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BY THE COMPTROLLER GENERAL

Report To The Congress

OF THE UNITED STATES

Is The Joint Air Force/Navy Alternate Engine Program Workable? GAO Thinks Not As Presently Structured

The Department of Defense is developing a backup engine, the F101DFE, for the engines in the Navy's F-14 and the Air Force's F-16 fighter aircraft in the event the improvement programs for those engines fail.

Unfortunately, the F101DFE program in its present form does not promise that a production engine with the required performance and supportability characteristics will be available when or if needed or that using the backup engine will be cost effective and affordable.

If the services are to pursue this program, experience in prior programs suggests specific actions are needed. Otherwise, the program should be terminated.

UNITED STATES GENERAL ACCOUNTING OFFICE

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This report describes the joint Air Force/Navy alternate engine program and discusses the need to (1) identify program objectives and (2) structure the program on a realistic basis that avoids taking overly ambitious steps under the guise of a modification program. The report also suggests that the program as presently conceived may not satisfy the directive of the Defense Appropriations Conference Committee and perhaps should be terminated.

Our review of the joint services' alternate engine program is part of an overall review of the Department of Defense's acquisition process for aircraft gas turbine engines. The alternate engine program is one of the first derivative fighter engine programs initiated under the Air Force's new concept for engine development.

We are sending copies of the report to the Director, Office of Management and Budget; the Secretary of Defense; and the Secretaries of the Air Force and Navy.

Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

IS THE JOINT AIR FORCE/NAVY ALTERNATE ENGINE PROGRAM WORKABLE? GAO THINKS NOT AS PRESENTLY STRUCTURED

DIGEST

The primary objective of the Department of Defense's (DOD's) F101DFE program is to modify the F101 engine, designed for the B-1 bomber, for use as an alternate for engines in the Navy's F-14 and the Air Force's F-16 front line fighter aircraft should programs to correct problems with those engines fail.

The Congress directed DOD to initiate the program because of concern over continued problems with the two engines--the Navy's TF30 and the Air Force's F100. However, GAO seriously questions whether the F101DFE program is a workable alternative to the Component Improvement programs for the two engines. There is no assurance that the

--F101DFE program can provide a production engine with enhanced operability, reliability, and durability characteristics;

--the production F101DFE will be available when and if needed; and

--F101DFE is an affordable and cost-effective substitute for these engines if the TF30 and F100 engine improvement programs fail.

DOD has spent $534 million on the Component Improvement programs to correct problems of compressor stalls and stagnations, turbine failures, and lower than desired durability of engine components since commencing production of the TF30 and F100 engines. It plans to spend another $420 million from 1979 through 1984. DOD and the services state that they fully expect these programs to demonstrate that they can correct the TF30 and F100 engine problems by 1981, at which time the F101DFE program will be terminated.

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INADEQUATE BACKUP PROGRAM

GAO believes the F101DFE program is at least as uncertain of producing a production engine with enhanced operability and supportability characteristics as are the TF30 and F100 improvement programs. This is due simply to the differences in the three engines' stages of development. The TF30 and F100 engines will have accumulated from 750,000 to 1 million flying hours in 1981 and will be reaching maturity in 1983. Conversely, the F101DFE will have accumulated only about 1,700 ground test hours and 200 engine flying hours in 1981 when the decision is to be made on whether to continue the program into full-scale development.

The F101DFE program will not have a production engine available in 1981-82 when the services determine whether their TF30 and F100 improvement programs have been successful.

Neither DOD nor the services have determined what constitutes sufficient failure of the improvement programs. They have not determined whether or upon what circumstances substituting the F101DFE for the TF30 or F100 engines would be affordable and cost effective. The enormous costs of $3 billion to $4 billion to back-fit the F-14 aircraft with the F101DFE on top of a $552 million TF30 improvement program raise serious questions concerning the worth and affordability of the alternative engine to the Navy. Risks and costs of concurrent development and production and the question of the engine's availability raise similar questions for the Air Force. (See pp. 13 to 15.)

AGENCY COMMENTS AND GAO ANALYSIS

Program managers in the Air Force and the contractor's organization were confident that the F101DFE will demonstrate enhanced operability and supportability characteristics. They based this on past experience with the technology being employed, early emphasis on operability and durability in developing the technology, improved analytical design tools, availability of actual mission usage profiles, and a willingness to trade performance for durability.

GAO agrees that the above factors represent significant differences between the F101DFE program and previous engine programs. Applying these factors should produce fewer big surprises during development and a more mature production engine at the end of the development period. However, these factors will not eliminate all surprises during development, production, and deployment. In fact, GAO believes the more extensive durability tests during development could result in the earlier identification of unexpected supportability deficiencies that will require more time to correct than is available before initial production in 1981 and full-scale production in 1983. (See p. 19.)

Air Force managers recognize that concurrent development and production creates some risks. They acknowledge that if major design deficiencies are discovered during development they will not be able to commence full-scale production in 1983. However, an Air Force representative added that sizable life-cycle cost savings could still be realized should the F101DFE not become available until 1984-85.

Regarding questions on the need for and affordability of the F101DFE, a DOD representative stated that it is unreasonable to now define the exact basis for full-scale development and production decisions of the F101DFE. (See p. 20.)

GAO believes that program planners need to know what is expected of the program now. What constitutes sufficient failure of the improvement programs and sufficient success of the F101DFE program? What are the chances for the substitution, and how sensitive are they to the F101DFE's availability, performance, and supportability characteristics? Answers to these questions are required not only to justify the initial investment of $93 million, but to structure, fund, and manage the program to meet identifiable needs.

RECENT AGENCY ACTIONS

On December 29, 1979, Air Force representatives reported that an effort headed by the Office of the Under Secretary of Defense for Research and Engineering would commence to validate the durability, operability, and cost of ownership claims for the F101DFE. They added that the current plan is to continue limited development through September 1981.

GAO agrees that the effort to assess the claims for the F101DFE is needed to determine its potential cost effectiveness, and that continuing limited development through September 1981 will be beneficial.

However, the funds requested for completing limited development in 1981 apparently will not (1) keep the contractor's engineering team intact, (2) appreciably increase early durability testing, or (3) assure first deliveries of the F101DFE before 1985 should there be a decision to go into full-scale development.

At a minimum, the uncertainties and questions should be addressed and the program established on a realistic basis that avoids taking overly ambitious steps under the guise of a modification program.

RECOMMENDATIONS TO THE SECRETARY OF DEFENSE

The Secretary of Defense should direct the Air Force, as the lead service, to:

--Assess the need for, worth, and affordability of the F101DFE program and define its objectives on the basis of the 1981 and 1983 decision points.

