United States General Accounting Office

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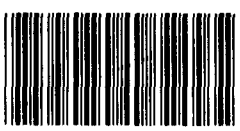
Report to the Secretary of Defense

January 1992

ARMY'S M109 HOWITZER

Required Testing Should Be Completed Before Full-Rate Production



GAO/NSIAD-92-44

GAO

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

National Security and International
Affairs Division

B-246266

January 23, 1992

The Honorable Richard B. Cheney
The Secretary of Defense

Dear Mr. Secretary:

We have reviewed selected aspects of the Army's Howitzer Improvement Program and are recommending that you direct the Secretary of the Army to ensure that the full-rate production decision for the improved howitzer, called the "Paladin," is not made until after successful completion of follow-on operational test and evaluation.

As you know, 31 U.S.C. 720 requires the head of a federal agency to submit a written statement on actions taken on our recommendations to the House Committee on Government Operations and the Senate Committee on Governmental Affairs not later than 60 days after the date of this report. A written statement must also be submitted to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of this report.

We are sending copies of this report to the Chairmen and Ranking Minority Members of the above Committees and of the House and Senate Committees on Armed Services; the Secretary of the Army; and the Director of the Office of Management and Budget. We will also make copies available to others upon request.

Please contact me at (202) 275-4141 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix II.

Sincerely yours,

Richard Davis

Richard Davis
Director, Army Issues

Executive Summary

Purpose

In 1984, the Army initiated a program to improve the responsiveness; survivability; lethality; and reliability, availability, and maintainability of the M109 howitzer. Through fiscal year 1991, the Army has received about $500 million for the program: $200 million to develop the improvements and about $300 million for low-rate initial production of 104 modified howitzers, called the "Paladin." The Army plans to continue low-rate production in fiscal year 1992 and to begin full-rate production of the Paladin in fiscal year 1993.

GAO reviewed the Army's Paladin program to determine (1) whether deficiencies disclosed during developmental and operational tests and evaluations have been resolved, (2) whether any further operational testing should be conducted before additional procurements are made, and (3) why the Paladin's unit cost has increased substantially from the Army's original estimates.

Background

The Army's M109 howitzer consists of a 155-mm cannon mounted on an armored, self-propelled tracked vehicle. It is a field artillery weapon system operated by a crew of four that provides direct support for armored and mechanized infantry divisions. The Army initially fielded the M109 howitzer in 1963 and has since made several modifications.

Developmental work for the Paladin began in 1985; the first developmental prototype system was delivered by the prime contractor in April 1988; and the Army approved the Paladin for low-rate initial production in February 1990. Low-rate initial production is intended in part to reduce the risk of large retrofit problems and costs while providing production items for final development and operational testing. The actual modification work began on the first production howitzer in June 1991. The Army expects the prime contractor to begin delivering Paladins in April 1992.

Results in Brief

The Army approved and contracted for low-rate initial production of the Paladin, even though the system had significant unresolved operational and technical problems with several subsystems. The Army has made changes to the howitzers to correct the problems and is currently producing howitzers containing most of the improvements. However, until these howitzers are tested further, decisionmakers will not have the benefit of knowing whether the changes have resolved the identified problems.

The Army plans to conduct a follow-on operational test and evaluation on Paladin howitzers to verify that the previously identified problems have been resolved and to support a full-rate production decision.[1] However, the Army will have contracted for 164 Paladins, or 20 percent of the howitzers to be modified, before any weapons are delivered and production items are tested during the planned follow-on operational tests. Thus, significant quantities could be procured before completion of operational testing and evaluation.

Since approval of the improvement program in 1984, the estimated unit cost for the Paladin tripled from $500,000 to about $1.5 million. This unit cost increase occurred primarily because of changes in the configuration of the howitzer, a quantity reduction, and 6 years of inflation.

Principal Findings

Test Objectives Not Met

During Army-conducted prototype qualification, technical, and operational testing from April 1988 to March 1991, the Paladin did not meet several test objectives and requirements. Problems were experienced with the automatic fire control system, generator, microclimatic conditioning system, and cannon.

- The automatic fire control system experienced computer lockups and computational problems. This sometimes resulted in system failure or shutdown. When this occurred, the crew had to operate the Paladin manually, thereby losing its improvement over the existing howitzer in the area of responsiveness.
- The generator experienced drive problems that frequently resulted in system shutdowns. When this occurred, the Army used power from the Field Artillery Ammunition Supply Vehicle to operate the on-board electronics. Under actual combat conditions, an alternate source of power may not be available. Although Army officials are now confident that the generator is fixed, it has not been tested by the user in its expected operational environment.
- The microclimatic conditioning system that was to provide each crew member with decontaminated and/or conditioned air did not function

[1]Department of Defense Instruction 5000.2, dated February 23, 1991, states that all operational test and evaluation conducted in support of a decision to go beyond low-rate initial production is "initial" operational test and evaluation. Since such a decision has not been made for the Paladin, we understand the Army's reference to "follow-on" testing to describe additional initial operational test and evaluation.

effectively at low or high temperatures. Consequently, it would not permit the crew to operate efficiently in nuclear, biological, chemical, or extreme temperature environments.

