United States General Accounting Office

GAO

Report to Congressional Committees

October 1991

DEFENSE ACQUISITION

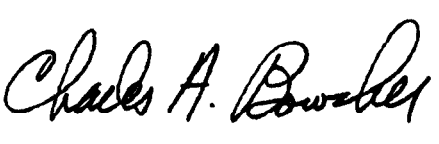
U.S.-German Examinations of the MLRS Terminal Guidance Warhead Program

GAO/NSIAD-92-7

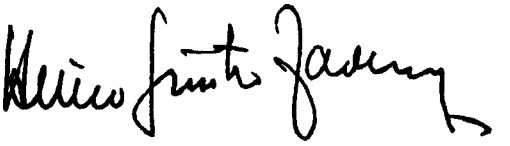
Preface

This report examines the status of the Multiple Launch Rocket System's Terminal Guidance Warhead program. It also discusses (1) the implications for this program of the U.S. selection of another system for full-scale development and (2) the Terminal Guidance Warhead's cost-effectiveness as compared to an alternative German national system in development.

This report represents the second cooperative examination of a multinational weapon system development program undertaken by the U.S. General Accounting Office and the German Federal Court of Audit.[1] We coordinated our work and shared information with each other. The results of our efforts are summarized in the accompanying letter and our separate reports are at appendixes I and II.



Charles A. Bowsher
Comptroller General
of the United States



Dr. Heinz Gunter Zavelberg
President,
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Germany

[1]The first effort resulted in a report entitled Navy Ship Defense: Concerns About the Strategy for Procuring the Rolling Airframe Missile (GAO/NSIAD-90-208, Aug. 27, 1990.)

GAO

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

National Security and
International Affairs Division

B-245720

October 31, 1991

The Honorable Robert C. Byrd
Chairman, Committee on
Appropriations
United States Senate

The Honorable Sam Nunn
Chairman, Committee on
Armed Services
United States Senate

The Honorable Jamie L. Whitten
Chairman, Committee on
Appropriations
House of Representatives

The Honorable Les Aspin
Chairman, Committee on
Armed Services
House of Representatives

This report presents the results of U.S. General Accounting Office (GAO) and German Federal Court of Audit coordinated examinations of the Army's Multiple Launch Rocket System (MLRS) Terminal Guidance Warhead (TGW) program.[1] GAO and the Federal Court of Audit examined the program's requirements, schedule, performance, and cost. Additionally, the Federal Court of Audit compared the MLRS TGW with another target-sensing artillery round under development in Germany.

Background

The program is a multinational cooperative development effort begun under a 1983 Memorandum of Understanding signed by the United States, Germany, France, and the United Kingdom. It is to develop a target-sensing submunition and warhead for attacking armored targets at distances up to 30 kilometers or more. The United States is funding about 40 percent of the development, while the other three partners are funding about 20 percent each. The MLRS TGW is currently in the system

[1]GAO previously reported on this program in Defense Acquisition: Examination of MLRS Terminal Guidance Warhead Program (GAO/NSIAD-91-144, Mar. 1991), Defense Acquisition Programs: Status of Selected Systems (GAO/NSIAD-90-30, Dec. 1989), and Defense Acquisition Programs: Status of Selected Systems (GAO/NSIAD-88-160, June 1988).

demonstration substage of development. At the end of the system demonstration substage—currently scheduled for October 1992—the system will have been in development for about 8 years and will have cost a total of about $660 million (U.S. share—$300 million; European share—approximately $360 million).

In accordance with congressional direction, MLRS TGW was also one of three competing U.S. target-sensing submunition development programs being reviewed by the Department of Defense for selection of a single option by March 1991.[2] In March 1991, the U.S. Army selected another system for full-scale development—the Brilliant Anti-armor Submunition, using acoustic and infrared sensor technologies—for use in the U.S. Army's preferred deep fires mission. The deep fires mission is typically done from considerably longer ranges than the MLRS rocket.

The other two programs, including MLRS TGW, were to be terminated. The Defense Department subsequently obtained congressional approval to reprogram $23 million for fiscal year 1991 and requested $46.8 million for its fiscal year 1992 budget to complete the current development phase of MLRS TGW. Defense reasoned that, if the program was to be terminated, the logical exit point from the program would be the end of this development phase. By completing this phase, the United States would (1) fulfill its agreement obligations, (2) avoid certain termination costs, and (3) obtain MLRS TGW technical data that could be used to enhance the performance of other systems, such as the Brilliant Anti-armor Submunition.

Results and Recommendations

Despite the U.S. Army's selection of another submunition for full-scale development and Defense Department discussions with the Congress, officials from the Army's Program Executive Office and the MLRS TGW project office told GAO the Army may seek to continue the MLRS TGW program into full-scale development. Army officials maintain there is a continuing requirement for a target-sensing anti-armor submunition at the MLRS rocket range and that MLRS TGW will have advantages over other systems. However, Defense and Army officials noted that it would be feasible for the Brilliant Anti-armor Submunition to be delivered by the

[2]In May 1991, the Office of the Inspector General, U.S. Department of Defense, issued a classified report on the three competing U.S. programs and the process of selecting one system for continued development.

MLRS rocket and that the technical data acquired from the MLRS TGW program at the end of the system demonstration substage would be sufficient to apply to other programs, including the Brilliant Anti-armor Submunition. GAO would question the basis for proceeding into full-scale development with MLRS TGW, given funding constraints, the Army's selection of another system for use at longer ranges, and the sufficiency of the MLRS TGW technical data acquired from this phase of development.

In view of these concerns, GAO recommends that the Secretary of Defense reassess the need for the MLRS TGW if the U.S. Army seeks to continue to full-scale development, considering all the other systems in development and procurement that could be used to fill the requirement.

In commenting on a draft of the GAO portion of this report, Defense and Army officials acknowledged that funding constraints are serious but that there may be an effort to continue the MLRS TGW development program. The Army has not yet made a decision on whether or not MLRS TGW should proceed beyond the system demonstration substage. Defense and Army officials noted, however, that (1) the current Army budget does not support continuation of the program beyond the system demonstration substage, (2) the Army does not have a program to integrate the Brilliant Anti-armor Submunition with the MLRS rocket, and (3) data is not currently available to fully assess the technical feasibility, cost-effectiveness, or operational performance of delivering the Brilliant Anti-armor Submunition with the MLRS rocket. They further emphasized that the Brilliant Anti-armor Submunition was selected for deep fires—not the MLRS rocket range.