--Complete the risk analysis of the trade-offs between time, costs, and performance that will be required to reasonably assure a credible alternative at the major decision points.

--Formally recognize the increased risks attendant with commencing initial production of the

F101DFE in 1982 and full-scale production in 1983 or 1984 if this timing continues to be a program objective.

--Structure, fund, and manage the program to minimize risks in meeting identifiable program objectives.

If the program is not structured, funded, and managed on a reasonably firm basis to assure that it is and will continue to be a competitive alternative to the current Component Improvement programs, GAO recommends that the Secretary of Defense terminate the F101DFE as the alternate engine program.

RECOMMENDATIONS TO THE CONGRESS

The Defense Appropriations Conference Committee report directed DOD to initiate an alternate engine program on the basis that it would be developed and available when needed. The congressional appropriations committees should reexamine their objectives for the program and determine whether the F101DFE program, as presently structured, funded, and managed, satisfies their directive.

If the program is continued in fiscal year 1981, the Congress should reexamine the program before authorizing and appropriating funds for concurrent full-scale development and initial production of the F101DFE in fiscal year 1982. The uncertainties as to the need for an alternative engine as well as the F101DFE's potential for effectively meeting the need will still be present at that time.

Contents

ABBREVIATIONS

CIP	Component Improvement program
DFE	Derivative Fighter Engine
DOD	Department of Defense
GAO	General Accounting Office
USDR&E	Under Secretary of Defense for Research and Engineering

CHAPTER 1

INTRODUCTION

The F101X Engine Model Derivative program, hereinafter referred to as the F101 Derivative Fighter Engine (DFE) program, is part of the Department of Defense's (DOD's) comprehensive fighter aircraft engine program designed to correct current engine problems and to meet midterm and long-term engine needs. The objective of the F101DFE program is to modify the F101 engine, designed for the B-1 bomber, as an alternative or backup engine for the TF30 (F-14) and F100 (F-16) engines should their current Component Improvement programs (CIPs) fail to resolve the engines' operability and supportability problems. (See app. I for contractor's picture of a F101DFE mockup and summary outline of the program.)

CIP consists of those engineering services applied to an aircraft gas turbine engine currently in production or in the operational inventory to achieve or maintain its operational capability over time and reduce its manufacturing and operational costs whenever possible. Correcting conditions which have or could result in engine failures is the most important CIP function. Significant CIP activities include investigating field deficiency reports, testing hardware to establish life prediction data, increasing reliability and maintainability, investigating and establishing manufacturing cost-reduction actions, establishing and proving repair procedures, providing technical advice and guidance on overhaul practices, and qualifying new vendors. Specifically excluded are those engineering services to increase performance beyond defined specification requirements. As a contractual engineering support service, CIP is normally performed by the original manufacturer and usually continues for as long as the engine remains in active inventory.

The TF30 and F100 engines' problems, although different, generally consist of compressor stalls and stagnations, turbine failures, and lower than desired durability of engine components. Compressor stalls, stagnation, and turbine failures have adversely affected flight safety. Collectively the problems result in reduced operational readiness, increased spare parts costs, and extensive and costly CIPs and retrofits. From initiation of the engines' production in 1971 (TF30) and 1973 (F100) to 1979, the services have spent about $534 million to correct the problems. Although some improvements have been made, major problems remain. The Under Secretary of Defense for Research and Engineering

(USDR&E) and the services state that the F101DFE program is insurance if the engine problems are not corrected.

CONGRESSIONAL DIRECTION

The Congress authorized and appropriated $15 million in fiscal year 1977 and $26 million in fiscal year 1978 to begin development of an alternative engine for the Navy's F-14 aircraft because of problems encountered with the aircraft's TF30 engine. The Navy, however, did not start an alternative engine program in fiscal year 1977 or 1978, and, consequently, the funds were not used.

Late in calendar year 1977 and early 1978, the Air Force became increasingly concerned over problems with its F100 engine and its growing dependence on that engine to power its tactical fighter aircraft. The Air Force began to consider guidelines for developing production engine alternatives.

During this time, the Congress was also concerned over the TF30 and F100 engine problems and the need for a program to develop an alternative engine that would be suitable for possible application on both the F-14 and the F-16 aircraft. The Defense Appropriations Conference Committee Report No. 95-1764, dated October 11, 1978, entitled, "Defense Appropriation, Fiscal Year 1979," stated:

> "The conferees approved the House proposal to transfer $15,000,000 from fiscal year 1977 to fiscal year 1979 so that a joint competitive Navy/Air Force effort to develop an alternative engine for the F-14 aircraft, the F-16 aircraft, and other near-term aircraft engine requirements can be undertaken. An additional $26,000,000 already appropriated remains available for this purpose. Modification of existing engines should be considered in this competition."

Public Law 95-457 of October 13, 1978, appropriating funds for DOD for fiscal year 1979 provided that the "* * * $15,000,000 which shall be derived by transfer from 'Research, Development, Test, and Evaluation, Navy, 1977/1978,' to remain available for obligation until September 30, 1980."

IMPLEMENTATION OF CONGRESSIONAL DIRECTION

In accordance with the Defense Appropriations Conference Committee's direction, DOD developed a comprehensive program to fix existing engine problems and develop new fighter engines in accordance with the two services' near-to-long-term objectives. The major segments of DOD's overall fighter engine program are summarized below.

Near term-high priority

Both services are depending primarily on their CIPs to solve existing problems in the TF30 (F-14) and the F100 (F-15/16) engines.

--The Navy is planning to spend approximately $75 million in its CIP for the TF30 engine from 1979 through 1981 and more than $552 million to modify about 1,000 TF30 engines from 1982 through 1985 or 1986.

--The Air Force is planning to spend about $345 million from 1979 through 1984 on its CIP for the F100 engine. Its CIP currently includes about 130 projects that are expected to result in improvements in the engine's operability, durability, reliability, and maintainability. Although the costs to retrofit all the fixes that may result from the program through 1984 have not been determined, the Air Force reports incurred and planned expenditures of about $109 million for retrofitting known improvements to its growing inventory of F100 engines through 1981.

Midterm

Under the Engine Model Derivative program, a limited development program of the F101DFE as an alternative engine for the F-14 and F-16 aircraft was initiated in fiscal year 1979, with the Air Force having management responsibility. It is a 30 month, $93 million effort which will culminate in a flight test program requiring 100 flight hours in the single engine F-16 and 50 flight hours in the two engine F-14 during calendar year 1981. The program is to be a limited demonstration of the engine's ability to overcome existing problems and its potential for use in both aircraft.

