the TEMP was returned without approval is irrelevant to concurrency or risk discussions. The IOT&E schedule is not the issue in the DOT&E review of the TEMP. Rather, the content of the IOT&E program, including the Under Secretary of Defense (Acquisition and Technology) directed tests and the proper description of those efforts, is the issue that has delayed approval of the TEMP.

See comment 8.

FINDING C: Development Risks with High Technology Systems and Subsystems. The GAO concluded that integrated avionics, engine, and stealth characteristics are the primary areas that increase the cost, schedule, and technical risk in the F-22 program. However, the GAO noted that the F-22 Program Office has taken a number of steps to reduce the technical risks of the program, including a 54-month Demonstration/Validation phase using an F-22 prototype, and a risk management program for engineering and manufacturing. Nevertheless, the GAO found that some deficiencies associated with the higher-risk features of the F-22 have been experienced during ground tests, requiring expensive redesigns.

The GAO observed that the F-22 is the first aircraft to use integrated avionics--i.e., critical systems, such as the radar, the weapons management system, and electronic warfare sensors that work as one unit. The GAO asserted that the key to achieving the necessary performance is the successful development of highly advanced integrated computer

processors, known as common integrated processors, and large amounts of software. The GAO reported in 1994 (OSD Case 9494-A) that, although the planned strategy for the F-22 software was generally sound in concept, some significant features of the strategy were not being followed--e.g., the independent verification and validation of software products, which is part of the quality assurance process, was less rigorous than initially planned. The GAO also reported that common automated tools for software development were not working as intended in the F-22 program.

The GAO also observed that, although the F-22 engine has not been flight tested, problems have been experienced during ground tests. The GAO indicated that the F-22 engine is expected to be the first to provide the ability to fly faster than the speed of sound for an extended period of time without the high fuel consumption characteristic of aircraft that use afterburners to achieve supersonic speeds. The GAO also indicated that the F-22 engine is expected to provide high performance and high fuel efficiency at slower speeds as well. The GAO found that problems with engine performance first surfaced after the initial engine ground tests began in December 1992. The GAO observed that the contractor is conducting a series of interim tests with the goal of having a complete engine with the redesigned turbine and other changes qualified for flight by December 1996 if tests currently planned for 1995 are successful. If not, the GAO concluded that the F-22 flight tests will be started with an engine that is not fully representative of the current approved configuration. The GAO also noted that the identified engine problems may cost as much as $479 million to remedy.

Finally, the GAO observed that low observability or stealth characteristics of the F-22 is another risk area. The GAO explained that the F-22 is to be the first supersonic, highly maneuverable fighter that uses low observable technologies to reduce radar, infrared, acoustic and optical signatures of the aircraft, making it difficult for an adversary to detect. The GAO found that an evaluation of the complete F-22 radar signature concluded the signature did not meet the contract specification. The GAO also found that the estimated development cost to resolve the signature problem is $20 to $25 million unless additional changes are required. (pp. 16-20/GAO Draft Report)

Now on pp. 9-12.

DOD RESPONSE: Partially concur. The DoD agrees that the primary areas of risk in the F-22 program are integrated

avionics, engine, and stealth. Those areas were identified by the Office of the Secretary of Defense (OSD) in its independent risk assessment conducted prior to the Milestone II decision in 1991. The DoD, however, does not concur with any of the other GAO assertions regarding the current level of risk in the program.

The DSB examined the key event milestones for each technical area of the F-22 program with particular emphasis on the critical technology advances and subsystems. The DoD acknowledges that the engine is currently deficient in performance, particularly subsonic specific fuel consumption, which has resulted in the redesign of the high-pressure turbine and exhaust nozzle. Also, the vibratory stress levels in the fan and turbine are higher than expected. The DSB found that fixes for all those deficiencies are currently being implemented and should rectify the current problems. The DSB found that the key event for the engine is a test of the redesigned engine scheduled for mid-1995. That is a key decision point with regard to technical and schedule risk.

