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UNITED STATES GENERAL ACCOUNTING OFFICE

REPORT TO THE CONGRESS

Problems In Managing The Development Of Aircraft Engines

B-179166

Department of Defense

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

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MAY 23, 1974

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

We are reporting on problems in managing the development of aircraft engines in the Department of Defense.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

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

R.F. Keller

Acting Comptroller General
of the United States

LV HSE 300

C o n t e n t s

ABBREVIATIONS

CIP	component improvement programs
DOD	Department of Defense
DDR&E	Director of Defense Research and Engineering
GAO	General Accounting Office
LMI	Logistics Management Institute
MQT	model qualification test
OSD	Office of the Secretary of Defense
RDT&E	research, development, test, and evaluation
TBO	time between overhaul

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

PROBLEMS IN MANAGING
DEVELOPMENT OF AIRCRAFT ENGINES
Department of Defense B-179166

D I G E S T

WHY THE REVIEW WAS MADE

Part of the $9 billion investment of the Department of Defense in aircraft engines consists of the cost of development effort under engine component improvement programs (CIP). Engine CIP is generally defined as effort to improve an aircraft engine, which has qualified for production, to its final operating performance.

About $3.28 billion has been used for CIP over a 17-year period. Sizable budgets for CIP are planned for engines currently in development or production for the F-15, B-1, A-10, remotely piloted vehicles, and the airborne warning and control system.

Traditionally the military services have developed engines using standard specifications with major milestones, including a model qualification test (MQT). The purpose of the MQT is to demonstrate that the engine meets specification requirements and is suitable for production.

Under present procedures, successful completion of MQT takes the engine out of research, development, test, and evaluation (RDT&E) funding and qualifies it for production, with financing from procurement appropriations.

Successful completion of MQT also marks the beginning of the engine's CIP, which for years has been funded with procurement, and sometimes operation and maintenance, appropriations.

The House Committee on Appropriations on several occasions questioned use of procurement funds for research and development work, such as component improvement. (See p. 5.)

FINDINGS AND CONCLUSIONS

Engine development

Need for continued development during the engine production and operation phases stems, at least in part, from the military practice of awarding development contracts based on specifications which are somewhat below the capability ultimately desired. Such additional capability is then obtained through CIP.

Military officials familiar with aircraft engine development generally acknowledge that, when an engine passes MQT and is approved for production, it is not fully mature and requires further development to achieve the desired level of capability. (See p. 8.)

Studies by independent groups, including one in August 1973 by the Air Force's Scientific Advisory Board Ad Hoc Committee on Engine Development, show that extensive development effort continues under CIP concurrent with production. (See p. 9.)

Tear Sheet. Upon removal, the report cover date should be noted hereon.

Use of CIP funds to increase capability after MQT is common and expected. Descriptions of contract and project tasks demonstrate that CIP effort is mainly developmental and is aimed at increasing capability beyond that existing at MQT.

CIP also triggers additional costs to implement modifications and retrofits to engines in production.

DOD and the military services are becoming more concerned about these sizable costs, many of which are avoidable because they result from decisions to start producing engines before they are fully developed. (See pp. 10 to 15.)

GAO found no evidence that the practice traditionally followed by the military services to develop and acquire engines is the best or most cost-effective method.

Substantial costs of CIP and related costs of retrofit and modification call for reassessing the method of developing and acquiring military aircraft engines because some new or advanced engines may be entering the production cycle prematurely. (See p. 16.)

Financing component improvement

DOD's guidance clearly shows that developmental effort should be financed by an RDT&E appropriation. However, the military services have interpreted an exception in DOD's guidance to mean that all CIP effort is engineering service rather than developmental effort and therefore can be financed with procurement and operation and maintenance funds. (See p. 21.)

The House Appropriations Committee reported that use of funds other than RDT&E to finance programs such as product improvement can cause (1) an insufficient review of the request, (2) a misleading assessment of the balance between development and acquisition, and (3) a premature entry into the procurement/production phase of a program. The Committee requested DOD to purge such efforts from the procurement appropriation.

CIP was planned for the F100 engine after the MQT. The Office of the Secretary of Defense recognized that CIP planned for the F100 engine after MQT was a continuation of the development program and directed that substantial CIP effort be cut from the procurement appropriation and financed with RDT&E funds.

This program/budget decision further indicated that future requests for CIP in the procurement accounts should be limited to specific programs designed to provide solutions to specific problems in production engines. (See p. 22.)

Although this is a step in the right direction, GAO questions whether a decision applicable to a single program will be broadly applied as long as DOD's formal guidance remains unchanged.

The Committee's concern encompasses the entire spectrum of engineering effort associated with advance production engineering, product improvement, component improvement, modifications, and alterations.

Only a broadly based effort evidenced by formal changes in DOD's Budget Guidance Manual could lead to the necessary corrective actions. (See p. 24.)

AGENCY ACTIONS AND UNRESOLVED ISSUES

Engine development

In November 1973 DOD agreed it was not clear that current methods of developing and acquiring aircraft engines are the practical optimum. DOD said that reevaluation of such methods is in order but that it preferred to await completion of Air Force studies then underway.