If the CIPs demonstrate that they can correct existing deficiencies by 1981, the services expect to terminate the F101DFE program. If CIPs do not demonstrate they can correct the deficiencies, a decision to continue the F101DFE into full-scale engineering development could be made. The Air Force estimates full-scale engineering development of the F101DFE would cost $454 million and would extend from mid-1981 to September 1983. It could provide a production option for the proposed follow-on F-16 buy currently scheduled for September 1983.

Long term

An advanced technology engine program was also initiated in 1979, with Navy having management responsibility. The Navy states that this is a long-range development program for a new technology fighter engine that will have multiple military applications during the 1990-2000 time frame. Conceptual design studies will be performed through mid-1981 to define requirements; balance requirements among performance, operability, durability, maintainability, and life-cycle costs; establish an optimum schedule; and develop strategy for future service engine developments. The services state that their objective is to provide time and resources for an orderly and complete development effort that will avoid the shortcuts taken in past programs which have created today's problems. Funding planned for fiscal years 1979 through 1981, including technology demonstration programs, total approximately $134 million. The services anticipate expenditures of $1.2 billion to develop the new fighter engine for full-scale production in 1990.

SCOPE OF REVIEW

Our review of the F101DFE program was performed at the (1) U.S. Air Force Aero Propulsion Laboratory and the Deputy for Propulsion, Wright-Patterson Air Force Base, Ohio, (2) Arnold Engineering Development Center, Arnold Air Force Station, Tennessee, (3) offices in the Naval Air Systems Command, Washington, D.C., and (4) the General Electric Company Aircraft Engine Group, Cincinnati, Ohio. We interviewed officials at each location which included representatives in the F-14 and F-16 program offices and examined pertinent studies, contracts, program plans, schedules, and other documents.

We submitted copies of our draft report to DOD, the Air Force, and the Navy for comment on November 27, 1979. We obtained agency comments during discussions with DOD, Air Force, and Navy officials responsible for the F101DFE program on January 3 and 8, 1980. Their comments are summarized in chapter 3.

During our January 8, 1980, meeting, the Air Force representatives requested that we visit the Air Force program office at Wright-Patterson Air Force Base and the contractor's program office in Cincinnati, Ohio, to be briefed on the F101DFE's current technical status. The results of these visits made on January 23 and 24, 1980, have been incorporated into this report.

CHAPTER 2

WILL THE F101DFE PROGRAM PROVIDE ADEQUATE BACKUP?

In our opinion, the concept that the F101DFE program will provide a backup engine should the TF30 and F100 engines' CIPs fail implies three conditions: (1) the F101DFE program can provide a qualified production engine with the desired operability, reliability, and durability characteristics if the current CIPs do not, (2) the production F101DFE will be available when and if needed, and (3) there is a recognizable risk the current CIPs may fail and that it would be both affordable and cost effective to substitute the F101DFE for the TF30 and F100 engines if that happens. The F101DFE program does not promise to satisfy any of these implied conditions as the detailed discussion which follows illustrates.

F101DFE PROGRAM UNCERTAINTIES

The F101DFE program involves modifying the F101 engine, designed and developed for the B-1 bomber, to power the F-14 and F-16 fighter aircraft. The F101 has never flown operationally and has not matured beyond its development as a bomber engine. Modifications to enable usage of the F101 engine in the fighter aircraft include development of a new fan, low-pressure turbine, afterburner, nozzle, outer casing, and resizing to fit into the F-14 and F-16 airframes. In testimony before the House Armed Services Committee, a Navy official described this effort as extensive, both in terms of redesign and development.

Currently, the technical and schedule risks associated with achieving enhanced operability and supportability are as great for the F101DFE as for the F100 and TF30 engines simply because of the three engines' different stages of development. The Air Force and Navy state that many operability, reliability, and durability problems with the F100 and TF30 production engines have been identified; some design modifications are being incorporated on the engines; and others are being defined, tested, and evaluated. (See p. 3.)

By 1981, when the full-scale engineering development decision for the F101DFE is to be made, the F100 production engines will have accumulated 1 million flying hours and the TF30 engines on F-14 aircraft at least 750,000 flying hours. By 1983, both should be near maturity. That is, operability, reliability, and durability problems should not only have been identified and analyzed, but should be well into the process of being reduced and possibly corrected. At the least, the engines should be nearly stabilized with the likelihood that any remaining operability and supportability problems would be understood and predictable for purposes of operational and logistical planning.

By 1981, the F101DFE will still be in development and will have accumulated about 1,700 ground test hours and 200 engine flying hours. Air Force officials state that the ground testing will provide flight clearance for the F101DFE; the 200 flying hours will be the minimum needed to determine whether the F101DFE is a viable alternative with the potential for full-scale engineering development. Many more flight test hours will be required during full-scale engineering development to fully qualify the F101DFE for production. Also, from 100,000 to 1 million operational flying hours will be required to mature the production engine. The maturing process involves identifying and resolving production and operational problems that may only be statistically identifiable. Identifying these problems requires a large number of production engines operating throughout the flight envelope for extended periods of time.

History has clearly shown in past derivative fighter engine programs--TF30 and TF34 are examples--that contractors and the services have tended to minimize technical risk and be overly optimistic in terms of cost and schedule. Past programs also show that problems do arise during development and operational use which, when identified, require corrective modifications that are costly and time consuming. Some of these problems are anticipated and others are not.

Representatives of both the contractor and the Air Force state that the F101DFE program is significantly different from past derivative fighter engine programs. They point out that the F101DFE is the beneficiary of a $1 billion investment in technology accumulated over the past 12 years--1968 to 1980. This investment includes a number of successful engine development programs--F101/B-1 ($621 million), CFM56 using the F101 core ($109 million), YJ101/YF-17 ($31 million), and F404/F-18 ($250 million). These representatives explain that the F101DFE is based on proven and demonstrated technology from the above programs and, in many cases, uses identical components from the F101 engine.

For example, the contractor points out that a well-developed engine core is the key to low life-cycle costs because it encompasses the components that operate under the highest pressures, temperatures, and stresses. The

F101DFE has been built around the core of the F101 engine which achieved over 20,000 operational test hours in the B-1 development program. The contractor reports that as of January 1980, this core common to the F101/F101DFE has accumulated over 33,000 operational test hours, further demonstrating its durability and long cyclic life.