- On seven occasions, gas accumulated and entered the Paladin's cab when the cannon breech was opened prematurely. This gas ignited within seconds, resulting in a "flareback," or fireball, which threatened the safety of the crew located inside the howitzer.

Additional Operational Tests Are Planned Before the Full-Rate Production Decision

The Army system developers believe subsequent changes have corrected the problems. These changes are expected to be user tested in an operational environment beginning in October 1992, when the crucial follow-on operational test and evaluation is scheduled to begin. Because the Army has not yet completed its test and evaluation plan, GAO was unable to determine whether the Army's planned follow-on operational test and evaluation will be sufficient to verify corrections to deficiencies disclosed during prior initial operational test and evaluation and during preproduction testing at the Cold Region Test Center.

The Army plans to procure 824 Paladins; 164 of them will be procured during low-rate initial production. The Army has already contracted for 104 and plans to contract for 60 additional Paladins in March 1992. This represents 20 percent of the total production quantity. Thus, significant quantities could be procured before completion of operational testing and evaluation. The continued procurement of the Paladin before completion of further operational testing increases the risks of costly retrofits or fielding an ineffective system. However, according to Army data, the cost of postponing the fiscal year 1992 procurements until after completion of the follow-on operational test and evaluation would be unacceptably high and would result in a production break of at least 10 months.

Several Factors Contributed to the Unit Cost Increase

The significant increase in Paladin's unit cost is largely attributable to the addition of components and subsystems beyond those originally planned for the howitzer, a reduction in procurement quantity, and inflation. The additional subsystems were designed to enhance the performance of the howitzer and establish a foundation for incorporating future improvements. The Army added a new turret, a computerized fire control system and associated equipment, a navigation system, a more powerful generator, and an upgraded transmission and engine.

Recommendations

To reduce the risks of costly retrofits or fielding an ineffective system, GAO recommends that the Secretary of Defense direct the Secretary of the Army to (1) include specific tests in the test and evaluation plan for the follow-on operational test and evaluation to verify that problems experienced with Paladins during earlier testing have been corrected and (2) successfully complete the follow-on test and evaluation before approving full-rate production.

Agency Comments

The Department of Defense provided official oral comments on a draft of this report. The Department fully concurred with GAO's recommendations and stated that (1) the follow-on operational test and evaluation to be conducted during October and November 1992 will be structured to verify that problems encountered during earlier testing are corrected and (2) successful completion of the follow-on operational test and evaluation will be accomplished before obligating funds for full-rate production of Paladins.

Contents

Abbreviations

AMSAA	Army Materiel Systems Analysis Activity
GAO	General Accounting Office
RCMAS	Reserve Component/Modified Armament System

Introduction

The Army's M109 howitzer consists of a 155-mm cannon mounted on an armored, self-propelled tracked vehicle. The Ml09, operated by a crew of four, provides direct artillery fire in support of operations conducted by the Army's armored and mechanized infantry divisions. The M109 155-mm howitzer was developed in the late 1950s and fielded in 1963. Over the years, the basic M109 howitzer has been modified several times. Modifications have included the installation of a longer gun tube; improvements to the loader, rammer, and ammunition stowage; and improvements for crew safety (see app. I). As a result of the modifications, all fielded M109 howitzers with the Army's active and reserve forces have virtually identical capabilities.

The ability of the current M109 system to respond rapidly to fire support demands is slowed by current, time-consuming requirements such as orienting the howitzers on a common direction of fire by the use of an aiming circle; establishing and maintaining wire communications with the fire direction center for exchange of fire mission and howitzer status information; and conducting that exchange of information by voice using manual methods of communication. All of the operations are slow and subject to errors and problems caused by terrain, visibility conditions, and the hazardous conditions in which the howitzer must operate. Some of these problems also lower both crew and system survivability. For the howitzer to be oriented with an aiming circle or for a wire line to be established for communications, crew members must exit the howitzer, exposing them to potential dangers posed by nuclear, biological, and chemical contamination or small arms fire.

Additionally, the separation distances between individual howitzers and between howitzers and the fire direction center are limited by the need to have a line of sight with the aiming circle or another howitzer and by the restrictions associated with using wire communications. If the howitzer should be attacked with nuclear, biological, and chemical weapons, the full protective ensemble would not sufficiently protect the crew against the resulting heat stress and exhaustion while conducting firing operations.