See comment 9.

Contrary to the GAO assertion, there have been no major problems in the observability areas of the F-22. The Program Office conducted a comprehensive review of the contractual specifications in the observability area, and concluded that there was some over-specification that could be eliminated. As a result, the contractual specification is being revised, but without jeopardizing the fundamental low observability requirements for the aircraft. The DSB review concluded that there was no unacceptable concurrency risk in this area. Furthermore, the DSB indicated that significant test data would be available prior to Lot 2 long-lead and contract award to more thoroughly evaluate program risks.

The F-22 program will be conducting full-scale low observability testing throughout the engineering and manufacturing development program. The testing of full-scale hardware, and in many cases full-scale production hardware (antennas, leading edges, radome, canopy, etc.) will significantly reduce the development risk. Prior programs with low observability features did not employ full-scale hardware as is being done for the F-22. The use of a radar-cross-section measurement system on the production line will allow for early evaluation of production manufacturing processes and their ability to achieve a low observable aircraft.

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See comment 10.

The F-22 is the first aircraft to employ an integrated avionics system. One of the keys to the success of that system is the common integrated processor. In its February 2, 1995, response to the referenced GAO report (OSD Case 9494-A), the DoD strongly disagreed with the GAO assertion that features of the software strategy were not being followed. The DoD pointed out that the F-22 program had established an innovative software process quality metric, which is a measure of adherence to all the processes identified in the software development plans, and the associated certification of those processes through software quality assurance evaluations. That metric currently shows program compliance at over 92 percent, well above the established target level.

Furthermore, the maturation of the system/software engineering environment (S/SEE) was accomplished early in the engineering and manufacturing development phase of the program. The S/SEE baseline has been established and currently provides all the functionality required for software development and management. Progress to date indicates that the common integrated processor (CIP) is not a critical technical risk area. Preliminary design of all of the avionics applications software has been completed, providing estimates that indicate the resultant software will easily be accommodated within the data processing assets in the two baseline CIPs. There is currently a 30 percent management reserve in both memory and throughput without adding any additional modules.

The F-22 program has established a disciplined and comprehensive software development process. The DoD is keenly aware that the continued success of the program is contingent on maintaining that approach.

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RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense reduce the degree of concurrency in the program because (1) the need for the F-22 is not urgent, (2) the percentage of planned F-22s to be committed to production before completion of IOT&E is higher than most prior fighter programs, and (3) independent testing of technology advances will not be completed before decisions are made to produce F-22s. (pp. 20-21/GAO Draft Report)

Now on p. 12.

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See comments 3 and 5.

DOD RESPONSE: **Nonconcur.** As indicated in the April 17, 1990, DoD letter to the Congress, completely sequential development of programs, i.e., no concurrency, is unacceptable because of time and cost penalties. The DoD focus is on determining how much concurrency makes sense in a program, and properly balancing the costs and risks, both of which require a detailed technical assessment.

The December 1994 independent DSB assessment of the program concluded that there was no reason, based upon risk and/or concurrency, to introduce a schedule stretch in the F-22 program. The DSB noted that while stretching a program may reduce risk, if stretching is not necessary it can result in increased total costs, possible loss of key manpower and suppliers, and earlier technical/operational obsolescence.

See comments 2 and 3.

The DSB further indicated that there were sufficient key events planned for each critical technical area prior to the Lot 2 long-lead and contract award for production which can be used to measure progress. If there are significant delays in accomplishment of those key events, or if performance levels achieved are unacceptable, the program can be adjusted.

RECOMMENDATION 2: To minimize commitments to production of F-22s until after successful completion of IOT&E, the GAO recommended that the Secretary of Defense limit LRIP quantities to that which can be produced using the first set of hard tooling--i.e., about 6 to 8 aircraft per year. (p. 21/GAO Draft Report)

Now on p. 12.

