112673 111

BY THE COMPTROLLER GENERAL

Report To The Congress

OF THE UNITED STATES

PAN 111405

XM1 Tank's Reliability Is Still Uncertain

Recent testing indicates that in the past year the XM1 tank is making steady progress in overcoming many of its reliability problems. However, doubts still remain about its turbine engine in view of the alarming number of losses in power which still persist.

The final phases of testing which begin this year should furnish reliable evidence as to the XM1's readiness for full production.

Until this readiness is demonstrated, the Congress should limit the tank's further procurement to a low rate.

The Secretary of Defense should initiate a full-scale diesel engine development program for the XM1 if the turbine problems persist.

008477

UNITED STATES GENERAL ACCOUNTING OFFICE

PSAD-80-20

JANUARY 29, 1980

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

AGC 5
DLG 1713
DLG 03742

B-196876

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

ID

This report presents our views on the results of the Army's most recent testing of the XM1 tank. Agency officials associated with the program reviewed a draft of this report, and their comments have been incorporated as appropriate.

For the past several years, we have reported annually to the Congress on the status of selected major weapon systems. This report is one in a series that is being furnished to the Congress for its use in reviewing fiscal year 1981 requests for funds.

We are sending copies of this report to the Director, Office of Management and Budget, and the Secretary of Defense.

Elmer B. Staats
Comptroller General
of the United States

military ~~defense~~ operations
military land vehicles
Testing
Product performance evaluation
Combat readiness
Weapons systems
military engineering
military contracts

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

XM1 TANK'S RELIABILITY IS STILL UNCERTAIN

DIGEST

Although production of the Army's first increment of 110 XM1 tanks has begun, the tank's reliability is still to be proven. Serious doubts remain about the performance of the XM1's turbine engine. Recent tests of the tank, which the Army has often called potentially the finest in the world, revealed many incidences of engine power losses and even some total aborts. The engine has yet to meet its reliability goals. A panel convened by the Secretary of Defense in 1979 to evaluate the engine's performance recommended additional engine testing. These tests are continuing. (See pp. 14 to 17.)

Last February the tank was achieving only 145 mean miles between failures in operational and development testing. This compared unfavorably with the 272 mean mile goal the Army had hoped to reach in the short time remaining until the conclusion of those tests in September.

The most serious problems reported by the Army test agencies concerned the tank's reliability and durability. Included were the more prevalent mobility failures, those affecting the tank's movement. Nonmobility failures, such as the inability to fully rotate the tank's turret, were also cited as problems. (See pp. 4 to 5.)

Additional mobility tests were conducted at Fort Knox from June to October 1979. According to the Army, modifications to the tank allowed it to achieve 299 mean miles between failures in those tests.

Although the score of 299 indicates that the XMI is overcoming many of its earlier problems, it may not be an accurate measure of the tank's progress. The Fort Knox tests were neither as comprehensive nor as rigorous as the operational and development ones, whose scores were either discarded or refined in the Army's latest evaluation.

PSAD-80-20

Also, to some extent, the improved performance at Fort Knox is attributable to extraordinary maintenance actions taken to keep the testing on schedule. (See pp. 7 to 12.)

The Fort Knox tests provided the opportunity to assess contractor modifications made because of earlier failures in the XM1's mobility. The principal problems in those tests were the XM1's tendency to frequently throw its track in certain soil conditions, ingestion of dirt into the engine damaging its internal parts, clogged fuel filters, malfunctions in the fuel and water separator, and fuel pump failures which cut the supply of fuel to the engine causing it to stop. Few incidences of track throwing or damaging dirt ingestion occurred in the testing at Fort Knox. (See pp. 5 to 6.)

Because of the uncertainty of the tank's performance with the turbine engine, members of the Congress have suggested on several occasions that the Army develop a backup diesel engine. If this were to be done, it would have to be tested in the same manner as the turbine. Switching to a diesel could possibly delay fielding the tank. However, if reliability and durability problems continue to plague the tank when operating with the turbine engine, the diesel would seem to offer the better alternative.

The Army, however, shows no enthusiasm for pursuing this alternative, maintaining that the turbine has proven its reliability. The Secretary of Defense is reconvening the panel early in 1980 to further assess the engine's performance and reliability. (See pp. 17 to 18.)

Although recent tests indicate that the XM1 has made consistent progress, its performance should be tempered with the realization that the many corrective modifications made to the tank in the past year are still to be tested in a combat environment. The tank's potential performance on the battlefield cannot be judged until the XM1 has demonstrated its reliability and maintainability in the next phase of operational and development testing. Until then it seems advisable for the tank's procurement to continue at a low rate. (See p. 19.)