The M109 howitzer's current range cannot adequately project fire support to the depth on the battlefield necessary for a deep battle and is not sufficient to allow the system to reach all the threat artillery it might encounter. In the area of reliability, availability, and maintainability, the current system is considered by the Army to be deficient primarily because of low operational availability. Major contributors to the low availability include poor armament reliability and high maintenance ratios. Additionally, most

maintenance activities on the system must be conducted at rear locations, further reducing the system's availability.

The Army currently has two major modification programs to further upgrade its M109 howitzer inventory: (1) the Howitzer Improvement Program, or Paladin, and (2) the Reserve Component/Modified Armament System (RCMAS). In addition, the Army is developing a new system, called the Advanced Field Artillery System, which is expected to eventually replace the M109 howitzer.

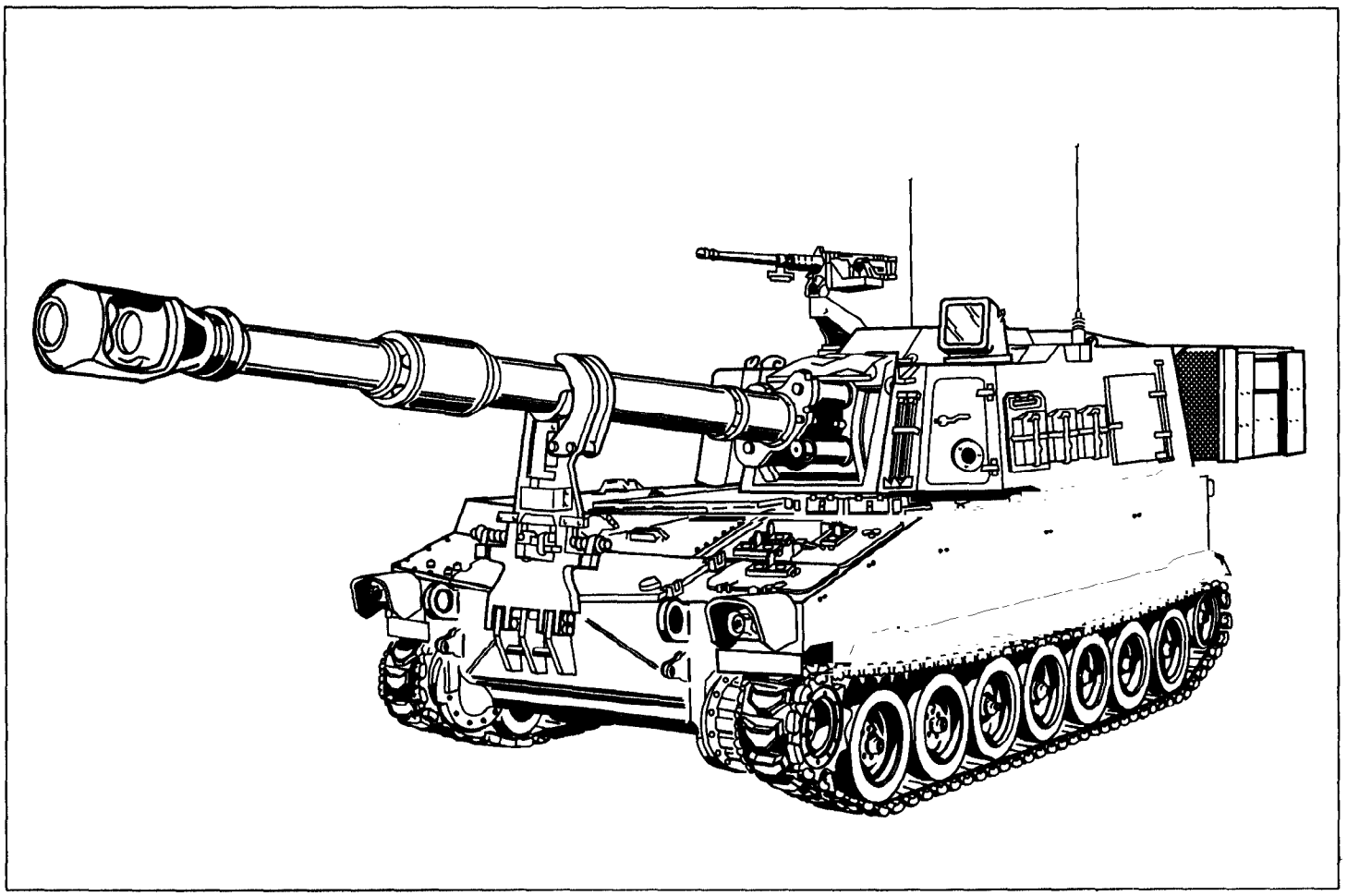
The Howitzer Improvement Program

The Paladin modification program is currently designed to upgrade 824 of the Army's M109A2 and M109A3 howitzers to a M109A6 configuration at an estimated total cost of $1.25 billion. The Army approved the program in 1984 and began developmental work in 1985. The Army originally planned to modify 1,700 howitzers as a part of this program. However, due to cost increases, Army-wide affordability issues, and force restructuring, the Army has reduced the total program quantity to 824 howitzers, or about one-third of the Army's 155-mm self-propelled howitzer inventory.