In January 1974 DOD furnished GAO a report by the Air Force's Scientific Advisory Board Ad Hoc Committee on Engine Development which concluded that the MQT is not the proper milestone for full-scale production release. Key Air Force activities in engine development agreed with the report and recommended major revisions in the milestones and evaluation procedures for future engine development programs.

These revisions include increases in both the period and scope of engine development. Production releases would be incremental, with small releases authorized to support aircraft test programs and higher production rates authorized later when more definitive milestones had been achieved. (See p. 19.)

Implementation of the proposed revisions should improve the methods of developing and acquiring aircraft engines if initiatives begun in this important area are followed through expeditiously. (See p. 20.)

Financing component improvement

DOD did not agree that budgetary guidance for financing developmental effort required revision because it believed it had provided sufficient guidance in January 1968. DOD acknowledged, however, that developments on the F100 engine initiated after 1968 were being conducted with procurement funds until the effort was properly redirected under RDT&E.

GAO recognizes that the 1968 guidance was supposed to preclude funding engine development under the CIP program but, on the basis of statements of knowledgeable officials, many examples of CIP effort which occurred after 1968, and studies made for DOD, GAO believes that DOD needs to revise its budget guidance to relate the method of funding to the type of effort involved rather than to whether the item is in production or operation.

Full implementation of revised guidance should result in proper and consistent use of CIP and give DOD and appropriate congressional committees the entire view of the extensive and costly engine development effort. (See p. 27.)

RECOMMENDATIONS

The Secretary of Defense should insure that the proposed revisions in the method of developing and acquiring aircraft engines are followed through expeditiously. The many studies already available should be used to determine what changes in engine procurement methods might promote cost reductions and increase operational effectiveness. (See p. 20.)

DOD's guidance should be revised to insure that research and development work be budgeted and funded through the RDT&E appropriations. (See p. 27.)

MATTERS FOR CONSIDERATION BY THE CONGRESS

The information in this report should assist congressional committees in their legislative responsibilities relating to development of aircraft weapon systems and the financing of aircraft engine component improvement programs.

CHAPTER 1

INTRODUCTION

The acquisition and maintenance of aircraft engines by the Department of Defense (DOD) is a major undertaking. DOD owns about 90,000 engines worth about $9 billion; $6 billion is for engines installed on aircraft and the remainder is for spare engines. DOD spent $1 billion to maintain these engines during 1971; some 29,000 engines were either overhauled or repaired during that period.

Part of the total investment involves development effort under engine component improvement programs (CIP) and the attendant cost of implementing engine changes as a result of CIP. Engine CIP is generally described as effort to improve an aircraft engine, qualified for production, to its final operating performance. For engines in production or in the services' inventories, the level of effort usually is negotiated annually under separate contracts with engine manufacturers for each engine. For some recent major aircraft acquisitions, CIP has been made a part of the initial engine acquisition contracts, but their levels of effort are subject to change in later production and operation phases.

Over a 17-year period about $3.28 billion has been used for CIP. Sizable CIP budgets are planned for engines currently in development or production for the F-15, B-1, A-10, remotely piloted vehicles, and the airborne warning and control system.

On several occasions the House Appropriations Committee has questioned the appropriateness of using procurement funds for research and development, such as CIP.[1]

Traditionally, the military services develop engines using standard specifications which involve major milestones, such as a preliminary flight-rating test and a model qualification test (MQT). The preliminary flight-rating test is to demonstrate engine suitability for limited use in experimental flight tests. It involves a number of tests, including an endurance test consisting of 10 cycles of 6 hours each.

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[1]H. Rept. 92-1389 (Sept. 1972) p. 130, and H. Rept. 93-662 (Nov. 1973) p. 148.

The purpose of MQT is to demonstrate that the engine meets specification requirements and is suitable for production. MQT includes such factors as endurance, reliability, fatigue life, engine stability, and mechanical integrity. Tests generally involve an engine running time of 25 cycles of 6 hours each. The engine's components are generally tested in the same manner as the engine.

Under present procedures, successful completion of MQT (1) takes the engine out of research, development, test, and evaluation (RDT&E) funding and qualifies it for production and financing with procurement appropriations and (2) marks the beginning of the engine's CIP.

SCOPE OF REVIEW

In reviewing selected aspects of DOD's practices in aircraft engine research and development, we examined the events surrounding qualification of an engine for production and the accomplishment of subsequent development efforts, primarily under aircraft engine CIP. We also considered how various appropriations were used to fund aircraft engine development and whether developmental effort during production was fully disclosed to the Congress and financed with the proper appropriations.

We made our review at:

Office of the Secretary of Defense (OSD)
Air Force Systems Command, Andrews Air Force Base, Washington, D.C.
Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.
Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base.
Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base.
Air Force Materials Laboratory, Wright-Patterson Air Force Base.
Naval Air Systems Command, Washington, D.C.
U.S. Army Aviation Systems Command, St. Louis, Missouri.
Aircraft Engine Group, General Electric Company, Evendale, Ohio.
Pratt & Whitney Aircraft Division, United Aircraft Corporation, East Hartford, Connecticut

CHAPTER 2

NEED TO REASSESS TRADITIONAL METHOD

OF DEVELOPING ENGINES

We found compelling evidence that an engine usually is not fully developed at the time it passes MQT. Observations of knowledgeable officials in the military and independent study groups, coupled with examples of CIP efforts, show that extensive and complex development effort continues under engine CIP concurrent with production.