The Federal Court of Audit found that numerous German army and air force weapon systems, including MLRS TGW, were designed to fight the second echelon armored forces. Three separate analyses done for the Ministry of Defense concluded that an overlapping German national system in development—a self-seeking, 155-millimeter artillery round with two submunitions—was more cost-effective at most ranges than MLRS TGW with three submunitions. One analysis concluded that the artillery round was generally about five times more cost-effective than the MLRS TGW, and its unit price is 1/18 that of an MLRS TGW.

The Federal Court of Audit recommends that the German Minister of Defense make a decision during 1991 on whether or not to continue participation in the MLRS TGW program. This decision should consider alternative army and air force systems, the anticipated reductions in the armored threat resulting from the Treaty on Conventional Forces in

Europe, the U.S. Army's selection of another system for full-scale development, and the economic effects of likely reductions in procurement quantities. A German Ministry of Defense decision on MLRS TGW during 1991 is needed to facilitate more reliable budgeting for the next 5-year plan.

Details on these matters are presented in appendixes I and II, along with each audit organization's objectives, scope, and methodology. GAO discussed a draft of this report with cognizant Department of Defense and U.S. Army officials and has incorporated their comments where appropriate. The Federal Court of Audit has included written comments from the Ministry of Defense and its response to those comments in appendix II.

This report was prepared under the direction of Joseph E. Kelley, Director, Security and International Relations Issues, who may be reached on (202) 275-4128 for further information. Other major contributors are listed in appendix III.

Frank C. Conahan
Assistant Comptroller General

Contents

Figures

Abbreviations

AMSAA	U.S. Army Materiel Systems Analysis Activity
BWB	Federal Office for Defense Technology and Procurement, German Ministry of Defense
DOD	Department of Defense
FLOT	Forward Line of Own Troops
MLRS	Multiple Launch Rocket System
MSOW	Modular Stand-Off Weapon
TGW	Terminal Guidance Warhead
SMART	Target-Seeking Ammunition for Artillery

Results of U.S. General Accounting Office Examination of MLRS TGW Program

Background

The Multiple Launch Rocket System (MLRS) is an all weather, indirect fire system with up to 12 rockets. The system is to be used to defeat enemy artillery, air defense, other light materiel, and personnel targets at ranges up to 30 kilometers or more. The objective of the MLRS Terminal Guidance Warhead (TGW) program is to develop a target-sensing submunition for attacking armored targets at distances up to 30 kilometers or more. The submunition is to have an all-weather capability and be launched from the basic MLRS. The system will use the standard MLRS rocket motor to propel a warhead structure to the target area, where the warhead will dispense three terminally guided submunitions. Each submunition will contain a seeker that is to activate the submunition's independent guidance and control functions and search for and engage the target. The submunitions, which use a tandem shaped charge, will rely on miniaturized, sophisticated, and complex components to perform these functions.

Figure I.1 shows a representation of the MLRS TGW warhead, and figure I.2 shows the components of the terminally guided submunition, which is encased in the warhead structure.