The need for improvements to the existing M109 howitzer stemmed from two Army documents developed in the early 1980s: the threat assessment report and a mission element needs statement. These documents reported that the Army's 155-mm self-propelled howitzers were deficient in (1) responsiveness, (2) survivability, (3) lethality, and (4) reliability, availability, and maintainability.

Because the Advanced Field Artillery System is not expected to be available until around year 2003, the Army decided to modify its current M109 howitzers as an interim measure in the event of a 1990s conflict. In addition, a 1985 cost and operational effectiveness analysis concluded that the current howitzer would not be able to adequately fulfill its role on the post-1990 battlefield. The Army received its first prototype howitzer—the Paladin—in April 1988 (see fig. 1.1).

Figure 1.1: The Paladin



Source: BMY Combat Systems

The Paladin incorporates a number of modifications to the M109A2 and M109A3 howitzers. The modifications include the following:

- A new, redesigned turret structure is to increase ballistic protection to the crew and critical components of the weapon system, provide better support for the added stress caused by firing a stronger propellant charge used for extended ranges, and enhance the integration of various turret improvements and vulnerability reduction measures. Also, the new turret structure is to improve overall crew compartment layout and space.
- An on-board automatic fire control system is to provide position location and azimuth references, automatically point the cannon tube, and permit

the use of a digital and voice communication system that is expected to provide high-speed and secure data transmissions.

- A modified cannon and gun mount is to increase the howitzer's firing range to at least 22 kilometers with conventional artillery projectiles and up to 30 kilometers with rocket-assisted projectiles.
- A microclimatic conditioning system is to provide the crew with decontaminated air and/or conditioned air through face masks and vests to operate in nuclear, biological, and chemical environments better than the existing howitzer.
- Kevlar ballistic liners are to be added to the howitzer to provide increased protection to the crew and critical components located inside the howitzer if the weapon system is hit by enemy fire.
- Several automotive and hull changes, such as a higher amperage generator, an upgraded engine and transmission, and improved suspension, are designed primarily to increase the system's reliability, availability, and maintainability.

Several Army and contractor locations are involved in producing the Paladin. During the production phase, the Letterkenny Army Depot, Pennsylvania, is to overhaul and modify the howitzer's hull, automotive and suspension systems, and remove the howitzer's turret and cannon. The howitzer's modified chassis is then to be sent to the prime contractor, BMY Combat Systems, York, Pennsylvania, where a new turret is to be installed. BMY also is to install a new 155-mm cannon produced by the Army's Watervliet Arsenal, New York.

In addition to the various hardware changes, the Paladin is expected to be able to operate semi-autonomously over a larger, dispersed battlefield area. The current howitzers lack the capability to independently establish a position and quickly fire its munitions. The howitzers are connected by wire to a fire direction center that positions the howitzers and provides target information, ballistic computations, and firing instructions. On the average, it takes 4.5 minutes before the howitzer is ready to fire. However, with certain on-board upgrades, such as the automatic fire control system and the radio communications, a moving Paladin howitzer is expected to be able to fire within 1 minute after stopping, move, and quickly reposition itself to fire again. It also will be able to fire at longer ranges than the M109A2 and M109A3—a deficiency noted in the recent Desert Storm conflict. However, this longer firing range still remains considerably less than similar foreign-made howitzers currently on the market.

In addition, the Paladin's design is to facilitate the future addition of certain preplanned product improvements. For example, such enhancements as an advanced armament system, a loader-assist mechanism, an automatic primer feed, an automatic fuze setter, and electrical firing, which are not currently on the Paladin, are expected to reduce crew labor and increase the howitzer's range and rate of fire.

Other Related Programs

Reserve Component/Modified Armament System

The $221 million RCMAS modification program is designed to upgrade the M109 howitzers that are not scheduled to be modified to the Paladin configuration. Although it is expected to cover about two-thirds of the Army's M109 howitzer inventory, the Army anticipates that it will be less costly and have fewer enhancements than the Paladin howitzers. The modified howitzers resulting from the RCMAS program are expected to have improved nuclear, biological, and chemical protective capability, some automotive system improvements, and the same cannon and gun mount as on the Paladin. The modified cannon and gun mount are expected to permit both the RCMAS and the Paladin to fire the same types of artillery projectiles at the same range.