RECOMMENDATIONS

The Congress should limit the further procurement of the XM1 to a low rate until the Army demonstrates conclusively that it has achieved acceptable levels of reliability, maintainability, and durability.

The Secretary of Defense should initiate a full-scale diesel engine development program for the XM1 if the panel's evaluation report expresses sufficient reservations about the turbine engine's test results to render the XM1's performance with that engine uncertain.

This report was discussed with Department of Defense officials responsible for the XMI program. Representatives of the Department of the Army who were present were confident that the turbine engine would eventually achieve its reliability and durability goals and that a backup diesel engine program was unnecessary.

C o n t e n t s

CHAPTER 1

INTRODUCTION

The XM1 tank was developed with the objective of providing significant improvement in combat capabilities over the present M60 series of main battle tanks. In May 1979, the Secretary of Defense approved the initial production of 110 tanks. Delivery of the first XM1 production tank from the Lima, Ohio, tank plant is scheduled for February 1980. Tooling and the conversion of Government-owned facilities for production at the Lima plant and other locations are expected to cost about $800 million. A work force of about 2,000 is producing the initial XM1 tanks. Eventually, the Government-owned Detroit plant now engaged in producing M60A3 tanks will be fully converted to XM1 production.

The decision as to whether to approve the second year's production of 352 tanks is scheduled for September 1980. The third year's production of 569 units represents full production. That production decision is scheduled for June 1981. The contract for the first 110 units is still being negotiated. The Army's current estimate of the total program acquisition cost for 7,058 tanks is $10.9 billion, or $1.55 million a unit.

DESCRIPTION OF SYSTEM

The XM1 is expected to provide the Army with greater ground combat power than provided by the current M60 tank system. According to the Army, crew survivability--the highest priority--is significantly improved through the incorporation of a special armor, which is less vulnerable than the conventional armor of existing tanks, and through compartmentalization of fuel and ammunition, which reduces the chance of a fire given a hit. An automatic fire detection and suppression system, a lower silhouette (than the M60's), and high speed and agility also add to the tank's survivability potential. The 1,500 horse-power engine and the tank's advanced torsion bar suspension and stabilization system are expected to provide a highly accurate capability for shooting on the move, a capability available only to a limited degree in some existing tanks. Initially the XM1 will be armed with a 105-millimeter main gun. The Army plans to incorporate a more lethal 120-millimeter gun in August 1984.

HISTORY OF PROGRAM

The M60 has been the Army's main battle tank since 1959. There have been other attempts to develop a successor, but these collapsed because the cost of the tanks, as designed, were considered prohibitive.

The XM1 program began in 1973 with two contractors, Chrysler Corporation and General Motors Corporation, each developing a competitive prototype. To power the tank, Chrysler proposed the use of AVCO's AGT 1500 turbine engine, while General Motors proposed a Teledyne Continental Motors AVCR 1360 diesel engine. After a competitive evaluation, the Secretary of the Army selected Chrysler's version.

The program entered full-scale engineering development in November 1976. Chrysler produced 11 prototype tanks, which were tested to determine whether the design met the Army's requirements for initial production. The major tests were development testing II and operational testing II. Development testing was principally conducted at Aberdeen, Maryland, from March 1978 through September 1979 and operational testing at Fort Bliss, Texas, from May 1978 to February 1979.

At the time of the initial production decision last May, the testing performed to that point disclosed that the XM1 generally met its performance requirements. However, frequent breakdowns and component failures gave rise to serious questions about its reliability and durability. As a consequence, the Secretary of Defense directed the Army to perform additional testing to determine the success of subsequent modifications undertaken to raise the XM1's reliability and durability to acceptable levels.

This report discusses the Army's efforts to improve the XM1's reliability and durability and its current status as it enters production.

SCOPE OF REVIEW

Our review was conducted from February through November 1979. We examined records at the XM1 Project Manager's Office in Sterling Heights, Michigan. We interviewed Army officials at Fort Bliss, Texas; Aberdeen Proving Grounds, Maryland; and Fort Knox, Kentucky, where the tanks underwent testing. We also interviewed personnel responsible for conducting and evaluating the tests from the Operational Test and Evaluation Agency, Army Materiel Systems Analysis Activity, the Test and Evaluation Command, and the Training and Doctrine Command. We discussed the program with several contractor officials including Chrysler Corporation, AVCO Lycoming Division of AVCO Corporation, Detroit Diesel Allison Division of General Motors Corporation, and Teledyne Continental Motors.