OBSERVATIONS OF KNOWLEDGEABLE OFFICIALS

Military officials familiar with aircraft engine development generally acknowledge that, when an engine passes MQT and is approved for production, it is not fully developed and mature and it requires substantial further development to achieve the desired capability level. Minutes of the July 1971 annual meeting of the tri-service engine coordination group (1) confirm that CIP is primarily continued development and (2) show that some military officials misunderstand the purpose of CIP.

> "* * * There is a fairly wide spread misconception in the Air Force that when an engine passes its qualification test it is a fully developed mature engine. This misconception is most pronounced in the Logistics Command but it also exists in the Systems Command. The impact in the Systems Command of this misconception is normally limited to failure to plan adequately for the changes in engines that occur after the qualification test. * * * Systems Command has been able to provide engineering support for engines after qualification because the Air Force has been fortunate in having a strong spokesman * * * that understand the limitation of qualification tests and have been able to make themselves heard in the budgeting process. The Logistics Command has a much more difficult problem. They have numerous items which must be supported and rarely is there enough money available to meet all of their serious needs. They

> are continually faced with the most difficult task of allocating shortages. The use of [operation and maintenance] funds for CIP in the Logistics Command means that CIP effort must compete with all other needs of the Command * * *. With the widespread misconception of qualification testing and therefore the engineering needs of engines when they are transferred to the [Air Force Logistics Command] for support, it is not surprising that funds for this purpose are difficult to obtain. Many Logistics Command personnel believe that the investigation of [unsatisfactory reports] and the development of repair procedures is all that should be necessary under the engine CIP effort * * *."

Further evidence that an engine requires development far beyond MQT is contained in a June 1972 report by the Logistics Management Institute (LMI). That report, prepared for the Assistant Secretary of Defense (Installations and Logistics), contends that for military engines the ratio of post-MQT development dollars to pre-MQT development dollars is about 2 to 1.

A September 1970 Rand Corporation report on estimating aircraft turbine engine costs defines development cost as including:

> "* * * the total expenses involved in developing a new engine, plus the costs of correcting service-revealed deficiencies and continued product improvement over time. Product improvement, which may be conducted by separate development contracts or other procedures, is an important part of the engine development process and should not be construed as simply improving reliability or increasing the number of applications. However, those funds expended for continued improvement of the components of a given engine model that are included in procurement contracts as a manufacturing cost are excluded from development."

Rand defined development cost similarly in a July 1972 report.

Development of higher time between overhaul (TBO) and otherwise increased capability after MQT using CIP funds is common and expected. For example, minutes of an Air Force engine advisory group meeting include the following overall achievements with CIP funds for the J79 engine.

--TBO growth increased from 450 to 1,200 hours.
--Thrust growth increased from 14,000 to 17,900 pounds.
--Specific fuel consumption reduced from 2.20 to 1.97.

Our discussions in October 1972 with OSD officials indicated differences of opinion on CIP. An OSD research and development official claimed that, once an engine passed MQT, research and development ends and engine problems surfacing later should be solved with procurement funds. On the other hand, OSD installations and logistics officials felt that product improvement programs and CIP were development activities, primarily concerned with increasing TBO and maximum operating time. They also said that the current policy is to buy an engine at a low TBO, then increase it to a higher TBO.

A program/budget decision document approved by OSD in December 1972 recognized, at least in one instance, that CIP is continued development after MQT. (See p. 23.)

SPECIFIC CIP DEVELOPMENTAL EFFORT

Data from contracts and specific projects demonstrates that CIP is predominately developmental and is aimed at increasing capability, including performance and endurance, beyond that existing at MQT.

TF39 engine for the C-5A aircraft

Beginning in June 1969, contracts were awarded for CIP on the TF39 engine. The objective of the work statements of the first three contracts was to increase the performance margins of the TF39 engine by adapting high-temperature turbine and combustor technology which had become available since the TF39 engine was originally designed.

The manufacturer's engineer responsible for the combustor/turbine project told us that the new combustor/turbine would provide increased thrust which can be used in two ways. The engine can be operated at a higher thrust, which results in little or no increase in durability, or it can be operated at its present thrust for a longer time, which increases the TBO to 5,000 hours.

The above contracts also indicated that other engine components would be redesigned during the program, as necessary. These redesigned components, after being tested to qualify, would be compatible with the higher temperatures and other engine parameters associated with the advanced high-pressure turbine and improved high-temperature combustor.

A succeeding contract for CIP for 1972 and a contractor's proposal for 1973 amounted to about $41 million. The objective of the 1972 program was to insure that the TF39 engine achieved and maintained its full operational capability potential. To accomplish this, the following programs were expected to be undertaken:

--Service-revealed problem resolution and implementation.

--TBO progression.

--Qualification of the advanced high-pressure turbine and combustor.

--Maintainability, reparability, and reliability support.

The contractor's proposal for CIP for 1973 was to insure that the engine would operate at its full potential. Resolution of service-revealed problems was one program to achieve the objective. Other programs generally involved such efforts as development and design, evaluation testing, and qualification of parts and materials to improve the engine.