Advanced Field Artillery System

The Army is proposing to develop a new family of armored combat vehicles under its Armored Systems Modernization Program. As a part of this program, the Army plans to develop and build a new 155-mm self-propelled howitzer, called the Advanced Field Artillery System. This new field artillery weapon is to have improved direct fire support by increasing its accuracy, range, rate of fire, lethality, and survivability. The new system is to incorporate several advanced technologies, including a new cannon, a new propellant charge, an on-board fire control system, and automated ammunition-handling equipment. The Army estimates that the first unit will be equipped with the weapon system by the year 2003. Our July 1991 report provides additional information on the Advanced Field Artillery System.[1]

[1]Armored Systems Modernization: Program Inconsistent With Current Threat and Budgetary Constraints (GAO/NSIAD-91-254, July 29, 1991).

Objectives, Scope, and Methodology

We reviewed the Army's Paladin program to determine (1) whether deficiencies disclosed during developmental and operational tests and evaluations have been resolved, (2) whether any further testing should be conducted before additional procurements are made, and (3) why the Paladin's unit cost has increased substantially from the Army's original estimates.

In conducting our review, we reviewed various Department of Defense documents, such as the threat assessment, required operational capability, test plans, test reports, independent agency evaluation reports, contractor proposals, manufacturer contracts, production and fielding schedules, cost and operational effectiveness reports, baseline cost estimates, and Army in-house production studies.

We interviewed Army officials at Headquarters, Department of the Army; the Army Armament Research, Development and Engineering Center; the Army Test and Evaluation Command; the Army Materiel Systems Analysis Activity (AMSAA); the Army's Operational Test and Evaluation Agency; the Letterkenny Army Depot; the Watervliet Arsenal; and the Rock Island Arsenal.

We conducted our review from July 1990 to October 1991 in accordance with generally accepted government auditing standards.

Howitzer Procurement Program Is Ahead of Testing Program

The Army approved and contracted for low-rate initial production of the Paladin even though the system had unresolved operational and technical problems. Although the Army has taken steps to correct these deficiencies and is currently producing howitzers containing most of the improvements, follow-on operational test and evaluation of production articles are required to verify that the previously identified problems have been resolved and to support a full-rate production decision in fiscal year 1993. The Army will have contracted for 164 Paladins, or 20 percent of the 824 howitzers to be modified, before any weapons are delivered and production items are tested during the planned follow-on operational tests. Thus, significant quantities could be procured before completion of operational testing and evaluation.

Prior Tests and Evaluations Disclosed Deficiencies

Army-conducted prototype qualification, technical, and operational tests and evaluations of the Paladin from April 1988 through March 1991 disclosed performance problems with several subsystems that affected the howitzer's responsiveness; survivability; and reliability, availability, and maintainability. Problems were experienced with the automatic fire control system, microclimatic conditioning system, generator, and cannon.

Automatic Fire Control System Problems

Increased responsiveness and a higher survivability rate for the howitzer are heavily dependent upon a properly functioning automatic fire control system. Without the system, the crew has to use the manual procedures employed in the current howitzer. The fire control system in the Paladin experienced anomalies that require the system to shut down and be restarted to fire. The problems with the fire control system occurred during prototype qualification and operational tests conducted on the prototype howitzers. An Army evaluation of the Paladin completed in March 1991 revealed several problems in the automatic fire control system ballistic solutions, including fuze incompatibility and the loss of current meteorological messages.

An upgraded software package that the developer believes will resolve the fire control system problem was approved for procurement in March 1991. However, the Paladin currently being produced will have the old software package. The new upgraded software is to be installed in future Paladins and will eventually replace the software in the Paladins currently being produced.

Microclimatic Conditioning System Problems

The Microclimatic Conditioning System being installed on the Paladin is intended to protect the crew in a nuclear, biological, and chemical warfare environment. It is also designed to permit the crew to operate the howitzer in a high or low temperature environment without degrading their performance. However, Army technical and operational testers have reported that the conditioning system did not provide adequate cooling to permit the crew to function without degrading their performance when operating in a high temperature environment. Although the airflow to the face mask was properly filtered and adequate, the airflow to the vests worn by the crew was inadequate at internal temperatures above 120°F. Cold weather testing of the conditioning system revealed that it did not meet the requirement of providing air to the crew face piece at a temperature of 68°F when the ambient temperature was -25°F. Additionally the heater used with the system was rated as unreliable, inadequate, and at times unsafe. Heater problems accounted for most of the safety problems encountered during the test, including fuel leaks, a fire, and toxic fumes entering the crew compartment.