The contractor representatives observe that past derivative fighter engines have not been recipients of such an extensive technology investment. They add that other major differences between the F101DFE program and past programs include the following:

--Past programs have emphasized attainment of performance goals with operability and durability becoming secondary, whereas the F101DFE and its predecessor programs have given at least equal emphasis to operability and durability goals. As a result, the F101DFE, which is more then 700 pounds heavier than the F100 engine, is inherently more durable.

--Past programs have had relatively poor mission usage data early in their design phases, whereas the F101DFE is being designed and tested against actual mission usage profiles for both its F-14 and F-16 applications.

--The F101DFE program will benefit from the use of analytical design tools that were not available as little as 5 years ago. These include the use of holography, computerized 3-dimensional finite element analysis, and photoelastical analysis to better understand component working stresses and stress fields early in the design process.

--Instead of straining for the last bit of performance, the F101DFE, for its F-16 application, will be derated from its maximum performance capability to improve durability while still satisfying the aircraft's current performance needs.

Because of the above differences, contractor and Air Force managers responsible for the F101DFE limited development program believe they can design, fabricate, assemble, and test three F101DFE's to demonstrate the engines' enhanced operability and durability and its ability to satisfy all performance requirements. These development objectives are to be accomplished by the end of 1981. The follow-on development program, if approved, would then consist of product validation testing conducted concurrently with initial production.

Our review indicates that the differences between the current program and past programs are real and significant, but the extent to which the differences assure a relatively trouble-free derivative engine program remain to be seen. For example, other facts that could adversely impact the F101DFE development are:

--The F101 engine is not an operationally proven bomber engine, and the F404, a much smaller fighter engine (less than 20,000 pounds of thrust), is still in development.

--A fighter engine's pattern of starts, stops, and snap accelerations are much different and more stressful than for a terrain-following bomber engine.

--Identification of a fighter engine's operability and supportability problems requires extensive field usage (flight hours) that subject the engine to the rigors of extreme g forces and altitude changes characteristic of the severe fighter and carrier environments.

--The modifications to the F101 engine, which have been described as extensive, may result in the type of problems found in a new engine.

--The F101DFE will be pushing the state-of-the-art in regard to operability and supportability as much as the F100 engine; for example, the turbine inlet temperatures, a source of turbine failures and other durability problems, are approximately the same.

--The developing contractor has no demonstrated experience in developing and producing high-thrust (greater than 20,000 pounds), afterburning turbofan fighter engines.

The Air Force and Navy representatives discount the above risk factors for the following reasons:

--The F101 engine program had the most trouble-free development period ever. Present status of the F404 development program is 11,235 development test hours and 2,500 hours flight time. The F404 engine has exceeded its design requirements for durability and operability by significant margins; for example, turbine blades and other hot parts life of 1,000 hours versus the 500 hours required, and distortion tolerance 50 to 100 percent better than original specification.

--Engine stresses in the F101/B-1 are similar to the fighter environment; however, the number of cycles per mission is more severe for the fighter than for the bomber. Comparative analysis has shown that a 1.4 hour F-14 mission is approximately equivalent to a 5.25 hour B-1 mission. Hence, the F101/B-1 engine life of 13,000 hours is a 3,500 hour life in fighter applications.

--The limited development program is addressing the critical components, such as turbine and augmentor controls, early to avoid any major surprises later on.

--Although turbine inlet temperatures are approximately the same, improvements in cooling technology have demonstrated lower actual metal temperatures of the F101DFE first stage turbine blades. This is the critical parameter.

--The contractor has demonstrated outstanding capabilities in the advanced technology fighter engine field by executing the F404 development program with a minimum of problems. Technology/design for the F101DFE hot section, control system, and component life analysis are essentially the same as that being used in the F404. The turbine blade cooling design and turbine vane/blade cooling design are identical.

We question the optimistic conclusions that the contractor has or will have solved the longstanding operability and supportability problems with high-thrust (in excess of 20,000 pounds), afterburning turbofan fighter engines. The differences between the F101DFE program and other derivative fighter engine programs, however, are significant and should produce fewer surprises and a more mature production engine at the end of the development period. Nevertheless, these differences do not eliminate the program uncertainties in modifying even a well-developed engine for new and severe applications. The limited development and flight demonstration phase followed by the full-scale engineering development phase that is to be conducted concurrently with initial production increases these uncertainties. Also, since service operational and maintenance environments cannot be realistically duplicated in ground tests or during flight tests, we believe it is unreasonable to assume that all big surprises can be eliminated prior to the engine entering service.

F101DFE ENGINE NOT AVAILABLE WHEN NEEDED

The F101DFE cannot provide a fully qualified production engine by 1981 when the Air Force and the Navy determine whether their CIPs have been successful. As discussed below, if the alternate engine is required, the Navy must plan on a $3 billion to $4 billion retrofit program, and the Air Force must plan on concurrent development and production to provide the alternate engine for its proposed follow-on buy of F-16 aircraft in 1983.

Concurrent development and production

If the F100 CIP is unsuccessful, the Air Force expects its F101DFE program to provide engines for the proposed follow-on production buy of about 750 F-16s starting in September 1983. Currently, the Air Force has no plans to retrofit its initial production buy of 650 F-16s or its F-15 aircraft with the F101DFE.

By substituting the F101DFE for the F100 engine in the proposed follow-on F-16 production buy, the Air Force expects to avoid the enormous costs of retrofitting the engines. However, for the F101DFE program to meet the 1983 production schedule, production preparation and initial production has to be initiated concurrently with completion of limited development and commencement of full-scale engineering development. The Air Force's F101DFE development plan schedules the design release for long leadtime items in September 1980 before any flight tests. Full design release is scheduled for June 1981, immediately following the 100 hour F-16 flight test. Initial production startup costs for tooling and 56 engines are scheduled for 1981 and 1982 and will be undertaken concurrently with full-scale engineering development. Initial operational test and evaluation of 4 F-16 aircraft with F101DFEs is scheduled to begin in July 1983, about the time the first production engine is to be shipped to the airframe contractor for the 651st F-16 aircraft--the start of the F-16 follow-on buy.

Although the F101DFE is not a new engine development program, it requires (1) modifying the F101 bomber engine to power the fighter aircraft and (2) adequately testing the modified engine to provide the confidence that the follow-on production engines will be more reliable, maintainable, and durable than the F100 engines, which by 1981 will have accumulated more than 1 million flying hours.

As previously noted, the services are relying on the contractor's technology and data base accumulated over the past 12 years and other cited factors to avoid the empirical, iterative process of designing, building, testing, analyzing, and fixing that goes on in other engine programs until an acceptable engine is demonstrated. They expect the contractor to design the F101DFE so well the first time that follow-on tests will be for the purpose of product validation. Although they do not expect any surprises, Air Force officials acknowledge some risk in the development schedule.