CIP was used to design a composite graphite/epoxy fan blade for the TF39 from a demonstration blade developed under another program. Failures resulted in several redesigns, and a third design was scheduled for testing in 1973. The manufacturer and the Air Force's project engineers said that no aircraft engines flying had composite fan blades and that another manufacturer had tried to develop one but failed. An Air Force project engineer classified the effort under the TF39 project as applied research because basic composite technology was being used in developing the fan blade.

Through 1972 about $78 million had been spent on CIP for the TF39. Much of this effort involved increasing TBO significantly higher than was called for in the original contract. The Air Force estimated that an additional $65 million would be needed for CIP on this engine through 1977. Since the aircraft's estimated life is 15 to 20 years, it will probably require considerably more funds for CIP beyond 1977. Through 1972 all CIP for the TF39 was financed with procurement funds; after 1972, financing was to be carried out with operation and maintenance funds.

J79 engine for the F-4 aircraft

The J79 engine, which has been operational for many years, is still receiving CIP funds. For example, a project begun in 1968 was to reduce excessive smoke emission and increase combustor life. The first redesign was flight tested in March 1970 but the smoke had not been reduced to an acceptable level. Development was continued, and a revised design was flight tested in December 1970. As in the first tests, the smoke still exceeded requirements. The contractor continued CIP. In December 1971 another redesign of the combustor was flight tested, but it showed no improvement. The combustor passed MQT even though it was producing smoke in excess of requirements.

The contractor has proposed an engineering change incorporating the latest redesign of the combustor. Approval is pending a service flight test which is evaluating the smoke level.

YJ97 engine

The YJ97 engine is being developed for a remotely piloted vehicle. The development program, costing about $27 million and financed with research and development funds, started in 1966. From 1966 through 1972, an additional $4 million was spent on the engine with CIP procurement funds; about $2.5 million more for CIP is envisioned through 1977. The CIP is directed toward

--developing and testing afterburners and components;

--redesigning engine components;

--testing other new components;

--investigating, analyzing, and defining problems identified in the field; and

--conducting engineering services to support an airframe manufacturer for using the YJ97 in a new remotely piloted vehicle.

F100 engine for the F-15 aircraft

For the F100 engine, significant CIP funds have been approved and more are planned for the next several years. CIP fund requirements have been projected at $244 million while the initial RDT&E costs were expected to be about $271 million. The statement of work in the August 1973 CIP contract between the Air Force and the F100 engine contractor clearly demonstrates that its nature is research and development.

This work includes redesign of most engine components when required to correct flight-revealed and production deficiencies or to improve engine reliability, maintainability, and durability. Components planned for redesign include the fan, compressor, combustor/diffuser, turbine, augmentor, exhaust nozzle, mechanical components, and engine controls and accessories. Much of the testing is carried out at Government facilities.

COST IMPACT OF CIP

Engine development with CIP funds is a significant cost of engine acquisition. Also, CIP triggers sizable additional costs to implement modifications and retrofits to the engines in production.

According to the June 1972 LMI report, some of the additional costs resulting from CIP developments are (1) purchase of modification/retrofit kits to accomplish design changes, (2) cost at depots to install the kits, (3) cost to rework old parts in the new design, (4) cost of scrapping usable but obsolete parts, (5) cost of more frequent repairs on early production engines which have a lesser maintenance performance than later models, and (6) cost of the investment in additional spare engines to support the early production engines because they have a lesser maintenance performance than subsequent models.

The TF39 engine illustrates the extent of changes arising from CIP. It went into production with a 1,000-hour TBO design, when a higher TBO of 3,000 to 5,000 hours was anticipated. By the time the 3,000-hour design was introduced, new hardware had to be retrofited on about 320 engines in service. This new design required 38 engineering changes which were the outgrowth of about 41 CIP projects. One engineering change alone required scrapping 17,229 parts, reworking 933 parts, and installing 6 different retrofit kits on the engines. We did not attempt to quantify the cost impact of the changes, but it seems evident that sizable expenditures were involved.

The Commission on Government Procurement found, in its study of DOD's system acquisition process, that commitment to extensive production when much development, test, evaluation, and redesign still remain to be done usually leads to major retrofit and modification costs. Components, equipment, and tools can be made obsolete by design changes as the development progresses.

PRIOR STUDIES

Some components of OSD and the military services are concerned about the sizable modification and retrofit costs. Over the years OSD has contracted for studies on procuring engines and related subjects, and the services have carried out a number of similar studies. The LMI report referred to at least 20 such studies bearing on engine acquisition. However, we were not able to identify any significant changes to date in the method of developing and acquiring engines.

LMI reports that the military services achieve engine growth by CIP funding, unlike the commercial practice of including it in the purchase price. The commerical engine almost always is grown from a higher base than is the military engine because it is normally derived from a military engine. According to LMI, the military and commercial engine acquisition methods differ enough to make comparison of the two not very worthwhile, yet it is clear that opportunities exist for trade-offs between the methods.

LMI created a hypothetical example comparing military and commercial methods which showed that the CIP method for engine growth is far more expensive than the commercial method. LMI admitted, however, that it cannot be demonstrated that life-cycle cost savings follow from increasing the engine development time because an essential ingredient--the cost of, and the results to be expected from, delaying production to incorporate solutions to defined problems--is missing. The study simply casts doubt on whether the military method is cost effective. The study asks, "What is the magic which selects 150 hours for the qualification of each new military engine model?"