CHAPTER 2

RELIABILITY OF THE XM1

NEEDS FURTHER DEMONSTRATING

Achieving an acceptable level of reliability is critical to the success of any new weapon system. A weapon system that is not operable when needed negates the value of its performance potential, as impressive as this may be. In the operational testing completed in February 1979 at Fort Bliss, the XM1's performance met or exceeded most of its design goals. However, in the critical areas of reliability and durability, the tank fell far short of its goal.

In operational testing the XM1 achieved a cumulative 129.5 mean miles between failures of its major components. This figure was later raised to 145 when the results were combined with development test results and the test data was further refined. Nevertheless, it was still far short of the goal of 272 mean miles the Army set as the objective to be reached in further testing through September 1979. The tank's ultimate goal is 320 mean miles between failures to be achieved at the conclusion of all testing by June 1981.

The Army's development testing is performed by its Test and Evaluation Command, whose engineers are responsible for testing and evaluating the system's performance against design specifications. Operational testing is performed by its Operational Test and Evaluation Agency, which tests and evaluates the performance in a realistic battlefield environment using Army troops.

Because of the compressed development schedule established for the XM1, operational testing was performed concurrently with development testing. Operational testing, conducted at Fort Bliss from May 1978 through February 1979, covered the critical areas of survivability, firepower, mobility, and reliability under simulated battlefield conditions. Development testing began at the Army's Aberdeen Proving Ground in March 1978 and was completed in September 1979. The last phase of development testing will start March 1980 and continue for 15 months. The last phase of operational testing will run from June 1980 to April 1981 to prove the system's performance in a combat environment.

TEST RESULTS WARRANTED DEFERRING PRODUCTION

Two broad categories of failures were disclosed in the operational and development tests. These were mobility failures, those affecting the tank's movement, and nonmobility failures, such as the turret's inability to rotate at all times.

The major causes of the tank's poor reliability showing at Fort Bliss were attributed to problems with (1) the XM1's turbine engine and components such as the tank's air filter with which it interfaced and (2) track retention.

Testing revealed inadequacies in the engine's air filtration, fuel control, and internal design. Leaking air filter seals were allowing excessive dirt to enter the engine, damaging internal parts, and eventually destroying the engine.

Other problems experienced with the auxiliary automotive components, which affected the engine's operation at Fort Bliss, concerned clogged fuel filters, malfunctions in the fuel and water separator, and fuel pump failures. These cut the supply of fuel to the engine and caused it to stop. Some problems were attributed by the test evaluators to inadequate design of certain internal engine components, such as the low-pressure turbine wheel and the turbine nozzle. As a result, one turbine engine was damaged and others stopped functioning properly.

In the sandy desert areas at Fort Bliss, the XM1 also experienced numerous track throws and broken track incidents. Army officials attributed this problem, in part, to the prevalence of deep, moist sand.

Development testing by the Test and Evaluation Command was completed in September 1979. Similar to the conclusions reached after the operational tests, the command's principal area of concern was the low reliability demonstrated by the XM1. A principal problem concerned the hydraulic system of the turret. The system did not function properly, sometimes inhibiting the turret's freedom of movement needed to permit firing in any direction.

Command personnel noted that, since the interim test results they had provided in March 1979 for the production decision and up to the conclusion of their testing in September 1979, there was a degradation in the XM1's reliability, rather than an improvement. They were skeptical about what they termed "band-aid" solutions being applied to correct deficiencies.

An example of this is a track retention ring initially devised to improve track retention. According to command personnel, development testing performed after this modification was tried disclosed the real problem to be improper track tension and wheel loading. Changes in the track tension and wheel loading have since been made, and command personnel are now confident that the track retention problem has been solved. However, the changes, which included increasing the track tension, reduced the operating range of the two tanks tested at the command from 270 to 246 miles because of a 10-percent increase in fuel use. The design requirement is 275 miles.

Command personnel are still concerned about the lack of adequate cold weather testing of the XM1. For example, they claimed there has never been a successful engine start at temperatures as low as -25 degrees (a performance requirement). Although they noted that since their tests the contractor had reported successful starts in cold room testing at Eglin Air Force Base, they claimed that such starts were made under procedures which differed from the command's standard procedures and with the use of a fuel nozzle still to be completely tested. In their view, it is still uncertain as to how the tank will perform in cold weather operations. Cold region testing in Alaska is scheduled for the winter of 1980-81.

According to XM1 project officials, the tanks presented to the Test and Evaluation Command for development testing did not include later modifications. Therefore, they contend that the emerging results from the more recent Fort Knox testing incorporating the latest modifications are a better indicator of the tank's reliability.