The concurrency in the F101DFE development schedule represents "planning for success," which if not realized can not provide production engines in 1983. Even if successful, the F101DFE program will not produce the quantities needed in 1983. Air Force officials report that initial engine production will be five per month or less in July 1983 and will slowly build up to full-scale production. The proposed follow-on buy of F-16s is currently scheduled for 10 aircraft per month. If substitution is required, either the less desirable F100 engine will make up the differences or the excess F-16s will be stored until F101DFEs are available.

Costs of retrofit

The Navy expects to have sufficient data in 1981 to determine whether its TF30 CIP will achieve the prescribed goals for enhanced operability and supportability. However, even if the goals are not achieved, the Navy plans to go ahead with incorporating about 33 improvements on its TF30 engines at an estimated cost of $552 million. The plans recognize that (1) a production F101DFE if needed in 1981 would not be available and (2) current engine problems are serious and costly, and the improvements will include replacement of worn out parts on existing engines that would have to be replaced anyway. For these reasons, Navy officials state that the problems with the F-14's engine cannot be ignored regardless of concurrent or subsequent reengining plans.

The Navy plans to incorporate the improvements on its TF30 engines during the period from 1982 through 1985-86. The Navy has informed the Air Force that it would not retrofit its F-14 fleet with the F101DFEs before 1985-86. The Navy, however, has also stated that detailed F-14 reengining planning prior to the 1981 decision is premature and essentially undefinable.

By 1983-84, the earliest the F101DFE could become available, most of the TF30 engines will have been produced with the few remaining under contract. To retrofit the F-14s with the newly developed F101DFE after 1983 will cost an estimated $3.3 billion, including the cost of the engines.

QUESTIONABLE VALUE AND AFFORDABILITY OF THE F101DFE

Retrofit costs of $3 billion to $4 billion on top of the TF30 improvement costs of $552 million raise serious questions concerning the worth and affordability of the F101DFE to the Navy. The additional risks and costs of concurrent development and production plus other factors raise similar questions for the Air Force. Neither DOD nor the services have addressed these questions and apparently do not plan to do so until 1981, after $93 million and 30 months have been spent on the F101DFE program.

The services state that they fully expect their CIPs to be successful. This is supported by their plans to spend billions of dollars in developing, procuring, and supporting the F100 and TF30 engines during the period from 1979 through 1985, regardless of the F101DFE test results in 1981 and any reengining decisions. As an Air Force official recently testified before the Congress, the service is sufficiently confident of the F100 CIP that it is continuing to spend nearly $1 billion a year on F100 engines. Besides the services' previously noted plans, the Air Force plans include spending $80 million to incorporate improvements on its growing inventory of F100 engines from 1979 through 1981 and $40 million through 1981 to continue development of an enhanced F100 engine which is dependent on a reasonably successful F100 CIP.

Although both services anticipate successful CIPs, they recognize that the CIPs may not fully achieve their prescribed goals in all the areas of operability, reliability, maintainability, and durability. The pertinent questions concerning need for the F101DFE program, however, are (1) what constitutes sufficient failure of the improvement programs that would justify continuing with development of the F101DFE in 1981 and its production in 1983 or later and (2) what are the risks of this happening?

The above questions on need for a backup engine have not been answered. Further, DOD has not reconciled the F101DFE's potential performance, availability, and costs with the services' present and projected engine capabilities, resources, and priorities to ascertain the F101DFE program's worth and affordability.

For example, the Air Force's decision to go into full-scale engineering development of the F101DFE cannot be based on whether the F100 CIP achieves its defined operability, reliability, maintainability, and durability goals. By 1981, when the decision is to be made, the Air Force will have completed about one-half of its planned F100 CIP and will not know whether its goals have been or will be achieved. Air Force representatives state that they will (1) have sufficient test data on most, if not all, of the currently proposed fixes to show whether the trends towards the goals are positive or negative and (2) be able to make a decision based on these trends and the initial F101DFE test results. However, the service's decision to develop the F101DFE as a substitute for the F100 engine on the second buy of F-16s must also be based on its willingness to accept the (1) increased risks and costs of concurrent development and production, (2) added logistical costs required to support two different engines in its F-16 fleet, (3) reduction in standardization of the North Atlantic Treaty Organization F-16 force, and (4) possible adverse impact on the F-16 multinational coproduction program.

The Navy will have more complete data in 1981 to determine whether its planned TF30 CIP effort has achieved the prescribed goals. However, after completing the planned TF30 CIP effort in 1981 and initiating a program to incorporate 33 improvements on the engines, the question will be whether any remaining supportability deficiencies are significant enough to warrant an additional estimated investment of $3.7 billion for the Navy's share of full-scale development plus its costs to retrofit the F-14 fleet during the mid- to late-1980s. Such a decision would also have to consider use of the advanced technology fighter engine, which is expected to be ready for full-scale production in 1990.

Neither the Navy nor DOD have determined the affordability of developing and producing the F101DFE after 1981, and, consequently, have not decided on any specific cost parameters. However, during fiscal years 1977 and 1978, when facing serious operational deficiencies with its TF30 engines, the Navy did not consider an alternate engine development and production program of from $1.5 billion to $3 billion affordable. Accordingly, the Navy did not spend the $41 million authorized and appropriated in fiscal years 1977 and 1978 to develop an alternative engine.

The alternatives to F101DFE reengining in the mid- to late-1980s that may be more cost effective and affordable include downtrimming 1/ the F100 engines to extend the life of engine parts, accepting whatever additional costs are required (for more frequent inspections and parts replacement) to achieve and sustain operational readiness until fixes are developed during continuing CIPs, or waiting until the advanced technology fighter engine becomes available in 1990. The Air Force is reviewing studies on the benefits of downtrimming the F100 engines. The F100 and TF30 CIPs will continue probably as long as the engines are in use and have problems. Feasibility and conceptual studies for the advanced technology fighter engine were initiated in 1979, and DOD spokesmen anticipate expenditures of $1.245 billion to develop the new fighter engine for full-scale production in 1990.

1/Downward adjustment of the engine's turbine inlet temperatures which decreases thermal loads on turbine blades. The benefits are increased life expectancy of engine hot parts, particularly turbine blades, and the costs are decreased thrust and fuel efficiency if it requires operating the engine longer at maximum power.