CONCLUSIONS

It is questionable whether the method traditionally followed by the military in developing and acquiring aircraft engines is the most cost effective or that it precludes engines from premature entry into production. It is widely acknowledged that an engine is not fully developed at the time it passes MQT and moves into production and that both the subsequent development efforts (accomplished through CIP) and the incorporation of changes that result from such further development have a significant impact on total engine costs.

One of the primary findings of the Commission on Government Procurement is that too many funds are committed to major systems before ideas, needs, designs, and hardware are tested and evaluated. Just before a planned full-production commitment, the system must be subjected to a tough and objective evaluation of its usefulness under expected operating conditions. The Commission recommended that agency approval and congressional commitments be withheld until the system performance has been tested and evaluated in such an environment.

The Commission also reported that, if the initial operating capability date of a system is treated as an imperative deadline, the study, development, and production phases may be compressed to force a program into final development or production before it is ready, thereby magnifying the impact of uncertainties on costs.

We recognize that any change from the present method would have some far-reaching aspects that must be considered, such as:

1. Against change:

--Fuller development would require greater amounts of RDT&E funds.

--The engine procurement decision would come later in the acquisition cycle.

--This later decision point could be detrimental to the predetermined initial operational capability date for the related aircraft.

2. For change:

--A better developed engine would enter production.

--Fewer changes would have to be made during production.

--An increase in built-in maintainability would decrease maintenance costs and reduce downtime.

--Fewer parts would require rework or scrapping.

--A smaller investment in spare engines would be required.

--Modification costs for engines in inventory would be reduced.

Recent DOD policy statements have indicated that predetermined initial operational capability dates should not influence the orderly development of weapon systems or their components. We believe that a change in development methods for aircraft engines, perhaps to a longer development period, would be appropriate and any potential impact on the development of aircraft weapon systems should be considered in the light of these policy statements. For new systems a longer time for engine development, if necessary, could be planned from the beginning.

The absence of firm assurance that the traditional method is the best method, together with the large costs of component improvement programs and the related costs of retrofit and modification, point conclusively to the need to reassess the manner in which aircraft engines are developed and acquired.

We recommended that the Secretary of Defense direct a thorough evaluation of the appropriateness of the method historically used for developing and acquiring military aircraft engines, giving special consideration to the practice of authorizing production when an engine has passed the model qualification test. We further recommended that the evaluation encompass an analysis of the many studies already made for DOD.

AGENCY COMMENTS AND OUR EVALUATION

Our views were made known to DOD in June 1973. In a letter dated November 7, 1973, (see app. I), DOD stated that it generally agreed with the intent of our recommendations. DOD acknowledged that it was not clear that current methods of developing and acquiring aircraft engines are the practical optimum and agreed that reevaluation is in order. However, it preferred to delay a reevaluation on a DOD-wide basis pending completion of studies currently underway in the Air Force.

In January 1974 DOD provided us with an August 1973 report by the Air Force's Scientific Advisory Board Ad Hoc Committee on Engine Development and comments on that report by the Air Force Aero Propulsion Laboratory, the Air Force Aeronautical Systems Division, and the Air Force Arnold Engineering Development Center.

The report concluded that "MQT is not the proper milestone for full scale production release" and recommended that "Development program schedules be adjusted to allow for a one-to-two year service test of engines in the actual aircraft throughout the expected operational envelope before committing to full production."

In their response, the Air Force organizations agreed that MQT has serious shortcomings as the milestone on which to base the decision to authorize a high-rate engine production program and stated "We must destroy the MQT syndrome which perpetuates the myth that engine development can be completed by that time and properly evaluated in one big series of tests." They disagreed, however, with the Scientific Advisory Board's recommendation for extended flight testing, calling it an insufficient solution. Instead they recommended major revisions of the milestones and evaluation procedures for future engine development programs which would include increases in both the period and scope of engine development.

The Air Force believed that production release should be an incremental procedure, with small releases authorized to support the aircraft test programs and higher production rates authorized later when more definitive milestones in development had been achieved. They stated that this new concept should be pursued aggressively and that the Aeronautical Systems Division is initiating this project.

The results of the recent Air Force Scientific Advisory Board's study and the resultant affirmative reaction by those Air Force activities directly involved in aircraft engine programs can result in positive steps toward modernizing and improving the methods of developing and acquiring aircraft engines. Well thought-out revisions can result in a more developed engine's entering full production (and thereby minimizing concurrency), promoting cost reductions, and increasing operational effectiveness.

RECOMMENDATION

We recommend that the Secretary of Defense insure that the proposed revisions in the method of developing and acquiring aircraft engines are followed through expeditiously. The many studies already available should be used to determine what changes in engine procurement methods might promote cost reductions and increase operational effectiveness.

CHAPTER 3

INAPPROPRIATE BUDGETING, FINANCING, AND DISCLOSING OF CIP FUNDS

INEFFECTIVE GUIDANCE FOR FINANCING CIP

Although the purpose and use of aircraft engine CIP funds clearly demonstrate that the effort should be financed through the RDT&E accounts, CIP development has for many years been financed with procurement and operation and maintenance funds. We think that CIP development effort is financed this way because formal DOD guidance permits it.

DOD's Budget Guidance Manual specifies that development, engineering, and testing required for the improvement or modification, including the redesign, of existing end items and major components are to be financed by RDT&E appropriations. But product improvement costs, including CIP, are contradictorily permitted to be financed by other appropriations under the label of special situations.