SECRETARY OF DEFENSE REQUIRED ADDITIONAL TESTING

Mobility failures were the most prevalent failures in the operational and development tests. Therefore, as a condition to approving production for the fiscal year 1980 proposed buy of 352 tanks, the Secretary of Defense directed the Army to conduct additional mobility tests. The testing, conducted by the Army Armor and Engineer Board at Fort Knox, began in June 1979. For this purpose, three refurbished XM1 tanks incorporating the latest improvement modifications were provided. Each tank accumulated 4,000 miles of basic mobility testing from June to mid-October 1979. Two of the tanks were modified and overhauled for further testing during which they accumulated an additional 2,000 miles each in November and December 1979. The report on the 2,000-mile test is not yet available.

The Secretary established new levels of reliability to be achieved before production beyond the first 110 tanks would be approved. The XM1 was to demonstrate a reliability level of at least 200 mean miles between failures before the Army could commit funds to procuring long-lead items for second year production. 1/ The XM1's reliability would have to improve to a level of at least 220 mean miles between failures before the second year's production could begin at a reduced rate. A reliability level of 272 mean miles between failures or higher would allow acceleration of monthly production to the monthly rate originally planned. However, failure of the XM1 to demonstrate these minimum acceptable reliability levels could result in complete deferment of production.

Also concerned about the durability and reliability of the XM1's power train (consisting of the engine, transmission, and final drive), the Secretary stipulated that the power train was to achieve a minimum durability level of a 30-percent probability of achieving 4,000 miles without replacement of major components at each of the abovementioned milestone dates. In addition, he requested the Army to plan for an alternate diesel engine as insurance against the turbine engine's failing to meet expectations.

RECENT TESTING INDICATES IMPROVEMENT BUT EXTENT IS UNCERTAIN

By mid-October 1979, each of the three tanks tested at Fort Knox had accumulated the prerequisite 4,000 miles (12,000 total). According to the Army's method of scoring the test results, the XM1 achieved a mobility mean miles between failures of 495 miles. The Army scorers then combined the mobility scores with the nonmobility scores achieved in the earlier operational and development tests at Fort Bliss and Aberdeen. This yielded a reliability and durability score of 299 mean miles between failures, the current official score used in Army briefings.

Our analysis of the Fort Knox test results disclosed no significant recurrences of the track throwing and engine dust ingestion problems encountered in the Fort Bliss operational testing. In general, the marked improvements in the

---

1/According to XM1 project officials, the restriction on procurement of long-lead items was relaxed and the Army is now buying some.

tank's track retention and air induction system were the principal reasons for the more favorable test score achieved in the Fort Knox tests.

Based on these tests and another recent test at the White Sands Missile Range, the dirt ingestion problem experienced earlier appears to be solved. In these tests, using redesigned seals, there was no recurrence of the dirt ingestion problem experienced in the earlier tests. In the tests at Fort Knox there were several engine aborts, but the Army attributed these to conditions other than dirt ingestion.

We observed the tests at both Fort Bliss and Fort Knox. Although conditions at Fort Bliss are dustier than at Fort Knox, the dust at Fort Knox is finer and may be as much of a test for the air cleaner as the dust at Fort Bliss. Also, soil conditions at Fort Knox are said to be closer to the type of soil found in the European theater where most of the XM1 tanks are to be deployed.

Chrysler completed a 1,200-mile air filtration test in October 1979 at the White Sands Missile Range with Army observers present. Conditions at this site present an extremely dusty environment. We were told there had been no engine failures. Since test reports had not yet been prepared, we could not verify the accuracy of these statements.

Track retention was also not a problem in the Fort Knox tests after certain modifications were made.

FORT KNOX TEST RESULTS MAY NOT BE ACCURATE BAROMETER OF XM1'S RELIABILITY IN COMBAT

While the resolution of problems, such as track throws and dirt ingestion, may have resulted in improved mobility scores at Fort Knox, a further analysis of the scored results indicates that the overall improvement in the tank's reliability may not be as favorable as indicated by the 299 mean miles between failures score.

Under Army scoring rules, all test incidents or mishaps at Fort Knox were to be recorded and scored by Army test personnel in accordance with prescribed criteria. These initial or raw scores were then reviewed and adjusted based on a majority vote by a four-member scoring panel representing the two test and evaluation agencies, the XM1 Project Office and the Training and Doctrine Command.

On the three tanks used during the test, each accumulating 4,000 miles, the testers recorded a total of 615 incidents which they attributed to mobility. The testers assigned a zero score to 521 of the 615 mobility incidents meaning that, in their judgment, the mishap would not have affected the tank's ability to continue its mission. Mishaps assigned a zero included such incidents as a loosened bolt requiring tightening, a fender skirt falling off, and a leak in the hydraulic line.

Ninety-four mishaps received a score. The most serious, such as an engine aborting, received a 1.0, the highest score that can be assigned a combat mission failure. Scores for the less serious mishaps ranged downward from that figure. The 94 incidents received the following scores.