Generator Problems

The generator that supplies power to the howitzer's electronic components and charges the system batteries experienced numerous failures during the initial operational test and evaluation. On occasions a Field Artillery Ammunition Supply Vehicle was used as an alternate source of power for the affected howitzer. Army developers believe the problem has been corrected. However, independent evaluators from AMSAA and the Army's Operational Test and Evaluation Command believe that determination should be made after completing the follow-on test and evaluation.

Cannon Problems

At least seven incidents of a flareback (a ball of fire) have occurred in conjunction with firings of the Paladin. For example, three flarebacks occurred during initial operational testing and evaluation training at Fort Sill in 1989. When the crew opened the cannon's breech, smoke entered the cab, and the smoke ignited 2 seconds later. In January 1991, an investigation team concluded that the bore evacuator used in the new cannon contributed to the flarebacks and recommended that it be replaced with the bore evacuator used in current howitzers. However, subsequent tests completed at the Cold Region Test Center in March 1991 revealed a problem with the current bore evacuator. The Army's August 1991 test report stated that the replacement bore evacuator was inadequate. The system relied on the lead particle filtering system to prevent flarebacks and the accumulation of

smoke in the crew compartment. The testers considered that arrangement as a system deficiency.

All Test Objectives Were Not Met

Operational availability measures the proportion of time a system will be available to successfully conduct assigned missions. Such availability depends on the reliability of component parts and the time it takes to maintain them, acquire needed spare parts, and repair or replace broken component parts. The Army initiated the Howitzer Improvement Program to improve the responsiveness; survivability; lethality; and reliability, availability, and maintainability of its M109 howitzers. Nevertheless, the Army's Operational Evaluation Command (formerly the Army's Operational Test and Evaluation Agency) rated the Paladin's reliability, availability, and maintainability as marginal. According to this Command, the Paladin did not meet its requirement of operating a mean time of 62 hours before failure of a vital subsystem. AMSAA calculated a 26.6-hour mean time between failure of a vital subsystem for the Paladin. The Paladin also failed to meet its maintenance hours per operating hours requirement of .13 hours for unit maintenance during the operational tests. The Paladin's overall unit level maintenance ratio during the 1989 operational tests was .54 hours when crew preventive maintenance checks and services are included and .24 hours when the checks and services are excluded. The Command recommended additional design or procedural improvements to reduce the maintenance time.

The Command's calculated operational availability for the Paladin is 55 percent, which equals the Army's stated requirement. This calculation was based on 24 operational mission failures requiring maintenance during the operational tests. AMSAA, however, calculated the operational availability to be 44 percent based on 29 operational mission failures. AMSAA counted five power generator failures as operational mission failures, while the Command did not. The Army's scoring committee for reliability, availability, and maintainability (consisting of representatives of the user, developer, operational tester, and development tester) categorized the five generator failures as hardware mission failures. Our review indicated that four of the five generator failures should have been categorized as operational mission failures because an alternative power source was required for continued operations of the Paladin. Therefore, the AMSAA calculation appears to be more accurate.

Although the independent evaluators at the Command and AMSAA recommended that the Paladin be type classified for limited production,

they stipulated that the problems experienced by the generator and the automatic fire control system be fixed and verified on production models before full-rate production.

Significant Quantities Could Be Procured Before Completion of Operational Testing and Evaluation

In February 1990, the Secretary of the Army approved the low-rate initial production of 222 Paladins for fiscal years 1989, 1990, and 1991. However, he granted the approval before completing all the technical tests and evaluations and verifying the corrective actions for system deficiencies revealed during development tests and initial operational test and evaluation. In addition, the May 1990 cost proposal from the sole-source contractor (BMY) to produce the initial 59 howitzers exceeded available funding.

In September 1990, the Army Acquisition Executive convened a special Army Systems Acquisition Review Council to review the program. The meeting focused on cost, production readiness, and acquisition strategy. After this meeting, the Army Acquisition Executive approved the award of a contract for the fiscal years 1989 and 1990 procurement quantities and the use of fiscal year 1991 funds to keep the program on schedule.

To reduce the contract cost, items such as the upgraded automatic fire control system software were deferred until later production years and the number of howitzers to be modified during the first production year was reduced from 59 to 44 howitzers. These actions permitted the Army to buy the initial quantities within the appropriated amounts. The Army awarded a contract to BMY after the September 1990 Council meeting for 44 howitzers at a cost not to exceed $74 million. The negotiated contract was subsequently agreed to by the Army and the contractor in March 1991. The Army also awarded the fiscal year 1991 contract fo additional Paladins in April 1991. The Army plans to award a contract for the production of 60 additional Paladins in March 1992.

The Council meeting to approve full-rate production is currently scheduled for the third quarter of fiscal year 1993. At that point, the total planned quantity of 164 Paladin howitzers to be procured for fiscal years 1989 through 1992 would be under production contracts. This would represent 20 percent of the total procurement objective of 824 howitzers.