Figure I.1: Multiple Launch Rocket System Terminal Guidance Warhead

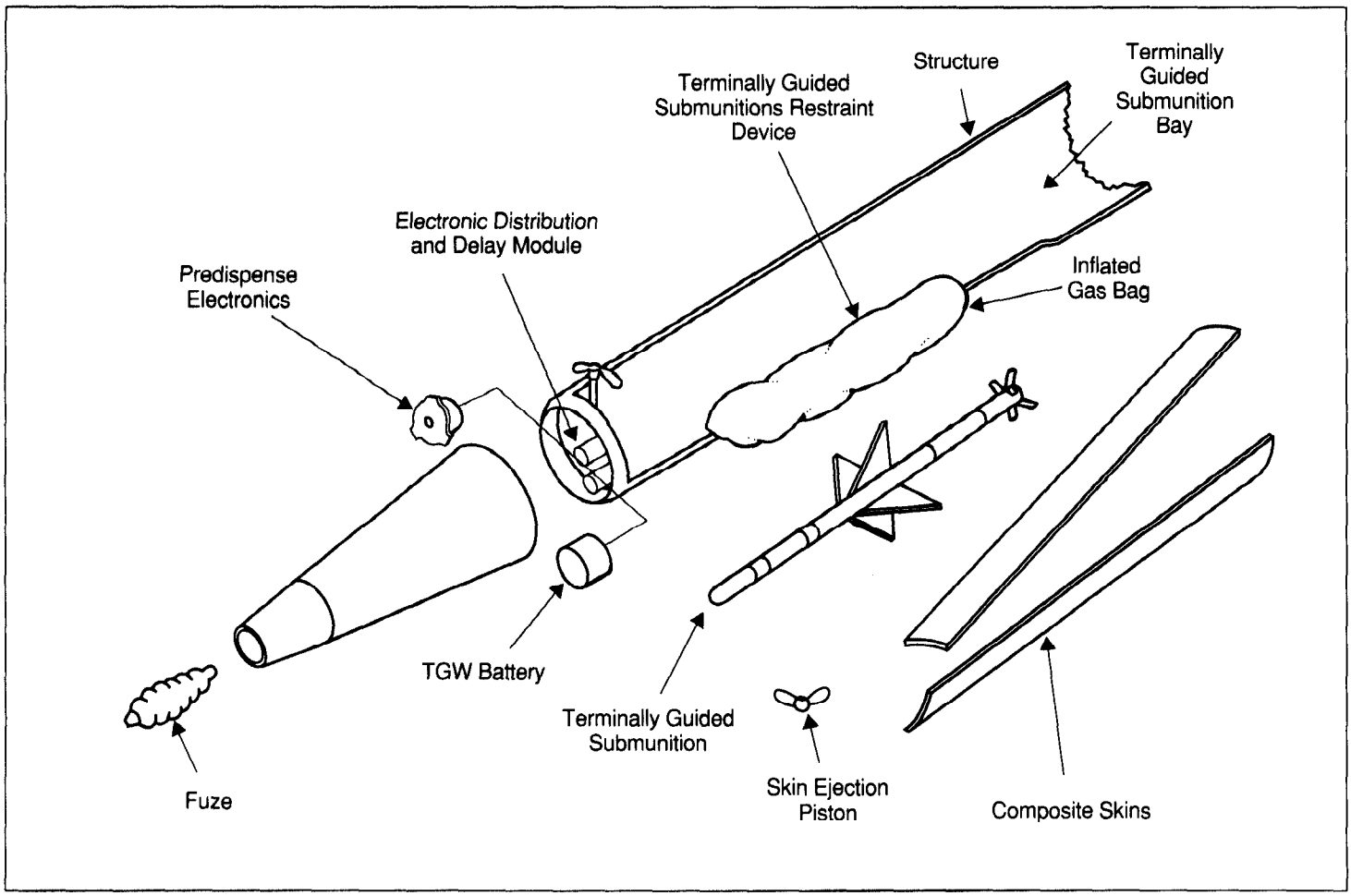
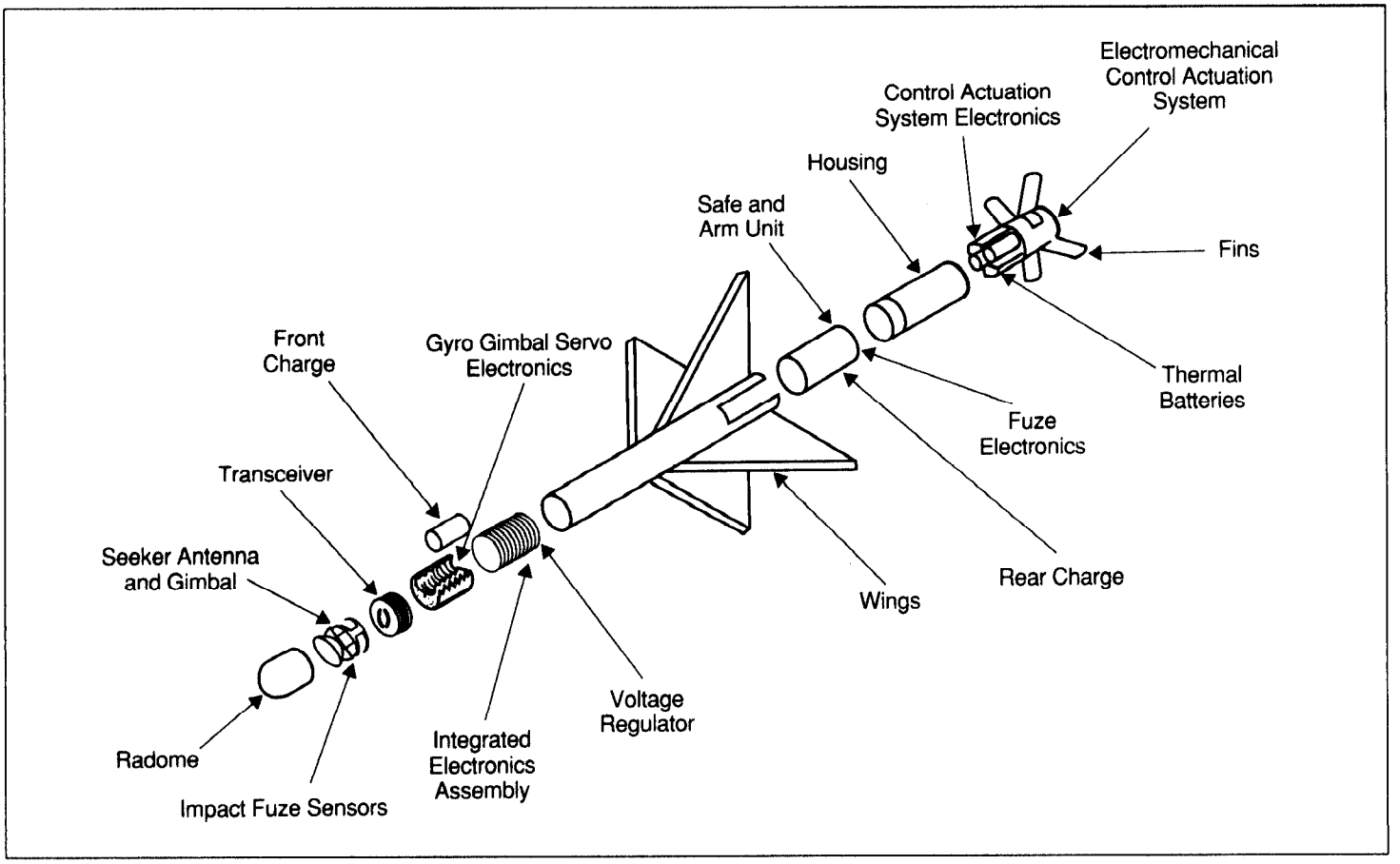


Figure I.2: MLRS Terminally Guided Submunition



The program required developing technology, including an active millimeter wave radar seeker,[1] that was not yet proven. If successfully developed, the new seeker technology will provide significant advantages over other technologies, such as those of infrared systems, but like other systems will also have some limitations and disadvantages. For example, in most adverse weather and under certain battlefield conditions, millimeter wave systems can perform better than systems using other technologies. However, millimeter wave systems operate reasonably on only two frequency bands and experience many normal transmission losses. According to a U.S. Army study, the acquisition range of millimeter wave devices tends to be limited by atmospheric absorption,

[1] An active millimeter wave radar seeker both receives and transmits on millimeter wave frequency bands.

even on clear days with high visibility. U.S. project office representatives noted that the MLRS TGW is being designed to mitigate the effects of atmospheric absorption. Finally, millimeter wave systems are generally complex and expensive to design and produce.

A four-country consortium is sharing the technology and the cost to develop the program. Because of the complexity of the technology, a cautious three-stage development approach is being applied to the program: a two-stage validation program (component demonstration and system demonstration substages) followed by a maturation/full-scale development stage. In late 1983, the four-nation codevelopment agreement was signed. In November 1984, the U.S. Army awarded a cost-plus-incentive-fee component demonstration contract to MDTT, Inc., a joint venture of Martin Marietta Corporation (United States), Thomson (France), Thorn EMI Electronics, Ltd. (United Kingdom), and Diehl GmbH & Co. (Germany).

In February 1989, the Department of Defense (DOD) approved the start-up of the system demonstration substage for the MLRS TGW on condition that the U.S. Army take the following actions: (1) perform a cost and operational effectiveness analysis comparing MLRS TGW to alternative approaches for defeating the armored threat, (2) define specific actions to be taken during the system demonstration substage to improve the ability to manufacture the submunition, and (3) prepare a test and evaluation master plan defining specific quantitative test goals for entry into full-scale development. In July 1989, the Army awarded a system demonstration contract to MDTT, Inc. In September 1991, DOD estimated that by the end of the system demonstration substage, the four partners will have spent about $660 million on the development program (United States—$300 million; European partners—approximately $360 million).