In brief, the DOD guidance defines costs to be financed with RDT&E funds, clearly showing that the type of effort determines the funding, as follows:

> "1. The conduct and support of basic and applied research and development effort including exploratory, advanced engineering, and systems development will be financed by the research, development, test and evaluation appropriation.
>
> "2. The development, engineering, and testing effort for the improvement or modification, including redesign (<u>other than product improvement allowable under special situations</u>) of existing end items or major components will be financed by the research, development, test and evaluation appropriation." (Underscoring supplied.)

Under the special situations provisions of the guidance, however, the funding for product improvement (CIP) of major end items and major components currently in production or in the operational inventory is prescribed, as follows:

> "Redesign of an item for the purpose of extending its useful military life by increasing the current performance envelope, including related development, test and evaluation effort, will be financed by the research, development, test and evaluation appropriation.
>
> "Engineering services and related effort applied to an item for the purpose of extending its useful military life within the current performance envelope should be financed by the procurement appropriation if the item is currently in production. For an item no longer in production but still in the operational inventory, such effort should be financed by the operation and maintenance appropriation."

The military services have apparently interpreted DOD's guidance to mean that all CIP effort is engineering service and can be financed with procurement and operation and maintenance funds. We agree that some CIP effort may be preliminary investigative activity and probably should be financed as engineering service but that activity is minimal compared with the development effort under CIP.

Initial step taken by DOD

The House Committee on Appropriations, on several occasions, expressed concern over the use of procurement funds for work which should have been more appropriately funded in the RDT&E accounts and requested DOD to purge such efforts from the procurement appropriation. The Committee's reasons for desiring that development work be financed through the RDT&E accounts were expressed in its report in September 1972,[1] which stated, in part:

[1]H. Rept. 92-1389, p. 130.

"The Committee feels that programs such as advance production engineering and product improvement have been used to finance efforts which should have been requested under the RDT&E appropriation. Such abuses can cause an insufficient review of the request, a misleading assessment of the balance between development and acquisition, and a premature entry into the procurement/ production phase of a program."

In December 1972 OSD recognized the desires of the Committee by including in a program/budget decision document some specific and general implementation of the Committee's direction.

The specific implementation involved a cutback of $33.2 million in the Air Force's 1974 request for CIP procurement funds for the F100 engine. The funds were restored as part of the RDT&E request. According to the OSD decision, the basis for the funding change was its judgment that planned CIP for 1974 was merely the continuation of the RDT&E program after MQT.

The House Appropriations Committee, in its November 1973 report[1] recommended a reduction of $28.5 million in the Air Force's procurement appropriation request for component improvement and a corresponding increase in RDT&E to properly fund improvements to the F100 engine. The Air Force was directed to fund future component improvement in the RDT&E budget until such work has been thoroughly designed, engineered, and tested.

The OSD program/budget decision of December 1972 directed for component improvement programs in general:

"* * * that future requests for component improvement programs in the procurement accounts be limited to specific programs designed to provide

[1]H. Rept. 93-662, p. 185.

solutions to specific problems which have been identified in production engines. The premise will be that the R&D program did its job and turned over an acceptable product for production. If subsequent operational usage or testing reveals that the production engine has encountered performance, reliability, or maintainability problems, then it would be appropriate to use procurement funds to correct these deficiencies."

OSD's recognition of CIP for the F100 engine as a continuation of research and development after MQT is a positive step in complying with the Committee's intent. However, we question whether the direction contained in this one budget decision will be broadly applied as long as DOD's formal budget guidance remains unchanged. The Budget Guidance Manual, which has permitted the use of procurement and operation and maintenance funds for CIP development effort in the past, would still permit such usage.

Furthermore, the Committee's concern encompasses the entire spectrum of the costs of engineering effort associated with advance production engineering, product improvement, component improvement, modifications, and alterations. On this point, we noted in our report on the comparison of military research and development expenditures of the United States and the Soviet Union[1] that DOD spent hundreds of millions of dollars annually that were not recorded as part of its RDT&E appropriations or its research and development program.

Therefore, we believe that only a broadly based effort evidenced by formal changes in the Budget Guidance Manual could effect the corrective actions necessary to be responsive to the Committee's interest.

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[1]Report to the Subcommittee on Research and Development, Committee on Armed Services, United States Senate (B-172553, July 23, 1971).

DISCLOSURE IN THE BUDGETARY PROCESS

The House Committee on Appropriations has also questioned a number of times whether the purpose and use of CIP are fully disclosed in the budgetary process.

In the procurement budget, the cost of CIP is part of the Air Force and Navy program activities for aircraft and aircraft support equipment. For operation and maintenance, the cost of CIP is part of the Air Force program activity called central supply and maintenance.

We reviewed the budget presentations to determine how CIP is defined in terms of purpose and use and the extent to which the total expected costs for CIP are disclosed. We found that Air Force and Navy definitions of CIP given in response to questioning during formal budget presentations generally differed as to the purpose and use of CIP. Examples follow.

Navy:

--1970, continue engineering effort to improve and uprate aircraft engines.

--1970, redesign, develop, test, and evaluate specific components, assemblies, or individual parts of an existing engine type.