DoD RESPONSE: **Nonconcur.** Delaying increases in rate production until after completion of dedicated IOT&E means that the high rate decision (Milestone III) would be made prior to demonstrating rate increase ability, or 4-5 years after dedicated IOT&E. Either approach practically assures additional or continued dedicated IOT&E-like testing to confirm production quality/ability before going into planned high rates. The costs for this stretch-out testing/low rate production process can be expected to be large (due to production loss-of-learning, inflation, and further engineering and manufacturing development stretch-out). The GAO report omits those consequences of their recommendation.

See comment 11.

Nearly 60 percent of the F-22 program is subcontracted to outside suppliers. The low rates suggested by the GAO are so unattractive due to their low profitability that many current suppliers would likely be lost. In that case, the

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program would either have to pay high prices to maintain the current supplier base, or would need to select and re-qualify new suppliers, again increasing costs. In addition, it is likely that continued dedicated IOT&E testing would be required prior to approval of high rate production.

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The following are GAO's comments on the Department of Defense's (DOD) letter dated February 24, 1995.

GAO Comments

1. These comments are dealt with on pages 12 and 13 of the report and in our responses to the DOD specific comments that follow.

2. For the most part, the risk/concurrency guidelines listed in the Office of the Secretary of Defense's April 1990 guide are specific requirements that should be met before a program progresses. We are aware of many of those requirements that are incorporated in the F-22 program. However, the only assessment provided for in the guide for measuring the degree of concurrency is the amount of initial operational testing and evaluation (IOT&E) completed at the time low-rate initial production (LRIP) begins. By that measure, the F-22 program clearly has a high degree of concurrency. In our opinion, the ramp up of production from 4 a year to 36 a year under the LRIP phase, and initiation of long lead for 48 a year essentially represents a plan to achieve a full-rate production schedule (now defined as 48 a year) before IOT&E is completed.

3. The F-22 program, as currently planned, schedules procurement of 80 LRIP aircraft at an estimated cost of $12.4 billion. We believe that exceeds the minimum needed to successfully complete the LRIP phase of the program and that the production rates should be restricted during LRIP. Although many important F-22 development tests are scheduled prior to the acceleration of production rates, many other critical developmental tests and most IOT&E testing are not scheduled to be complete until after significant commitments are made to production.

4. We adjusted the report to reflect this information. However, it should be noted that the total number of each type of aircraft produced was much higher than planned for the F-22. This results in a higher degree of concurrency in the F-22 program when using the percentage of aircraft procured at completion of IOT&E as a measure of concurrency.

5. Our report does not, either explicitly or implicitly, suggest "total avoidance" of concurrency.

6. The Defense Science Board (DSB) portrayal of the F-22 program as relatively conservative was based on the amount of development testing to be completed at early production decision points. However, using the measure called for by DOD's own 1990 guidance—the amount of IOT&E

completed at the time LRIP begins—shows that the F-22 program is far from conservative.

7. Production ramp up from 4 aircraft a year to 36 aircraft a year appears to provide a more rapid acceleration than we believe is necessary in the LRIP phase of the program. In our opinion the ramp up of production from 4 a year to 36 a year under the LRIP phase, and initiation of long lead to support 48 a year, essentially represents a plan to achieve a full-rate production schedule before IOT&E is completed.

8. This material has been deleted from the report.

9. Additional information concerning this matter has been added to the body of the report.

10. DOD response to our prior report on embedded computers has been recognized in the body of this report.

11. We did not attempt to quantify potential cost growth in the F-22 program that may result from a change in the program schedule. However, the thrust of the LRIP legislation is to authorize only minimum necessary quantities. DOD acquisition profiles created for other weapon programs have often proven to be optimistic and are rarely carried out as initially planned because of technical, financial, or test problems. If the baseline against which to compare potential growth of costs is optimistic, an estimate of cost growth would have limited meaning at this point because those problems are likely to occur in highly concurrent programs that involve substantial advances in technology.

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