CHAPTER 3

CONCLUSIONS, AGENCY COMMENTS, OUR EVALUATIONS, AND RECOMMENDATIONS

CONCLUSIONS

As discussed in the previous chapter, we seriously question whether the F101DFE program is a viable competitive alternative to the TF30 and F100 CIPs. First, the F101DFE as a backup engine is at least as uncertain of producing a production engine with enhanced operability and supportability characteristics at major decision points as are CIPs. Second, there is a question of whether production F101DFEs will be available as planned in 1983. Finally, there is a question of whether and under what circumstances the F101DFE would be an affordable and cost-effective alternative when it does become available.

The issues of affordability and cost effectiveness raise the following questions. What constitutes sufficient failure of CIPs and sufficient success of the F101DFE program at major decision points that would make the proposed substitution both affordable and cost effective? What are the chances for the substitution and how sensitive are they to the F101DFE's availability, performance, and supportability characteristics? Answers to these questions are needed not only to justify the initial investment of $93 million, but to structure, fund, and manage the program to meet identifiable needs.

The absence of answers to the above questions indicates that DOD and the services have initiated the F101DFE program as an insurance hedge against failure of CIPs without fully assessing the risks being covered or the adequacy of the coverage being provided. As a result, the program is structured, funded, and managed on the basis of schedule and funding constraints that may give the program viability if it is trouble free in solving longstanding problems with high-thrust, afterburning turbofan fighter engines.

However, it is also possible, and based on past experience highly probable, that the F101DFE cannot be structured, funded, and managed to assure that its objectives can be met simply because of its early stage of development and because of the early production dates required for a backup engine. If this is the case and if the early production dates cannot be extended, the program as presently conceived should be terminated. At a minimum, the uncertainties and questions should be addressed and the program established on a realistic basis that avoids taking overly ambitious steps under the guise of a modification program, particularly in light of the support provided. This has been the problem with past modification programs--J85-GE-21, TF30-P-100, TF30-P-412, and TF34-GE-100 engine modifications.

AGENCY COMMENTS AND OUR EVALUATIONS

We submitted drafts of our report to DOD, the Air Force, and the Navy for comments. We obtained agency comments during discussions with DOD, Air Force, and Navy officials responsible for the F101DFE program. These comments are summarized in the following sections.

Program objectives

In responding to a draft of this report, the services' representatives pointed out that the F101DFE program has other objectives than to serve as a backup engine for the TF30 and F100 engines. Navy representatives stated that the program is to:

--Establish the groundwork for preserving production options for alternate fighter engines for the 1983-84 time period.

--Provide return from previous engine development investments--F101/B-1, YJ101-YF-17, and F404/F-18.

--Reestablish competition in the high-thrust fighter engine market.

--Enhance the industrial manufacturing and technology base for high-thrust fighter engines.

Navy officials also pointed out that the decision to reengine the F-14 will be made on other factors besides TF-30 supportability deficiencies. They reported that improved, more effective F-14 configurations are under consideration, and the potential for incorporating a new engine installation will be weighed in the decision process.

Air Force representatives from the Office of the Deputy Chief of Staff Research, Development and Acquisition added that the F101DFE is potentially a more durable engine with lower cost of ownership and higher thrust. For these reasons, they feel the engine program is justified on its own merits, regardless of the results of the TF30 and F100 CIPs. The representatives also seriously question whether the TF30 and F100 CIPs will solve current problems and add that they won't know until late 1981 or early 1982 if the F101DFE should continue for either the F-16 or F-14, or for new mid-1980 requirements which are as yet undefined.

The other objectives and/or justifications for developing the F101DFE may have merit, but the engine program's stated purpose is to provide a backup engine for the TF30/F-14 and F100/F-16 engines should their CIPs fail. This objective is in accordance with congressional direction and statements by the Office of the Secretary of Defense and service representatives before the Congress. It is also the basis for the program's structure, funding, and management. Consequently, our review and report assesses the program on this basis and not on secondary benefits that may accrue.

We recognize, however, the implications in the services' comments that if the engine is developed some applications as yet undefined will probably be found. For this reason, we believe DOD, the services, and the Congress may want to reassess the F101DFE program not only on the basis of its current objectives and needs, but the potential objectives and needs that its continuing development may create.

Program uncertainties

In contrast to our reservations, F101DFE program managers in the Air Force and within the contractor's organization expressed confidence that the F101DFE will demonstrate enhanced operability and supportability characteristics during limited development and that the follow-on, full-scale development, if approved, will be a relatively trouble-free series of product validation tests. Relatively trouble free means that in contrast to past programs, there will be no engine problems or deficiencies that are not easily and readily corrected and no big surprises after the engines enter service. The managers base this confidence on past experience with the technology being employed, early emphasis on operability and durability in developing the technology, improved analytical design tools, availability of actual mission usage profiles, and a willingness to trade performance for durability.

We agree that the above factors do represent significant differences between the F101DFE program and previous derivative fighter engine programs. Applying these factors should produce fewer big surprises during development and a more mature production engine at the end of the development period. However, the factors will not eliminate all surprises during development, production, or deployment. In fact, we believe the more extensive durability tests during development could result in the earlier identification of unexpected supportability deficiencies that will require more time to correct than is available before initial production in 1981 and full-scale production in 1983.

We also believe it is unreasonable to assume that all big surprises can be eliminated prior to the engine entering service. Identification of all service-related deficiencies before operational deployment is not possible primarily because an engine's operational and maintenance environments cannot be realistically duplicated in ground and flight tests during development. For this reason, experience in prior engine programs suggests that unexpected service-related deficiencies will be identified with the high-thrust, afterburning turbofan fighter engine during early production and deployment, and critical CIP efforts will be required to correct them.

In summarizing his views on our report, a USDR&E representative stated that it reflects an absence of engineering analysis and judgment on those factors that weigh on the potential advantage of the F101DFE. Specifically, he stated the report does not give sufficient weight to the fact that (1) the engine has the same core as the F101 and CFM56 engines, (2) critical engine components from previously successful development programs will not be changed, (3) new components are low risk, and (4) the stability of the F101DFE with and without afterburner operation has been established in ground tests.

It is true that we did not make an engineering analysis or judgment on factors affecting the potential advantage of the F101DFE over the TF30 and F100 engines. However, we did assess the program on the basis of accumulated experience from past programs and we did discuss the technical and schedule uncertainties in the F101DFE program based on that experience. The engineering assessments are the responsibility of DOD and the services. Such assessments should be the basis for clarifying program objectives for the 1981 and 1983 decision points and for determining the potential worth and affordability of the F101DFE now, not in 1981 or later.