Requirements

In 1979 and 1982, the four participating nations determined that an MLRS autonomous, anti-armor terminal guidance warhead capability was the best technical approach for jointly (1) improving munitions accuracy and lethality deficiencies and (2) providing effective field artillery to conduct strikes behind enemy lines. A November 1989 U.S. Army cost and operational effectiveness analysis concluded that a complementary mix of technologies, delivery vehicles, and submunitions would optimally satisfy this need but recommended further study before selecting the best option. However, in the Department of Defense Appropriations Act, 1991 (P.L. 101-511), the Congress directed the U.S. Army to select a single option from three competing target-sensing submunition development programs by the end of March 1991.

DOD completed another cost and operational effectiveness analysis in January 1991, and ultimately selected the Brilliant Anti-armor Submunition which uses acoustic and infrared sensor technologies for the deep fires mission.[2] Nevertheless, Army officials maintain there is still a requirement for a target-sensing anti-armor submunition in the MLRS range.

Although the U.S. Army had expected to approve its draft operational requirements document (defining MLRS TGW system requirements) by September 1989, as of August 1991 it had not been finalized. U.S. Army officials noted that the document did not have to be finalized until just prior to the full-scale development phase of the program, currently scheduled to begin in late 1992. U.S. project office representatives were uncertain as to when the document would be finalized.

MLRS TGW Quantity Requirements

For planning purposes, the four partner nations' quantity requirements for the MLRS TGW have been affected by events leading up to the November 1990 Treaty on Conventional Armed Forces in Europe. If ratified and implemented, the treaty will result in reductions in the number of armored threats. While these requirements are tentative and classified, for planning purposes the U.S. Army project office is currently using an overall quantity that is 70 percent of the original estimated requirement. The German defense ministry is currently estimating its requirements at substantially lower than 70 percent of its original estimate for planning purposes.

Threat Environment for MLRS TGW

While the armored threat in Central Europe is likely to be reduced in number, MLRS TGW is expected to face a more difficult and challenging threat in terms of armor protection and countermeasures. According to the U.S. Army Training and Doctrine Command, MLRS TGW is being developed to defeat a future Soviet tank (FST 2). Details on the characteristics of the actual and projected threats and countermeasures are classified.

Potential for Future Development

In March 1991, the U.S. Army selected the Brilliant Anti-armor Submunition as the preferred system for deep fires—the Army's preferred range. The congressional direction included a requirement to terminate

[2]The range required for the deep fires mission is considerably greater than that provided by the MLRS rocket. The deep fires missions are typically conducted out to ranges of 150 kilometers.

the other programs, including MLRS TGW, but DOD requested and the Congress granted authority to reprogram funds to complete fiscal year 1991 MLRS TGW development efforts. In addition, a fiscal year 1992 budget request of $46.8 million for completing the system demonstration substage was pending congressional approval.

During congressional consideration of the reprogramming request for MLRS TGW, DOD reasoned that, if the program was to be terminated, a logical exit point from the program was at the end of the system demonstration substage. Completing this phase of development would allow the United States to fulfill its agreement obligations, avoid certain termination costs, and obtain the technical data package resulting from the development effort. The MLRS TGW technical data package could then be used to enhance other systems' performance, including the Brilliant Anti-armor Submunition. DOD and Army officials told us that the technical data acquired from the MLRS TGW system demonstration substage would be sufficient to adapt to and enhance the performance of the Brilliant Anti-armor Submunition.

Despite (1) the selection of the Brilliant Anti-armor Submunition, (2) congressional direction to terminate the other programs, and (3) discussions with the Congress regarding U.S. departure from the program at the end of the system demonstration substage, officials from the Program Executive Office and the MLRS TGW project office told us the Army may seek to continue the program into maturation/full-scale development. Army officials noted that there is a continuing requirement for an anti-armor capability in the MLRS rocket range and, if successfully developed, the MLRS TGW technology has advantages over other systems. Both DOD and Army officials stated, however, that it would be feasible to deliver the Brilliant Anti-armor Submunition with the MLRS rocket. They added that before the MLRS TGW program could enter into full-scale development, it would need to undergo reviews by an Army Systems Acquisition Review Council and the Defense Acquisition Board.

Conclusion and Recommendation

Given funding constraints, the Army's selection of another system for use at longer ranges, and the sufficiency of the MLRS TGW technical data acquired from the system demonstration substage, we would question the basis for proceeding into full-scale development with MLRS TGW. In view of these concerns, we recommend that the Secretary of Defense reassess the need for MLRS TGW if the U.S. Army seeks to continue to full-scale development, considering all the other systems in development and procurement that could be used to fill the requirement.

Agency Comments

In commenting on a draft of the GAO portion of this report, Defense and Army officials acknowledged that funding constraints are serious, but there might be an effort to continue the MLRS TGW development program. The Army has not yet made a decision on whether or not MLRS TGW should proceed beyond the system demonstration substage. They noted, however, that (1) the current Army budget does not support continuation of the program beyond the system demonstration substage, (2) the Army does not have a program to integrate the Brilliant Anti-armor Submunition with the MLRS rocket, and (3) data is not currently available to fully assess the technical feasibility, cost-effectiveness, or operational performance of delivering the Brilliant Anti-armor Submunition with the MLRS rocket. They further emphasized that the Brilliant Anti-armor Submunition was selected for deep fires—not the MLRS rocket range.

Schedule

Table I.1 shows the original December 1984 schedule and revised December 1987 and 1989 schedules. From the time originally approved, the U.S. Army's schedule for making the initial production decision slipped nearly 6 years, from April 1989 to March 1995; the slippage includes a more than 3-year delay in the scheduled completion of the system demonstration substage and the beginning of full-scale development.

Table I.1 MLRS TGW Program Schedule Changes

Event	Dec. 1985 Original Schedule	Dec. 1987 Revised Schedule	Dec. 1989 Revised Schedule
Army system demonstration substage decision	Feb. 1987	Nov. 1988	Feb. 1989
DOD system demonstration substage decision	Mar. 1987	Jan. 1989	Feb. 1989
DOD system demonstration substage review	[a]	[a]	[a]
Army/DOD full-scale development decision	Mar.-Apr. 1989	Nov. 1991-Jan. 1992	Oct. 1992
Initial production decision	Apr. 1989	Jan. 1992	Mar. 1995
Initial production contract award	June 1989	Feb. 1992	Apr. 1995
Production qualification testing	Dec. 1990	Aug. 1993	June 1997
Full-rate production decision	Aug. 1991	May 1994	Oct. 1997
Full-rate production contract award	Sept. 1991	June 1994	Nov. 1997
First unit equipped		Classified	
Initial operational capability		Classified	

[a]DOD established the system demonstration review milestone after February 1988. At that time, the review was scheduled for September 1989. This review was not done and, according to project officials, is no longer applicable.