Score	No. of incidents
1.0	64
.8	1
.5	10
.2	19
Total	94

Since these scores were considered raw scores, the Army did not calculate the mean miles between failures at this point.

The four scoring conferees analyzed the 94 mishaps and reduced some and eliminated others. They also assigned a score to a few that had received a zero. Their calculations were as follows.

Score	No. of incidents
1.0	27
.5	9
.2	11
Total	47

These changes yielded a score of 338 mean miles between failures.

A further refinement of the scores by the scoring panel resulted in a score of 495 mean miles between failures. In this adjustment the entire record of the Fort Knox tests was reviewed. When the panel determined that causes of earlier problems in the mobility tests were no longer occurring in the later stages of the tests, for example as a result of a modification, the earlier scores against the tank were eliminated.

In a final step, the 495 mean miles were substituted for the earlier mobility results achieved in the second phase of operational and development testing. The 495 figure was merged with the nonmobility test score of 756 mean miles between failures achieved in April 1979. According to the Army, this merging yields a final figure of 299 mean miles between failures. This result could be sufficient, in accordance with the criteria established by the Secretary of Defense, to permit the Army to procure the second increment of tanks at the full production rate.

Most of the changes the panel made to the original scores appear valid. Our tabulation of the reasons given for reducing or eliminating the original scores showed the following.

Reasons for reducing or eliminating scored incident	No. of incidents
Crew error or improper maintenance	15
Repeat of incident already scored against tank	9
Original scorers misinterpreted scoring criteria	6
Performance only partially diminished	5
Could have been fixed by crew	4
Unrealistic operating conditions	3
Incident not related to reliability	3
Aged component	3
Miscellaneous	6
Total	54

Crew or maintenance error was the most frequently cited reason for reducing or eliminating incident scores. Generally this meant that if the panel found that a component failure had occurred because the tank crew or maintenance personnel had failed to observe prescribed operating or maintenance procedures, the score for the failed component was reduced to zero. For example, in one test incident, an engine abort, the incident was initially given a score of 1.0. However, the scoring conferees reduced it to zero because its investigations disclosed that the engine's fuel nozzle, the cause of the incident, had not been cleaned within the 25-hour interval period prescribed for the test.

Fuel nozzle coking has been a continuous problem. Although the contractor has developed a new nozzle to provide longer life, it was not available for use in the Fort Knox test to see if it works. Similarly, fuel filters were also frequently changed throughout the test to prevent engine aborts due to dirty fuel. Although preventive maintenance actions such as these to minimize hardware deficiencies may be an acceptable short-term solution, the ultimate result, unless corrected, is reduced tank availability and high maintenance costs. In this respect, extent of maintenance that will be required to support this tank is uncertain. While the previous operational and development testing was designed to assess the tank's maintainability, this could not be done adequately because of deficiencies in test sets and maintenance manuals, among other reasons. As now planned, the Army expects to obtain sufficiently valid data during the next phase of operational testing to make this assessment.

We believe that the final score of 299 mean miles between failures does not accurately measure the progress made in reliability and durability since last March. The complete discarding of the mobility test results achieved previously at Fort Bliss appears to unduly weight the final score of 299 in favor of the tank for two reasons.

First, the Fort Knox mobility tests were neither as comprehensive nor as vigorous as those at Fort Bliss. For example, operational testing rounds at Fort Bliss were fired every 5 miles. In the Fort Knox tests, rounds were fired every 20 miles. More frequent firings place greater stress on the vehicles. Also, the tanks at Fort Knox did not fire on the move, as was the case at Fort Bliss. For another example, the cross-country courses at Fort Bliss were selected at random so that drivers were less familiar with the obstacles and ruts. At Fort Knox the same cross-country course was used consistently. In addition, at Fort Bliss there were more cross-country maneuvering and quick turns.

Second, the improved showing at Fort Knox was due, to some extent, to extraordinary maintenance actions taken to keep the tests on schedule. For example, fuel nozzles were inspected every 25 hours and cleaned as needed although the Army hopes to get 150 hours of usage between cleanings.

Another reason to question the 299 mean miles between failures is that the nonmobility scores used in the Army's computation were not the latest scores. The Army used a nonmobility score of 756, which was the score at April 1979 when operational testing had ended. Development testing continued to September 1979, and at that point the tank's performance had deteriorated so that the final nonmobility score became 500. The Army believes the 756 score is more valid primarily because a principal problem affecting the turret's hydraulic system contributed to the lower score but did not occur at Fort Knox. The Army believes modifications have improved the hydraulic system's performance. As with the mobility modifications, the turret's reliability is still to be demonstrated in operational and developmental testing.