The 104 howitzers currently under contract are more than adequate to permit the Army to conduct the follow-on operational test and evaluation, which is scheduled to begin in October 1992. According to the Army's

May 1991 production schedules, the 104 howitzers currently under contract with appropriations from fiscal years 1989, 1990, and 1991 are scheduled to be delivered between April 1992 and November 1993. Modification of the first production howitzer began in June 1991. A total of 22 howitzers will be delivered by the time the follow-on tests are scheduled to begin in October 1992. The Army plans to use four of these howitzers during the follow-on tests.

Although the Army will have sufficient howitzers for the follow-on operational test and evaluation, it plans to procure additional Paladins in 1992. According to Army data, the cost of postponing the fiscal year 1992 procurement until after completion of the follow-on operational test and evaluation would be unacceptably high and would result in a production break of at least 10 months.

The Army plans to conduct a follow-on operational test and evaluation on production articles to verify that the previously identified problems have been resolved and to support a full-rate production decision. However, we were unable to determine whether the Army's planned follow-on operational test and evaluation will be sufficient to verify corrections to deficiencies disclosed during prior initial operational test and evaluation and during preproduction testing at the Cold Region Test Center because the Army has not yet completed its test and evaluation plan for the follow-on tests.

Conclusions

Tests of prototypes disclosed problems with the automatic fire control system, generator, microclimatic conditioning system, and cannon. The Army made changes to the howitzers to correct the problems and is currently producing howitzers containing most of these improvements. However, until these howitzers are tested further in their expected operational environment, decisionmakers will not have the benefit of knowing whether changes have resolved such identified problems. Thus, significant quantities could be procured before completion of operational testing and evaluation.

Recommendations

To reduce the risks of costly retrofits or fielding an ineffective system, we recommend that the Secretary of Defense direct the Secretary of the Army to (1) include specific tests in the test and evaluation plan for the follow-on operational test and evaluation to verify that problems experienced with Paladins during earlier testing have been corrected and (2) successfully

complete the follow-on test and evaluation before approving full-rate production.

Agency Comments

In its official oral comments, the Department of Defense fully concurred with our recommendations and stated that (1) the follow-on operational test and evaluation to be conducted during October and November 1992 will be structured to verify that problems encountered during earlier testing have been corrected and (2) successful completion of the follow-on operational test and evaluation would be accomplished before funds are obligated for full-rate production of Paladins.

Total Program Costs Remain Unchanged, but Unit Costs Have Increased Substantially

In 1984, when the Army Vice Chief of Staff authorized the Howitzer Improvement Program, the Army planned to modify 1,700 M109 howitzers at a unit cost of $500,000 a howitzer in constant fiscal year 1985 dollars.[1] This figure was to include the cost to apply a series of product improvements to the current howitzer and other associated expenses, such as research and development, overhaul, and testing.

During the developmental phase of the program, several mandated improvements were replaced or eliminated and additional improvements were added. By 1990, the modified howitzer's original configuration had changed significantly, unit cost had tripled, and the number of howitzers to be modified had dropped to less than half the original quantity.

The Army has taken several actions to control costs. For example, the Army Acquisition Executive must now approve all design changes. Beginning with the fiscal year 1991 procurements, the Army began procuring certain components for the Paladin that in the past had been procured by BMY.

Changes to the Approved Program and Inflation Increased Unit Cost

In 1984, when the Howitzer Improvement Program was approved, the Army Vice Chief of Staff permitted the system designers to include additional improvements to the howitzers, but only if the $500,000 ceiling would not be exceeded. During the 6 years after the modification program was approved, a number of improvements were made to the howitzer's original design. Some of the improvements included a new turret, a computerized fire control system and associated equipment, a navigation system, a more powerful generator, and an upgraded transmission and engine.

The changes in weapon system design were a major cause for the Paladin's unit cost increase. Another contributing factor has been 6 years of inflation. An Army analysis showed that by 1990, design changes and inflation had increased unit costs by $666,000, bringing the total cost to modify each howitzer to $1.16 million. Therefore, it would have cost about $2 billion to modify 1,700 howitzers. Concurrent with this unit cost increase, the Army reduced the number of howitzers to be modified from 1,700 to 824. According to Army officials, the Army reduced the program quantity not only because of the unit cost increase but also because of reductions in the

[1]The Department of Defense has several ways to calculate unit cost, which vary depending on what expenses are included. The $500,000 unit cost estimate is the program acquisition unit cost. It includes the total costs for research, development, test, and evaluation and for production. The program acquisition unit cost is the most complete unit cost calculation and is used in Selected Acquisition Reports.