Project officials attribute the 3-year delay in the schedule for completing the system demonstration substage and beginning full-scale development to (1) a warhead redesign required to meet an upgraded armor threat, (2) contractor problems in developing and manufacturing submunition components, (3) contractor start-up difficulties, and (4) a delay in awarding the system demonstration contract. An Army official responsible for monitoring the tests currently projects actual completion of system demonstration substage testing in December 1992, with final documentation expected in January 1993. The project office concurs with this assessment but has not yet officially changed the schedule.

Performance

Testing shows progress towards meeting performance goals, but U.S. Army officials agree that the most critical performance aspects have not been tested at the system level. These tests are scheduled to be conducted between late 1991 and October 1992.

Currently, the U.S. Army Materiel Systems Analysis Activity (AMSAA) considers the overall performance risk to be medium.[3]

Testing Shows Progress, but Most Critical Tests Not Yet Begun

For the system demonstration substage, development tests performed or planned include "captive flight tests"[4] to collect initial seeker and radar data, system-level flight tests to collect launcher-to-target data, and submunition drop tests to collect data on the fully integrated hardware performance. To gather data on clutter and stationary and moving targets in varying terrain, countermeasures, and environmental conditions, the U.S. Army has performed captive flight tests at Eglin Air Force Base, Florida; White Sands Missile Range, New Mexico; and Fort Drum, New York.[5]

[3]Technical risk is assessed as low, medium, and high. For the purposes of the MLRS TGW risk assessment, the Army defined medium risk to exist when analysis, simulation, or testing of components or subsystems uncovers shortcomings in their performance that should be corrected (1) before completion of component demonstration or (2) during system demonstration, to provide a high probability of successful demonstration of the function they support. The European partners made separate assessments of technical risk and may have reached different conclusions.

[4]Captive flight tests involve mounting a component, such as a seeker, or a system on an aircraft and simulating its functions and performance under various conditions.

[5]MLRS TGW project officials noted that, during the component demonstration substage, captive flight tests were also conducted at six different locations and in all seasons in Germany and at Redstone Arsenal, Huntsville, Alabama.

At the time of our examination, AMSAA had not prepared any formal written assessments on the system demonstration substage test data or results. U.S. Army officials stated, however, that captive flight testing was successful. On the basis of captive flight test data, U.S. Army Missile Command officials believe system simulation and modeling have demonstrated that the system's software works and the system meets or exceeds stated test requirements. According to the project office, limited test results indicate that the MLRS TGW lethal mechanism can defeat a more difficult armor than that projected in FST 2.

In addition, according to a responsible AMSAA official, although AMSAA had not formally reviewed the test results, the results indicated some additional confidence in MLRS TGW performance might be warranted. However, he noted that the real success of MLRS TGW could not be measured until the fully integrated hardware testing is done during 1992. During this testing, the seeker's ability to track and hit the target will be evaluated, and overall system performance will be demonstrated.

According to June and August 1991 reports on susceptibility analyses[6] done by the U.S. Army Vulnerability Assessment Laboratory, MLRS TGW has been tested against various categories of active and passive countermeasures. The analyses indicate that the system can defeat certain, selected passive and active countermeasures, while its performance may be degraded by others. However, DOD and Army officials acknowledged that MLRS TGW had not yet been tested against certain, more rigorous existing and projected countermeasures.

Overall Technical Risk Assessment Remains Medium

In its November 1988 assessment, AMSAA concluded that TGW's overall risk—including the critical area of seeker performance—was medium. Although no formal risk assessments have been done since that time, an AMSAA official noted that TGW's risk will remain medium until critical testing is done on the integrated hardware. He recognized that added confidence could result from captive flight testing but believed the results would be insufficient to warrant changing the original risk assessment.

Additional integrated hardware testing data would be needed before AMSAA could change its risk assessment, and unless directed to do so,

[6]Susceptibility analyses are intended to identify system weaknesses against countermeasures outside a battlefield environment. Vulnerability assessments are more complete analyses, taking into account the feasibility of employing countermeasures on the battlefield and other factors.

AMSAA does not plan to do another formal risk assessment until the next milestone decision, currently planned for late 1992.

Cost

In a September 1989 baseline cost estimate, the Army estimated U.S. costs of developing and producing MLRS TGW to be about $7 billion (then-year dollars), but the cost estimates are subject to uncertainties. According to DOD cost analysts, the production estimate may be understated. In addition, economic and exchange rate adjustments, as well as potential changes in production quantities and the number of production lines, could alter the development, production, and unit cost[7] estimates. The U.S. Army is also attempting to reduce costs by improving the ability to manufacture key MLRS TGW components.

Most Recent Cost Estimate

The estimated acquisition cost of the U.S. portion of MLRS TGW is $7 billion (see table I.2). This acquisition cost was based on a September 1989 baseline cost estimate that was validated by the U.S. Army Cost and Economic Analysis Center.

Table I.2: September 1989 MLRS TGW Cost Estimate—U.S. Share

Dollars in millions

Item	Fiscal year 1990 constant dollars	Then-year dollars
Development	$473.5	$482.3
Production	4,985.1	6,528.1
Total	**$5,458.6**	**$7,010.4**

On the basis of this estimate, the total development cost to the four partners would be about $1.2 billion. The Cost and Economic Analysis Center said it withdrew a February 1991 tasking to the project office to update its baseline cost estimate because of uncertainties regarding the program's continuation.

Cost Estimate May Be Understated

The DOD Cost Analysis Improvement Group has not reviewed the most recent validated U.S. Army cost estimate. However, the group analyzed the U.S. Army's January 1989 estimate, which varied little from the estimate shown in table I.2. According to the group's Chairman, when reviewing the Army's January 1989 production cost estimate, the group believed it could be understated by as much as 50 percent. The

[7]The estimated unit cost for the MLRS TGW is classified.

Chairman stated that the group questioned the estimate in the areas of (1) estimating methodology and assumptions, (2) exchange rate projections during the production phase, and (3) seeker production cost.

Group officials acknowledged that they had not analyzed the U.S. Army's current (September 1989) estimate but believed the concerns they expressed regarding the January 1989 estimate may still be valid. They stated that they did not have evidence that the system had matured sufficiently to warrant greater confidence in the production estimate.

A U.S. Army MLRS TGW project cost official disagreed with the group's position. In his opinion, the maturity of the seeker and hardware design and more reliable vendor quotes on some items should increase overall confidence in the production estimate. Group officials noted, however, that at this stage of a program, vendor quotes are not highly reliable, and they expressed less confidence in them.