--1973, continue engineering effort to improve performance, reliability, and maintainability and to correct service-revealed problems.

--1973, increase the mean TBO.

--1973, continue development refinements.

Air Force:

--1973, upgrade and improve aircraft engines.

--1973, correct service-revealed problems and improve repair techniques.

--1973, make minor improvements in maintainability and reliability and increase service life of an engine.

Annual estimates of CIP costs usually were identified as such and listed by engine as part of the procurement budget presentation. We found, however, no projections to enable a full view of the CIP cost of engine programs.

CONCLUSIONS

Although many CIP efforts are developmental, they have been financed through the procurement and operation and maintenance appropriations rather than through the RDT&E appropriations. We believe this situation exists because DOD's budgetary guidance inappropriately relates the method of financing component improvement programs to whether the items (in this case aircraft engines) are in production or operation or to whether increased performance will result, instead of relating the method of financing to the type of work or effort to be performed.

OSD's action in cutting back the services' request for CIP with procurement funds is a step forward in following the Committee direction on purging the procurement account of research and development effort. However, it is not sufficient to result in an orderly and consistent budgetary process. Unless DOD revises its formal guidance to provide for budgeting and financing component improvement and other development efforts through the RDT&E appropriation, such efforts will continue to be financed contrary to the desires of the House Appropriations Committee.

The Congress, in addition to not having the opportunity to consider CIP development work in conjunction with requests for other RDT&E programs, has not been presented with a full view of the total amount of CIP programed for engines. The services contract for many years of CIP, often for many millions of dollars. The annual procurement budget requests, however, show only the current year's increment.

AGENCY COMMENTS AND OUR EVALUATION

DOD did not agree that it should revise its guidance to require that CIP of an RDT&E type be budgeted and financed through the RDT&E appropriation. DOD believed the guidance it had issued in January 1968 was quite detailed and specific. It also did not agree with our broad interpretation of what engine work should be funded under RDT&E. However, DOD acknowledged that developments on the F100 engine initiated after that guidance was promulgated were being conducted under procurement funds until the effort was properly redirected under RDT&E.

We are aware that the guidance issued in January 1968 was supposed to preclude the use of CIP funds for RDT&E effort. Nevertheless, statements of knowledgeable officials, specific examples of CIP efforts, and other studies made for DOD (see ch. 2) show that CIP funds were used for RDT&E effort after 1968. Further, the August 1973 report of the Scientific Advisory Board and Air Force viewpoints on it (also discussed in ch. 2) acknowledge that further development effort is required after MQT. Such development is accomplished with CIP funds because RDT&E funding normally ends with completion of MQT.

The Air Force's proposed revisions to engine development and acquisition methods in response to the Scientific Advisory Board report include increasing RDT&E funding while decreasing CIP (procurement) funding.

Since the Air Force has agreed that engines are developed further after MQT, it is difficult to understand DOD's reluctance to change its budget guidance accordingly. In our opinion, DOD still needs to revise its budgetary guidance to more properly relate the method of funding to the type of effort involved rather than to whether the item is in production or operation.

RECOMMENDATION

We recommend that the Secretary of Defense have formal DOD guidance revised to require that RDT&E-type work be budgeted and financed through the RDT&E appropriation. We think that full implementation of revised guidance should result in proper and consistent use of CIP and give DOD and the appropriate congressional committees the entire view of the extensive and costly aircraft engine development effort.

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING
WASHINGTON, D. C. 20301

7 NOV 1973

Mr. Harold H. Rubin
Deputy Director, Procurement and
Systems Acquisition Division
(Technology Advancement)
U. S. General Accounting Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Mr. Rubin:

The draft report dated June 29, 1973, "Problems in Managing the Development of Aircraft Engines: (OSD Case #3660)" addressed to the Secretary of Defense, has been reviewed and the following comments are forwarded.

The report essentially makes two recommendations. The first recommendation is to conduct an evaluation of the methods used to develop and acquire aircraft engines and the second is to revise the formal DoD guidance so that work of a research and development nature is budgeted and funded through the RDT&E appropriation.

We are in general agreement with the intent of the two recommendations and believe that we are presently proceeding in this direction. As you know, the subject of the engine acquisition process has been studied by the Services on many occasions. Some additional studies as discussed in the attachment [See GAO note] are now in process and we will continue to study this area.

In regard to the second recommendation, the Department has revised its budgetary procedures and as discussed later it is believed that sufficient guidance has been issued.

The primary theme developed by the report is that engines are not in a mature configuration when they pass Model Qualification Test (MQT). In stating that the traditional military practice is to award development contracts on specifications somewhat below the capability desired, the TF 39 engine was singled out as going into production with a 1000 hour time between overhaul design when a higher time of 3000 to 5000 hours was desired. The report does not recognize that it is not possible to bring an engine to maturity through test stand development alone and that flight and maintenance experience in the total operational environment is necessary to reveal and correct problems resulting from this environment.

When an engine is placed in development, design objectives are set in terms of reliability and durability of major engine components and in terms of total engine mean time between failure and low-cycle fatigue life of rotating parts. Factory test schedules are set up to simulate as nearly as practicable the environment in which the engine will be operated in service. However, the testing is in a static environment, while the engine in service will be in a dynamic environment which is radically different and which cannot be duplicated.