Availability of alternate engine

Air Force managers recognize some risk in the program that requires concurrent development and production. They acknowledge that if major design deficiencies are discovered during development, they will not be able to commence full-scale production in 1983. However, an Air Force representative added that based on expectations for the F101DFE, sizable life-cycle cost savings could still be realized should the engine become available in the 1984-85 time frame.

Although there may be some schedule flexibility, the F101DFE program is currently structured, funded, and managed to provide production engines in 1983. Also, contractor expectations for sizable life-cycle cost savings are based on limited test data that will require considerably more ground and flight test time to adequately support. Only extensive field operational experience can fully validate such expectations. Finally, the important related questions of the F101DFEs availability and affordability have not been answered. Consequently, there is a serious question on the F101DFE's affordability should it become available in 1983 or later.

Need and affordability

In reply to our statements questioning the need for and affordability of the F101DFE, an Air Force representative stated there was no advantage in describing a priori, the exact circumstances which would force a full-scale development commitment. The unfolding scenario of TF30 and F100 operations and their CIPs, coupled with the continuing development of the F101DFE and an enhanced version of the F100 engine, will provide the technical and cost data essential to address issues of what is affordable and cost effective. A USDR&E representative stated that it is unreasonable to demand a priori, the exact basis for decision and production of the F101DFE. The decision will be made based upon a broad range of economic and technical considerations of the facts at the time.

DOD and the services, consequently, do not expect to determine whether the F101DFE is needed or is even a potentially affordable alternative until 1981, after spending 30 months and $93 million on the program. If the Air Force determines there is a need for an alternate engine at that time, it will then have to decide whether to commence full-scale engineering development concurrently with initial production. Even if the results are positive from the limited development and flight demonstration, an affirmative decision will be expensive ($750 million) and risky because of the concurrency.

Recent agency actions

In commenting on our recommended actions on December 29, 1979, Air Force representatives from the Office of the Deputy Chief of Staff Research, Development and Acquisition reported that an effort headed by USDR&E and including Air Force and Navy participants would be commenced immediately to validate the durability, operability, and cost of ownership claims for the F101DFE. They also stated that the current plan is to continue limited development from June 1981 through September 1981 to further assess the durability and operability characteristics of the engine prior to any full-scale development decision.

We agree that the effort to assess the claims for the F101DFE is needed to determine its potential cost effectiveness and that continuing limited development through September 1981 to further assess durability and operability characteristics of the engine prior to the full-scale development decision will be beneficial. Because of this extension, DOD is not requesting funds for full-scale development or production startup in 1981. This was a major concern when Air Force planning documents showed full-scale development funds of $98 million and production startup funds of $54 million for fiscal year 1981.

We note, however, that the funds requested for limited development in 1981 will not keep the contractor's engineering team intact and will not maintain the option for first deliveries of the F101DFE in 1983, or even 1984. USDR&E testimony in March 1980 before the House Armed Services Subcommittee on Research and Development stated that first deliveries of the F101DFE would not occur before 1985 should there be a decision to go into full-scale development during fiscal year 1982. The delay in first deliveries is the result of the 1-year delay in production startup.

In our opinion, the above actions are more indicative of phasing the program down than strengthening its development phase to better support an early production date. If the alternate engine program is needed and if the alternate engine's concurrent development and production is a possibility in 1982 and/or 1983, we believe there should be an increase in early durability testing and development. The objective should be to complete development as early as possible and avoid or at least minimize the need for concurrent development and production.

In our opinion, DOD should firmly establish the need for the program--determine what constitutes failure of the TF30 and F100 CIPs and whether the chances for failure are sufficient to justify continuing with the alternate engine program. Second, DOD should determine what is required of the F101DFE to make its substitution both reasonably cost effective and affordable. Assuming what is required is obtainable, DOD should then structure, fund, and manage the program to achieve its identifiable objectives. Otherwise, the F101DFE program should be terminated, not just phased out.

RECOMMENDATIONS TO THE SECRETARY OF DEFENSE

Therefore, we recommend that the Secretary of Defense direct the Air Force, as the lead service, to:

--Assess the need for, the worth, and affordability of the F101DFE program and define its objectives on the basis of the 1981 and 1983 decision points.

--Complete the risk analysis of the trade-offs between time, costs, and performance that will be required to reasonably assure a credible competitive alternative at the major decision points.

--Formally recognize the increased risks attendant with commencing initial production of the F101DFE in 1982 and full-scale production in 1983 or 1984 if this timing continues to be a program objective.

--Structure, fund, and manage the program to minimize risks in meeting identifiable program objectives.