In addition to the production cost uncertainties, a December 1990 change in the program led to an increase in the estimated U.S. development costs. At that time, the partners agreed to change the basis for calculating economic and exchange rate adjustments. On the basis of these changes, the U.S. project office has increased its estimate for the U.S. development share by $21.8 million (fiscal year 1990 constant dollars). As a result, the current estimate of the U.S. development share increased from $473.5 million to $495.3 million.

Potential Program Changes Could Alter Cost Estimates

The U.S. Army's September 1989 cost estimate may be based on outdated assumptions. Since that time, the U.S. Army has tasked MDTT, Inc., to consider lower quantities and an additional production facility in planning the program's completion. These potential programmatic changes could change the U.S. Army's current production and unit cost estimates.

Quantity and Production Changes

The U.S. Army tasked MDTT, Inc., to consider the effects of producing only 70 percent of the baseline quantity included in the September 1989 estimate. It also tasked the company to consider producing the four partner nations' reduced quantities at two complete production facilities—one in Europe for the European requirements and one in the United States for the U.S. requirements. Earlier program plans involved having two seeker production lines (one in Europe and one in the United States) and a single integration facility in the United States. Although it

has not been validated, the MLRS TGW project office has estimated that even with these new conditions, production and U.S. unit costs would decrease when compared to the September 1989 estimate.

Neither we nor the Cost Analysis Improvement Group audited or assessed the project office estimate,[8] but we noted that a reduction in quantities normally results in an increase in unit cost.[9] An MLRS TGW project office cost official attributed the lower unit cost to (1) a more mature hardware cost estimate; (2) reduced production start-up costs, since the United States would only be responsible for its production facility; (3) the opportunity to produce the entire system more efficiently, since the seeker would not have to be delivered, disassembled, and retested prior to final integration; and (4) establishment of a less costly production lot acceptance procedure.

Cost Analysis Improvement Group officials had not reviewed this estimate or its assumptions and did not refute its conclusions. They stated, however, that it would be unusual for unit prices to decrease with a lower production base and they would have to carefully review the accompanying analysis to be convinced.

Other Cost Considerations

DOD is currently funding initiatives designed to improve the ability to manufacture and reduce the cost of millimeter wave technology. The initiatives are to develop affordable millimeter wave circuitry and manufacturing methods for DOD systems. According to project officials, MLRS TGW is the primary focus. To date, the initiatives have not progressed sufficiently to quantify savings once applied to production. Consequently, current TGW cost estimates do not consider the potential effects of the initiatives.

Objectives, Scope, and Methodology

We updated our prior work by examining the requirements, schedule, performance, and cost aspects of the MLRS TGW program. We reviewed relevant program documents such as system threat analyses, selected acquisition reports, cost and operational effectiveness analyses, contract documents, test and evaluation plans and assessments, various cost estimates, and budget exhibits. We did our work at the offices of the Under Secretary of Defense for Acquisition, the Assistant Secretary of Defense

[8]The estimate was subject to change.

[9]Although U.S. and German unit costs may not be comparable, the Federal Court of Audit concluded that the average MLRS TGW unit cost will increase as a result of reductions in quantities.

for Program Analysis and Evaluation, the U.S. Army, and the Defense Intelligence Agency in Washington, D.C.; the U.S. Army Missile Command, Huntsville, Alabama; and the Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, Maryland.

We and the German Federal Court of Audit coordinated work and shared information we obtained on the program. We also contacted the British National Audit Office and the French Cour des Comptes (Court of Accounts) to determine their interest in participating in the coordinated effort. However, these organizations did not participate.

We did not examine or compare MLRS TGW with the other two competing development programs or monitor the selection process because of ongoing work being performed by DOD's Office of the Inspector General. We monitored the Inspector General's efforts under a separate review. The Inspector General issued a classified report in May, 1991. Formally updated, assessed, and validated test and cost data on the MLRS TGW system demonstration substage were not available at the time of our examination. We did, however, review U.S. Army Vulnerability Assessment Laboratory reports, informal AMSAA analyses, and U.S. Army Missile Command laboratory assessments.

We discussed a draft of this report with cognizant DOD and U.S. Army officials and incorporated their comments where appropriate. We did our work from November 1990 through January 1991 and updated it during August and September 1991, in accordance with generally accepted government auditing standards.

Results of German Federal Court of Audit Examination of MLRS TGW Program

Introduction

The Federal Court of Audit reviewed the development of the Terminal Guidance Warhead (TGW) for the Multiple Launch Rocket System (MLRS) in coordination with the U.S. General Accounting Office. Because of the partially different situations in each nation, each audit institution is reporting its results in separate appendixes. The French Cour des Comptes and the British National Audit Office were informed of this audit and expressed interest in a possible follow-up audit.

The following events affected the MLRS TGW program:

- The Treaty on Conventional Armed Forces in Europe, dated November 19, 1990, reduced the ceiling for battle tanks, armored vehicles, and guns with large caliber to 70,000 per alliance and 47,000 per signatory nation.
- The U.S. Army and German Federal Armed Forces substantially reduced their quantity requirements for MLRS TGW for planning purposes.
- The U.S. Congress required the U.S. Army to decide by the end of March 1991 on one of three competing weapons development programs. Although MLRS TGW was not selected, the U.S. Congress agreed to fully fund the program through fiscal year 1991 and was considering the U.S. Army's fiscal year 1992 request. There is a risk that the United States may not participate in the program beyond the system demonstration substage. Under these conditions, the other participants would need to fund the maturation/full-scale development phase without U.S. participation.

These recent events also influenced our audit scope and timing, to include an examination of possibly competing and overlapping development and procurement programs and analyses of these programs done within and for the Ministry of Defense. Our recommendations refer to a decision on the continuation of the development of MLRS TGW. We plan to advise the Budget Committee of the Bundestag of our findings and recommendations.

Background on MLRS TGW

Operational Concept

More than half of the enemy's armed ground forces are expected to execute an initial attack; the remainder will be held in reserve in the rear. Fighting the moving armored vehicles in these remaining forces—the

second echelon—at medium range beyond the forward line of own troops (FLOT) is a high priority. Numerous German air force and army weapon systems are deployed and being developed to fight the second echelon forces.

MLRS TGW is one of the army's weapon systems being developed to fight the enemy's armored vehicles in the second echelon. The system is expected to have a high probability of success in destroying less than half of the armored targets in the second echelon. Thus, MLRS TGW would reduce the number of armored vehicles in the second echelon that could reinforce an initial attack after reaching the FLOT. A secondary role for MLRS TGW is to defeat stationary armored artillery in a firing position.