Army's force structure and affordability concerns affecting all of the Army's modernization initiatives. However, documentation to support this view was not available. In current 1991 dollars, the Army estimates it will cost $1.25 billion ($1.52 million each) to modify 824 howitzers. Through fiscal year 1991, the Army has received about $200 million to develop the improvements and about $300 million for low-rate initial production of 104 modified howitzers.

Army Actions to Control Future Cost Growth

The Army recently changed its competition-based strategy for acquiring the Paladin to control future cost growth. In September 1990, the Army Acquisition Executive expressed concern about the lack of sufficient configuration control over the Paladin program and stated that no additional design changes were to be made without his approval. Also, in 1991, the Army began contracting directly with several subcontractors for certain components that were initially procured by the prime contractor.

The Army now plans to have full and open competition for work done by both the prime contractor and various subcontractors beginning with the fiscal year 1993 program. The Army had planned to compete the fiscal year 1992 program but recently decided to postpone competition until fiscal year 1993, because it believed contractors might not submit bids until the Army approved full-rate production. Further, the Army felt it needed additional time to educate and validate other potential contractors to increase and improve the competition environment.

Several Expenses Not in Unit Cost Calculations

The Army's cost estimate for the Paladin program does not include all costs related to the program. The excluded costs relate to expenses involving the howitzer's overhaul cost at the Letterkenny Army Depot and 2 years of early research and development work related to the modification program. In addition, the Paladin program cost does not include procurement costs for the new radio to be installed in the Paladin because the Army has a separate acquisition program for the radios.

Overhaul Costs

The Army's cost estimate for the Paladin program does not include $107 million in operation and maintenance appropriations to overhaul the howitzers' chassis. This overhaul work is directly related to the Paladin program and might not have been done at this particular time if not for the scheduled modification work. Army officials said overhaul costs were excluded because howitzers require general overhaul at Army depots, and

the Army can perform the overhaul work while the weapon system is being modified.

Research and Development Costs

The Army's program cost estimate also excluded $46 million for research, development, test, and evaluation in fiscal years 1984 and 1985. The early stages in developing the Howitzer Improvement Program stemmed from two programs, which were merged into the Howitzer Improvement Program in 1984. Therefore, this early research and development work is related to the Paladin program. Army officials said the research and development costs related to the two predecessor programs were excluded because one program was canceled and only some of the modifications from the other program were incorporated in the modified howitzer's design.

Radio Costs

The Army's program cost estimate includes the cost to install new radios, known as the Single Channel Ground and Airborne Radio System, in the Paladin but not the $17 million required to buy the radios. This radio, one of several vital components on the Paladin, contributes to the increased responsiveness of the weapon system. However, it is not Paladin peculiar. The Army is managing the acquisition of the Single Channel Ground and Airborne Radio System for all of its host systems through a single budget line.

Conclusions

The significant increase in the Paladin's unit cost is largely attributable to inflation and the addition of components and subsystems beyond those originally planned for the howitzer. These additional subsystems are designed to enhance the performance of the howitzer and establish a foundation for incorporating future improvements. Because of cost growth, affordability concerns, and force restructuring, the Army has substantially reduced the program's total procurement objective. Also, the Army has taken steps to control future growth. The Army's cost estimate for the Paladin program does not include all costs related to the program.

Agency Comments

In its official oral comments, the Department of Defense generally agreed with the facts and findings presented in this chapter.

Configurations of the M109 Howitzer

Configuration	Description
M109	The basic 155-mm self-propelled howitzer was initially fielded by the Army in 1963 and was designated the M109.
M109A1	New gun tubes were installed on fielded M109 howitzers beginning in 1973 to extend the gun's range. The modified M109 howitzer was designated the M109A1.
M109A2	New howitzers were procured beginning in 1979 with improvements to the loader, rammer, ammunition storage, and crew safety. This reconfigured version was designated the M109A2.
M109A3	Fielded M109A1 howitzers were modified to incorporate the features of the new M109A2 howitzer. The modified howitzer, which is virtually identical to the M109A2 howitzer, was redesignated the M109A3.
M109A4	Under the Reserve Component/Modified Armament System (RCMAS) program, the Army plans to modify about two-thirds of its inventory of M109A2 and M109A3 howitzers. The RCMAS program is executed in two phases. The first phase involves the installation of an automotive kit and a nuclear, biological and chemical kit on the M109A2 and M109A3 howitzers. The modified howitzers then become the M109A4.
M109A5	The second phase of the RCMAS program involves the installation of a new cannon kit and a new gun mount to the M109A4 howitzer. The modified howitzer now becomes the M109A5. It has the same firing range and ammunition utility as the howitzer being modified under the Army's Howitzer Improvement Program.
M109A6	The remaining one-third of the Army's inventory of M109A2 and M109A3 howitzers are being modified to the M109A6 configuration as a part of the Howitzer Improvement Program and is the focus of our review.

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