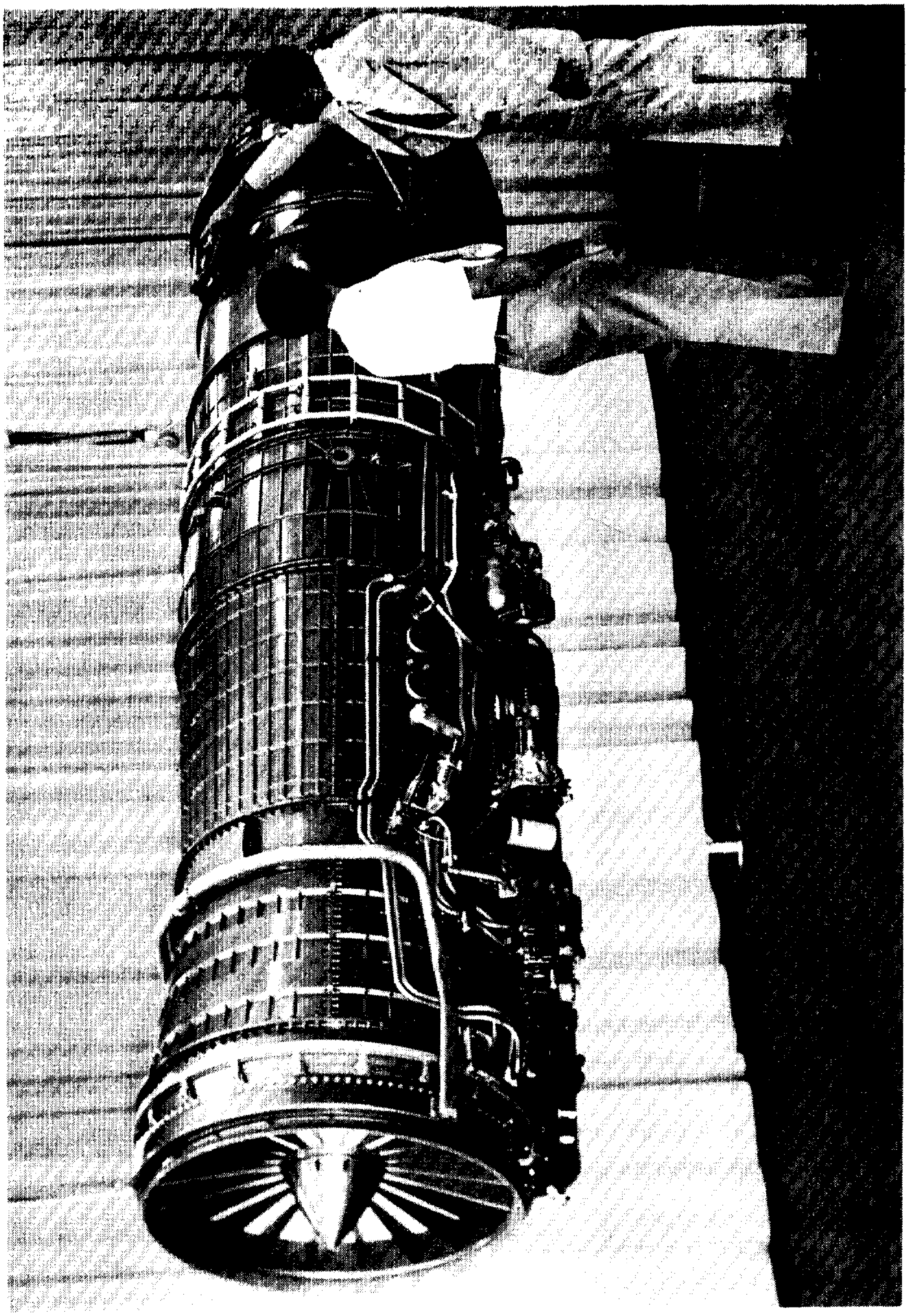
If the program is not structured, funded, and managed on a reasonably firm basis to assure that it is a competitive alternative to existing CIPs, we recommend that the Secretary of Defense terminate the F101DFE program.

RECOMMENDATIONS TO THE CONGRESS

The Defense Appropriations Conference Committee report directed DOD to initiate an alternate engine program on the basis that it would be developed and available when needed. Based on questions raised in this report, we recommend that the congressional appropriations committees reexamine their objectives for the program and determine whether the F101DFE program, as presently structured, funded, and managed satisfies their directive.

If the program is continued in fiscal year 1981, we recommend that prior to authorizing and appropriating funds for concurrent full-scale development and initial production of the F101DFE in fiscal year 1982, the Congress reexamine the program based on the uncertainties discussed in this report. Our review shows that uncertainties as to the need for an alternate engine as well as the F101DFE's potential for effectively meeting the need will be present at that time.

APPENDIX I



F101 DFE Afterburning Turbofan Engine

GENERAL ELECTRIC
U.S.A.

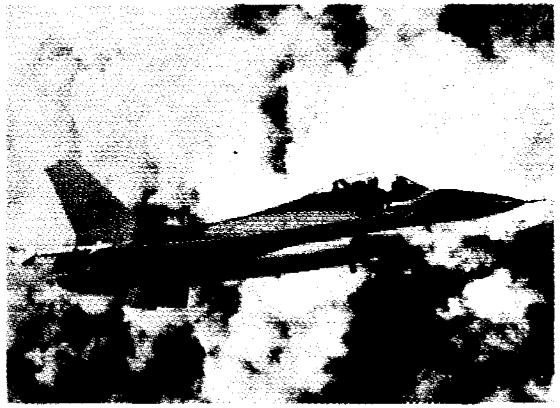
F101 DFE (Derivative Fighter Engine)
26 - 29,000 lb Class

Status

The GE F101 DFE augmented turbofan engine is a derivative fighter engine using common hardware and technology of the F101 engine for the B-1 strategic aircraft and the YJ101 and F404 engines used in the YF-17 and F-18 aircraft. This marriage of proven hardware not only lowers the development risk and cost but also produces a reliable, rugged engine with emphasis on reliability, durability, low shop visit rate, low maintenance man-hours, and low maintenance cost per flight hour.

General Electric funded a highly successful demonstrator engine program and in March 1979, the 26-29,000 lb thrust class F101 DFE was awarded a 30-month contract as part of a cooperative plan between the United States Air Force and Navy for joint propulsion efforts to develop a potential alternate engine for advanced fighter aircraft. The effort is being directed by the U.S. Air Force Systems Command — Aeronautical Systems Division, Wright-Patterson AFB, Ohio.

The contract will lead to flight testing of the engine in the F-14 and F-16 fighters in 1981. Three F101 DFE engines will be delivered for the U.S. Air Force and Navy flight test Programs. The F-16 will fly in the first quarter of 1981 and the F-14 in the third quarter of that year.



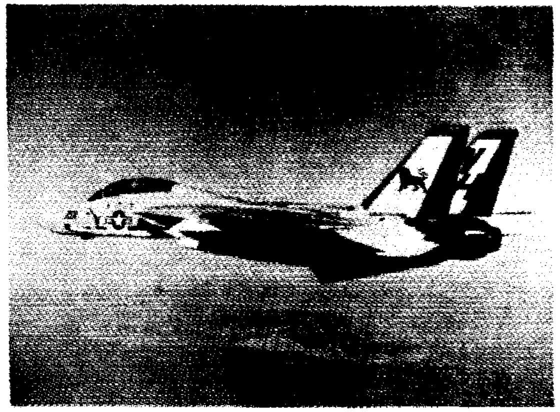
General Dynamics F-16 Multi-Role Fighter

Specifications

Thrust Class (lb)	26-29,000 pounds
Length (in.)	181
Max. Diameter (in.)	50
Air Flow Class (lbs/sec)	250-270
Bypass Ratio	0.85
Fan	3 stages, variable IGV's
Compressor	9 stages, axial flow
High Pressure Turbine	1 stage
Low Pressure Turbine	2 stages
Combustor	Annular/direct fuel injection carburetor
Augmentor	Mixed flow
Exhaust Nozzle	Convergent/Divergent
Engine Controls	Hydro-mechanical/electrical limit protection

Key Milestones

Demonstrator Testing	1977-1978
Flight Engine Design Released	Oct. 1978
USAF Contract	March 1979
1st Flight Engine Test	Jan. 1980
Flight Clearance	4th Qtr. 1980
Fly in F-16	1st Qtr. 1981
Fly in F-14	3rd Qtr. 1981



Grumman F-14 Tomcat

APPENDIX I

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