Description

The MLRS TGW is a warhead that is propelled by a ballistic rocket fired from a 12-tube rocket launcher. Each warhead contains three terminally guided submunitions that operate like missiles without propulsion. Each submunition contains a radar seeker and a tandem shaped charge. The ballistic rocket has a caliber of 236 millimeters, and the submunition has a caliber of 110 millimeters. The maximum range of MLRS TGW is reduced by its distance from behind the FLOT.

MLRS TGW depends on target reconnaissance devices, such as remotely piloted vehicles with daylight cameras and infrared sensors. Those devices will transmit the target data in real time through their ground stations to the artillery. After computing the target data with the support of a fire control computer, the MLRS rocket will be launched with the terminal guidance warhead, which will dispense the guided submunitions. The self-seeking submunitions will begin to fly horizontally near the target area and perform a short search phase. After discovery and verification of a target, the submunition will execute a steep terminal approach down to the target (top attack) and penetrate the armor with its tandem shaped charge. Initially, the TGW warhead was intended to carry six submunitions. Improvements in the armor to be penetrated, especially the introduction of reactive armor, required the use of a tandem shaped charge in the submunition and thus reduced the quantity of submunitions to three per rocket warhead. This reduction in submunitions substantially reduced the efficiency of each MLRS TGW.

One special feature of MLRS TGW is the large "footprint," or area, covered by the seeker. It can cover target areas the size of a company or larger without reducing the efficiency of the system by compensating for scattering, targeting mistakes, or other inaccuracies. This feature required a

sensor system that is technically very complex and thus very expensive. At the same time, the large footprint requires maintaining a large safety distance from the FLOT.

The most recent German milestone document describes the technical risks as low for most of the components and medium for some components. Tests of the total system are not yet available.

Program Performance, Development, and Procurement Costs

MLRS TGW originated from a 1979, four-nation agreement (military equipment characteristics document) that corresponds to German tactical requirements. The next German milestone document was signed in 1983, and the most recent milestone document was signed in October 1989, with a cost cap for the total German share of development of 513 million deutsche marks. The German procurement costs are estimated at 6.52 billion deutsche marks (the German share as of December 1989). Full-rate production is not scheduled to begin until October 1997.

The four nations that participate in the program are the United States, the United Kingdom, France, and the Federal Republic of Germany. Total development costs are estimated at 2.2 billion deutsche marks. The United States pays 40 percent of these costs, and each of the European partners pay 20 percent. In December 1986, the German share of the development costs had a cost cap of 368 million deutsche marks. The December 1989 projected development cost of 513 million deutsche marks represents a 39.4 percent increase over the 1986 cost cap. The Minister of Defense attributes the increase to inaccurate estimates, price negotiations, and economic conditions.

The estimates of the total unit price increased by 20.7 percent between 1983 and 1989. The German Ministry of Defense attributes this increase to economic conditions (exchange rates and inflation). The December 1990 cost structure sheet shows a total unit price for each rocket which is based on the originally planned procurement quantities.[1] The most recent plans call for a substantial reduction in the procurement quantities. As a result, the average unit cost for MLRS TGW rockets will increase due to the impact of the learning curve and nonrecurring costs. To reduce the anticipated production costs, the companies in the consortium MDTT, Inc., are currently considering technical design changes and simplifications. These changes will increase MLRS TGW development costs, however.

[1]Original and planned procurement quantities of MLRS TGW are classified.

The current development schedule is considered difficult to achieve but feasible. The development phase is divided into several substages.

Other Weapon Systems for Fighting the Second Echelon

Due to the lack of long-range weapon systems in the army, the air force has been principally responsible for fighting armored vehicles at medium range beyond the FLOT. The available carriers are the Tornado (in the interception role), the Phantom F-4F, and the Alpha-Jet. In the air force, the following weapon systems are available: (1) the conventional multipurpose system (MW 1) with bomblet ammunition (KB-44) and the MIFF mine (called MIX 1), and (2) the television and infrared, sensor-controlled MAVERICK missile (or its replacement). The air force is also developing the modular stand-off weapon (MSOW), version C, for fighting the second echelon.

In the meantime, the army is capable of reaching beyond medium range with the MLRS, using the M-77 bomblet rocket with 644 submunitions each and the AT 2 anti-tank rocket with 28 submunitions each.[2]

The MLRS TGW with three submunitions each, the SMART artillery round with two submunitions each, and the army's fighting drone, which is a large, self-seeking aerial vehicle, are still in development.

Table II.1 shows the types, ranges, and costs of the army and air force weapon systems to demonstrate that the fighting of the second echelon has a high priority. It also demonstrates that the army is assuming more of the responsibility for this task and is therefore increasing the range of its weapon systems.

[2]AT 2, however, will be used only in an improved version against the second echelon.

Table II.1: Available and Planned German Army and Air Force Systems for Fighting the Second Echelon

Deutsche marks in millions

System	Range	Cost	
		Development	Procurement
Army			
MLRS AT 2	Long	284	563
MLRS TGW	Long	513 (German) 2,200 (Total)	6,552
SMART	Medium	264.2	2,389
Fighting drone	Very long	470	1,155
Air Force			
MAVERICK B	Very long		158
MW-1	Very long	533	2,210
MSOW, C version	Very long	221	1,600

The variety of technologies applied to the sensors and warheads is considerable. MAVERICK is controlled by television and infrared sensors, the MLRS TGW system uses millimeter wave radar, and the SMART ammunition uses a three-channel seeker based on infrared, millimeter wave radar, and radiometer technologies. The various warheads use shaped charges, tandem shaped charges against reactive armor, and projectiles with high kinetic energy.

Impact of the Treaty on Conventional Armed Forces in Europe

The Treaty on Conventional Armed Forces in Europe limits battle tanks, armored vehicles, and artillery with large calibers to 70,000 each, per alliance. Because of the elimination of the Warsaw Pact, it is more useful to refer to the ceiling per signatory nation mentioned in article VI of the treaty. This article states that "40 months after the ratification of the treaty and beyond, the total number for each signatory nation within the treaty area shall not be greater than

- 13,300 battle tanks,
- 20,000 armored vehicles, and
- 13,700 artillery guns."

This represents a total armored force of 47,000. Because of the sharing agreement, Germany will have a maximum force of

- 4,166 battle tanks,
- 3,446 armored vehicles, and
- 2,705 artillery guns with large calibers.