Generally speaking, when an engine passes the MQT, it has accumulated somewhere between 10,000 and 15,000 total engine hours compiled by testing many experimental engines plus substantial component test hours. If the engine is to be used in a subsonic aircraft which operates in a generally mild environment, such as the TF 39 in the C-5A, at the time the engine passes MQT it will have achieved a mean time between failure rate of about 1000 hours, so that a TBO of 1000 hours can be assigned. As service experience is amassed, engine components and parts begin to display the design improvements which are required if the allowable TBO is to be increased. If the engine is basically of a sound design, these improvements are technically minor in nature, such as adding weight to beef up static structures or making small aerodynamic changes to lower stresses on rotating parts. These changes however can be costly. Gradually, over a period of time and service experience, the allowable TBO can be increased to an optimum from a cost tradeoff between additional engineering expenditures vs. savings because of lower maintenance costs.

A subsonic transport engine at the time of MQT with 10,000 hours of factory testing will have a mean time between failure rate of about 1000 hours. After about two million hours in service, this will be increased to about 5000 hours. To get a perspective with regard to the cost-effectivity, non-recurring development cost through MQT of the TF 39 was approximately $175 million exclusive of flight test hardware. Since factory testing of an engine like the TF 39 costs about $1500 per hour, doubling engine hours to 20,000 would add about $15 million to the development cost with an insignificant improvement in TBO capability. Even if it were possible to simulate the actual flight environment, the cost of factory testing to get the eventually-required two million hours of experience would be something like $3 billion.

The TF 39 development contract required an initial TBO on entering service of 1000 hours, with an objective of reaching 5000 hours after two million hours in service, to be achieved in two stages. Initial engines shipped in production were rated at 1000 hours TBO. With improvements that were recognized in factory and early flight testing, the last 68 production engines were shipped with an initial TBO of 1500 hours which since has been increased on the basis of satisfactory service experience to 2000 hours. As a part of the plan, design changes were made to improve durability which resulted in TBO growth to 3000 hours in the TF 39-1A engine model. At the present time, the TF 39 has approximately 500,000 hours of service. While further changes required to bring the engine TBO to 5000 hours are known, the Air Force has concluded that this would not be cost effective from a C-5A systems standpoint because of airframe structural limitations.

Many changes, which are not discussed in your report, have been made in engine development and acquisition methods as a result of the many studies conducted over the years. Even so, it is not clear that current methods are the practical optimum, and I concur that re-evaluation is in order. The extent and scope of the re-evaluation on a DoD-wide basis should await the completion of studies currently under way in the Department of the Air Force.

Regarding the second recommendation of the report, there appears to be some misunderstanding of current Component Improvement Program (CIP) policy and we must acknowledge we do not agree with GAO's broad interpretation of what engine work should be funded under RDT&E.

Prior to January 1968 CIP funds were used in many areas to correct Service revealed difficulties, improve reliability and durability, reduce maintenance, etc. In fact, there are cases where CIP funds were used for development of new models of engines with greater power output. However, on 24 January 1968 DoD Instruction 7220.5 was issued which provided more specific guidance relative to how CIP funds were to be used. Subsequently, this was superseded and guidance provided in the Budget Guidance Manual. The present guidance and definitions found in Part II, Section 5, Chapter 251 of the Budget Guidance Manual, DoD 7110-1-M, dated 1 July 1971, are quite detailed and specific; yet as you pointed out developments on the F-100 engine initiated after that guidance was promulgated were being conducted under procurement funds until the effort was properly redirected under RDT&E.

We have again reviewed the wording of the Budget Guidance Manual and feel that it is sufficiently specific that no revisions are necessary, pending possible changes which might follow as a result of the aforementioned engine studies. In the meantime, every effort will be made to preclude a recurrence of the use of other than RDT&E funds for engine development by closer surveillance on the part of management at all echelons.

Attached are detailed comments of the Air Force which are representative of those received from all the Services on this report. [See GAO note]

In light of our comments, you may wish to amend this report prior to its being published.

Sincerely,

Malcolm R. Currie

Attachment

GAO note: Air Force comments are not included in this report because of their length. The major comments were reflected in this letter from DDR&E.

PRINCIPAL OFFICIALS OF DOD AND THE DEPARTMENTS OF THE ARMY, NAVY, AND AIR FORCE RESPONSIBLE FOR ADMINISTERING ACTIVITIES DISCUSSED IN THIS REPORT

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Elliot L. Richardson	Jan. 1973	May 1973
Melvin R. Laird	Jan. 1969	Jan. 1973
DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING:		
Malcolm R. Currie	June 1973	Present
John S. Foster, Jr.	Oct. 1965	June 1973
ASSISTANT SECRETARY OF DEFENSE (INSTALLATIONS AND LOGISTICS):		
Arthur I. Mendolia	June 1973	Present
Barry J. Shillito	Feb. 1969	Feb. 1973
DEPARTMENT OF THE ARMY		
SECRETARY OF THE ARMY:		
Howard H. Callaway	May 1973	Present
Robert F. Froehlke	July 1971	May 1973
Stanley R. Resor	July 1965	July 1971
DEPARTMENT OF THE NAVY		
SECRETARY OF THE NAVY:		
John W. Warner	May 1972	Present
John H. Chafee	Jan. 1969	May 1972
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