In spite of any reservations one may have about the 299 score, indications are that the XM1's reliability has improved consistently since last April. In our opinion, to determine how far the tank has progressed in meeting its mean miles between failures objective requires putting it through operational and development testing once again and measuring the results of those tests. This the Army intends to do. The final results, however, will not be available for more than a year.

XM1'S MAINTAINABILITY REMAINS A QUESTION MARK

Although the Army distinguishes between a weapon system's reliability and maintainability, one influences the other. Thus, the ease of maintenance which would get a tank back into action after it has been disabled is one indication of how much the tank can be counted on when needed on the battlefield. In assessing a weapon system's reliability, the Army does not weigh the consequences of the weapon's being unavailable for action. By the Army's terms, if the XM1 achieves its mean miles between failures objective, it would then be considered reliable <u>when in action</u>. The question to be answered is how often will it be ready for action. The answer will be determined in the next test phases beginning this year.

So far we have heard conflicting views about the tank's maintainability. At a briefing we attended at the Test and Evaluation Command, we heard the XM1's turret described as "a maintenance nightmare." On the other hand, Army personnel at Fort Knox who did some of the maintenance during the durability testing said they had no unusual problems. The tanks at Fort Knox had several modifications incorporated which were not present in the tanks tested at the command.

The Army's goal is to experience no more than 1.25 hours of maintenance for every hour of operation. The latest statistics based on combined operational and development testing show 1.9 hours of maintenance necessary for each hour of operation, which is considerably short of the goal.

CHAPTER 3

DURABILITY AND RELIABILITY OF THE XM1'S

TURBINE ENGINE STILL A PRINCIPAL CONCERN

Since its selection as the power plant for the XM1 tank, the XM1's turbine engine has generated much interest and controversy. While turbine engines have been used for years in aircraft and in ships, their use in ground vehicles has generally been limited to experimental programs. Consequently, if the turbine engine proves successful, the XM1 will not only be the Army's first turbine-powered tank, but also its first mass-produced ground vehicle of any type powered by a turbine engine. Some critics have voiced doubts and concerns about the Army's selecting a promising but unproven engine to power its new tank. As a result, there have been several congressional efforts to fund a backup diesel engine program to ensure against possible failure of the turbine engine.

Our review of the tests conducted so far indicates that these doubts and concerns are warranted. Even though production of the tank has begun, the engine has not yet met its required durability and reliability goals. Even with a more intensive development and testing program, some turbine engine experts doubt that the engine can achieve required durability and reliability levels by the end of the first year's production of XM1 tanks.

ARMY EXPECTED TURBINE ENGINE TO BE MORE DURABLE AND RELIABLE THAN DIESEL ENGINE

At the time the turbine engine was selected over a competing 1,500-horsepower diesel engine, both engines required additional development to get them ready for production within 3 years--the scheduled time frame for getting the XM1 tank into production. An Army ad hoc group drawn from Government, universities, and private industry evaluated the two engines. The group found that the estimated cost to develop the turbine was $90 million, compared to $40 million for the diesel. Also, the schedule risk was greater for the turbine because its design was not as mature as the diesel's. On the other hand, the group concluded the turbine had better long-term growth potential for improved durability and performance. The maximum predicted durability level was 1,000 hours for the turbine versus 650 hours for the diesel. The group also projected better power and acceleration for the turbine, but better fuel consumption for the diesel.

It was the expected long-term growth in the turbine's durability, however, that the Army considered the key factor in offsetting the life-cycle cost advantage enjoyed by the diesel. According to the ad hoc group's calculations, the time between overhaul for the turbine would have to be about 1-1/2 times greater than the diesel's in order for it to equal the diesel in terms of life-cycle costs over 20 years. The group's projections of 1,000 hours between overhauls for the turbine versus 650 hours for the diesel indicated that this goal could be accomplished, though with difficulty.

The decision to select Chrysler's turbine version of the XM1 tank was announced by the Secretary of the Army on November 12, 1976. Further development of the diesel as a potential powerplant for the XM1 tank was discontinued. Through fiscal year 1979, the Army and its contractors had expended development funds totaling $117 million to develop the turbine engine.

ENGINE DURABILITY AND RELIABILITY GOALS NOT ACHIEVED

Following operational testing, the Department of Defense appointed a blue ribbon panel of technical experts to independently assess the status of the XM1's power train. According to the panel's assessment, completed in April 1979, the engine's demonstrated durability and reliability levels were so low that they could be doubled and the engine would still fall short of its durability and reliability goals. Moreover, even with a much more intensive development and testing program, the panel doubted the required levels could be achieved much before the end of the first year's engine production. Testing performed subsequent to the panel's assessment tends to confirm this assessment.

Assessment of turbine engine's durability and reliability

In its assessment, the panel compared the engine's demonstrated durability and reliability in testing against established requirements. Shown below is the result of these comparisons.

	Design objective (note a) (MMBF) (note c)	Panel assessment (note b) (MMBF) (note c)	Percent
Durability	10,000	3,160	32
Reliability:			
System	2,825	420	15
Mission	5,000	470	9

a/Design objectives as set forth in the engine manufacturer's contract.

b/Assessment based on available test data with testing about 60-percent completed.

c/Mean miles before failures of major components.

The durability goal of 10,000 mean miles between failures is based on a .87 probability of achieving 4,000 miles without a major component failure and is equivalent to the goal of 1,000 hours between overhauls predicted for the engine in 1976 by the ad hoc group. The panel's assessment of 3,160 mean miles between failure equates to 316 hours between overhauls.

The panel also made the following projections of the turbine engine's performance.

	Design objective (MMBF) (note a)	Demonstrated performance (MMBF) (note a)	Panel's projected performance (MMBF) (note a)
System reliability	2,825	420	860
Mission reliability	5,000	470	1,050

a/Mean miles between failure.

The panel's projected performance levels were still considerably short of the design goals. Nevertheless, the panel believed that the turbine engine was the proper choice for the tank and that it would provide significant benefits so long as an adequate engine improvement and verification test program were promptly initiated and successfully completed.

To obtain an acceptable engine, the panel recommended that the Army develop an engine product improvement program to be implemented during production. Subsequent to the panel's report, the Army's test plan was modified to incorporate the additional engine testing recommended by the panel.

Results of additional engine testing are not yet available

The additional engine testing consists of 1,000-hour laboratory tests of four engines at AVCO. The 1,000-hour test 1/ is to consist of a 400-hour durability test and 600 hours of simulated operational testing. The testing is to be conducted in two phases. Phase I testing began in 1979 and is still underway. Although one of the two engines did complete the 1,000-hour test, testing on this engine was interrupted to replace engine components. The components were replaced as a preventive measure to avoid the possibility of engine damage. The other engine is still being tested.

Because of the ongoing durability testing, the Army does not yet have all the data it needs to assess the durability and reliability status of the engine. However, data from the completed Fort Knox test provides some insight into the engine's current status. During that 12,000-mile test, six engines were replaced, indicating a durability factor of 2,000 mean miles between failures (12,000 miles divided by six engine failures). Two of the engine failures were determined to have been traceable to engine components, and the others were induced by failures elsewhere in the tank's mobility system. Counting only the inherent design failures, the durability level is increased to 6,000 mean miles between failures (12,000 miles divided by two engine failures)--4,000 short of the design goal.

The Army plans to use the latter method in determining whether the durability requirement has been met. This method is reasonable; that is, it would be unfair to penalize the engine manufacturer for failures caused by failures of subsystems designed by the prime contractor or other subcontractors. However, it does not permit an accurate assessment

---

1/The panel considered the 1,000-hour test as being equivalent to the engine design goal of 10,000 mean miles between failures. However, the Army believes the panel underestimated the severity of the test. The Army says the 1,000 hours is equivalent to 16,000 to 20,000 operating miles if idling time were eliminated.

of the time required between engine overhauls or replacements. Regardless of the cause, engines that fail still have to be replaced or overhauled.

To achieve the 1,000-hour time between overhauls projected for the turbine engine, the engine has to properly interact with other power train components, such as the transmission and final drive, and support systems, such as the air induction system and fuel system. In terms of this goal, the 2,000 mean miles between failures indicated by the Fort Knox test is equivalent to 200 hours between overhauls.

In terms of the engine contractor's design goal of 10,000 mean miles between failures, the 6,000 mean miles indicated by the Fort Knox test represents an improvement over the 3,160 mean miles calculated by the panel earlier in the year. The preventive maintenance practices followed in the Fort Knox tests may have contributed in part to this improved performance. If they are to become a routine procedure, it would add to the engine's life-cycle costs.

The Secretary of Defense is to reconvene the blue ribbon panel early in 1980 to make a further assessment of the turbine engine's performance and reliability.

PROPOSED BACKUP DIESEL ENGINE PROGRAM

Since 1976 there have been congressional proposals that funds be provided to develop a backup diesel engine for the XM1 tank to minimize risk to the overall tank program. The fiscal year 1980 budget contains $14.2 million for this purpose. Despite congressional concerns, the Army has consistently maintained that a diesel backup program is unnecessary and that a better use of available dollars would be to improve the turbine engine.

However, in March 1979, the Tank Automotive Research and Development Command awarded Teledyne Continental Motors a $2.8 million contract to resume a limited development effort on its 1,500-horsepower diesel engine. The Army does not view this as an effort to develop a backup diesel engine program. However, should a backup diesel program be initiated, the experience generated in this development effort could prove beneficial.

Cost and schedule impacts of diesel engine

The Project Office believes that it would take 2 or 3 years to develop a diesel engine for the XM1. A diesel engine would have to be tested in the same manner as the turbine engine. Therefore, any change in the program to provide sufficient time to complete development and incorporate the diesel engine in the XM1 design would undoubtedly result in delayed deployment of XM1s in the field.

The Project Office estimates the cost of developing and testing a diesel engine at about $144 million. Of this amount, an estimated $43 million would be required to develop and test the diesel engine and $101 million would be required to redesign and test the tank after the diesel engine is incorporated.

The Project Office estimates, however, that XM1 production costs would be reduced by $412 million if the diesel engine were installed in the 5,600 tanks remaining to be produced when that engine's development is complete.

In addition to the indicated reduction in production costs, there is a potential for reductions in support costs due to the better fuel economy of the diesel engine, whose fuel consumption is said to be about 20-percent less than the turbine engine's. Savings in fuel costs and support equipment could be substantial over the tank's lifetime.

These indicated reductions would help in offsetting increased program costs resulting from disruption of the current XM1 production program if the turbine engine fails and the Army decides to switch engines. Such a decision would require the Army to restructure the total tank program. In restructuring the program, the Army would have to address such questions as:

--Should the present production of turbine-powered XM1's be terminated? If so, when?

--Should turbine powered tanks be retrofitted with diesel engines? If not, what are the logistics impacts?

--What is the most appropriate use of the Lima and Detroit tank plants and labor forces if there is to be a change in the rate of production?

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

The XM1's improved performance in the reliability and durability testing at Fort Knox indicates that recent modifications may have solved many of the faults disclosed in previous tests. These include at least two serious ones--the tank's inadequate air filtration and throwing of its track. A final judgment should be reserved, however, until these modifications are put through the final phases of operational and development testing which begin shortly and are to continue through the first half of 1981. Those tests will be more comprehensive and vigorous than the tests run at Fort Knox and should give a better indication of the progress the tank has made towards improving its reliability and durability since the production decision last April.

In our opinion, the score of 299 mean miles between failures based on the Fort Knox test results is not an accurate barometer for measuring the extent of the tank's progress since the earlier tests. Not only were the tests at Fort Knox less stressful since they did not attempt to fully simulate realistic combat conditions as operational tests do, but also the tanks at Fort Knox received the benefits of extraordinary maintenance.

The Army still has to bring up the tank's performance with the turbine engine and must demonstrate that the principal nonmobility problem concerning the operation of the turret has been solved.

In our view the Army's optimistic assessment of the XM1's performance should be tempered with the realization that the tank's corrective modifications are still to be tested in a simulated combat environment. We believe a fair judgment of the tank's potential performance in combat cannot be drawn until the XM1 further demonstrates its reliability and durability in the next phase of operational and development testing. Meanwhile, we believe the tank's procurement should be continued at a low rate.

RECOMMENDATIONS

We recommend that the Congress limit the further procurement of the XM1 to a low rate until the Army demonstrates conclusively that it has achieved acceptable levels of reliability, maintainability, and durability.

We also recommend that the Secretary of Defense initiate a full-scale diesel engine development program for the XM1 if the blue ribbon panel's evaluation report expresses sufficient reservations about the turbine engine to render the XM1's performance with that engine uncertain.

AGENCY COMMENTS

The Department of the Army did not agree that a backup diesel engine program is needed. Army officials were confident the turbine engine will eventually achieve its reliability and durability goals.

(951482)

Single copies of GAO reports are available free of charge. Requests (except by Members of Congress) for additional quantities should be accompanied by payment of $1.00 per copy.

Requests for single copies (without charge) should be sent to:

U.S. General Accounting Office
Distribution Section, Room 1518
441 G Street, NW.
Washington, DC 20548

Requests for multiple copies should be sent with checks or money orders to:

U.S. General Accounting Office
Distribution Section
P.O. Box 1020
Washington, DC 20013

Checks or money orders should be made payable to the U.S. General Accounting Office. NOTE: Stamps or Superintendent of Documents coupons will not be accepted.

PLEASE DO NOT SEND CASH

To expedite filling your order, use the report number and date in the lower right corner of the front cover.

GAO reports are now available on microfiche. If such copies will meet your needs, be sure to specify that you want microfiche copies.

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U. S. GENERAL ACCOUNTING OFFICE

U.S. MAIL

THIRD CLASS