The implementation of the treaty will result in a major reduction in the size of the second echelon armored threat. The anticipated reduction in the armored threat has already been reflected in the Federal Armed Forces' planning, as follows:

- The originally requested procurement quantities of anti-tank mine rockets (AT 2) were reduced by 50 percent.
- The requested quantity of MLRS TGW rockets will possibly be reduced substantially.
- The requested procurement quantity of SMART self-seeking ammunition will be reduced by about 38 percent.

Despite the substantial reductions in planned and actual procurement quantities for these systems, the various development programs continue.

Comparison of MLRS TGW and SMART

The development of the self-seeking ammunition SMART (155-millimeter round designed for hardened targets) began in 1983, initially with a caliber of 203 millimeters. The concept originated from the U.S. ammunition concept for Search and Destroy Armor. Joint German-American development failed because of technology transfer issues, and as a result, a national development program began in Germany in 1984. Since then, SMART's performance has been improved. In addition, its range will increase with the use of the armored howitzer 2000. Finally, a target reconnaissance system under development—the KZO—will further enhance its performance. As a result, the operational areas of SMART and MLRS TGW will increasingly overlap. The cost-efficiency of SMART has also been increased substantially, depending on the range. Because of these factors, the Minister of Defense sees a certain comparability between SMART and MLRS TGW.

To demonstrate this point, table II.2 compares the essential features of both weapon systems as documented in their milestone decisions. This table shows the commonality of the operational concepts, the performance criteria, and the target groups. Because the unit price of a SMART

round, however, is only 5.5 percent of that of a TGW rocket, the calculated cost-efficiency of SMART per target is five times higher than that of MLRS TGW in a specified range.

Table II.2: Comparison of MLRS TGW and SMART Features

Feature	MLRS TGW	SMART
Operational concept	Fighting moving armored vehicles in the second echelon at medium to long range beyond the FLOT Scattering of moving and stationary battle tanks, armored fighting vehicles, and armored artillery Fighting artillery in firing position	Efficient scattering of targets like tanks, anti-air missile batteries, and armored artillery in firing position (stationary and quasi-stationary targets) at medium range and at medium to long distance after the range is increased by howitzer 2000
Performance characteristics	High probability of destroying or disabling less than one-half of the target elements of a battle tank company, motorized infantry company, or armored artillery battery Lethality in a top attack mode sufficient to defeat characteristics of a future Soviet tank Three submunitions per rocket warhead	High probability of destroying or disabling less than one-half of the target elements of a reinforced tank company Lethality in top attack mode sufficient to defeat characteristics of up to future Soviet tank 3 Two submunitions per round
Seeker technology	Millimeter wave radar with doppler beam sharpening	Infrared Millimeter wave radar Radiometer
Warhead technology	Tandem shaped charge	High kinetic energy projectile-forming charge
Required efficiency	Classified quantity of submunitions against a company target	Classified quantity (twice as many as MLRS TGW) of submunitions against a reinforced battle tank company
Unit price	About 18 times the cost of SMART	1/18 the cost of MLRS TGW
Costs per kill per company target	About 5 times the cost of SMART	1/5 the cost of MLRS TGW
Technical risk	Medium/low	Low
Initial production schedule date	October 1997	January 1996
Development phase costs	343.8 million deutsche marks (German share)	166 million deutsche marks
Total development costs	513 million deutsche marks (12/89 estimate)	264.2 million deutsche marks (6/89 estimate)
Total procurement cost estimate	6,552 million deutsche marks (12/90 estimate)	2,389 million deutsche marks (12/90 estimate)

This comparison alone, however, is not sufficient because it does not take into account the differences in range, the costs of the carrier vehicles, the probability of detection, or the reduction of the effectiveness of

each system in a combat situation. Therefore, the Undersecretary of Defense imposed a condition on the acceptance of the army's June 2, 1989, SMART request. He required that a cost-effectiveness analysis be done comparing SMART with MLRS TGW and other ammunition types prior to SMART's introduction into the army. For the same reasons, the Generalinspekteur (equivalent of the U.S. Chairman, Joint Chiefs of Staff) ordered a reassessment of the future concept of the armed forces, raising the following question: "What is the optimum combination of weapon systems to fight the second echelon in the various ranges after the reduction of the threat due to armament agreements?"

Preliminary answers to this question are provided in the following section.

Evaluation

Cost-Efficiency Comparison by BWB

In 1988, the experts of the BWB (Bundesamt fuer Wehrtechnik und Beschaffung, or Federal Office for Defense Technology and Procurement), Ministry of Defense, were tasked by the Minister to do a simulation calculation of the cost-efficiency of MLRS TGW, the Autonomous Precision Guided Munition, and the SMART self-seeking ammunition, using various targets and ranges. Most of the results of this study should be used only as a tendency prognosis because MLRS TGW and SMART were simulated against different target types. In one case, however, there was sufficient comparability: for TGW, a battle tank company was assumed to be a linear road target (route column) at a close to medium range beyond the FLOT, and for SMART, a battle tank company reinforced by three armored vehicles was assumed to be spread out at roughly the same distance from the FLOT. The cost-efficiency comparison in combination with the performance criteria shows that the MLRS TGW cost per kill is up to 17 times higher than the SMART. In the case of the MLRS TGW, the costs per rocket were assumed to be more than 20 times higher than SMART.

Results of the Study by Industrieanlagen-Betriebsgesellschaft

After the BWB study was completed, the Minister of Defense requested another, more complex study. Therefore, in 1989, the army contracted with the company Industrieanlagen-Betriebsgesellschaft to calculate the efficiencies of various self-seeking ammunitions. The study, completed in December 1990, contains a comparative analysis of the same three

systems analyzed by the BWB. The numbers of required rounds for a specified target configuration and the costs per kill were calculated, the operational impact of the range of targets was simulated, and the degradation of performance caused by various combat conditions was considered. The results show a direct comparison of the efficiency of the three systems at various ranges beyond the FLOT, used in combination and separately. The unit cost estimate used for the simulation, however, was only 60 percent of the actual unit cost estimate for the MLRS TGW rocket (low by a factor of 1.67) but was nearly 100 percent of the actual cost estimate for a SMART round. Furthermore, the study assumed that all MLRS launchers were loaded only with TGW rockets (bomblet and mine rockets were not considered). In addition, the calculations did not account for the greater availability of target-seeking ammunition in the armored howitzer compared with the 12 TGW rockets per launcher. Also, the study recognized the greater availability of artillery guns (2,700 according to the treaty) as compared to the relatively small numbers of available German MLRS launchers (150).

Because this study has been classified, detailed results cannot be discussed in this report. In general terms, however, the study confirms the distinct cost-efficiency of SMART compared to MLRS TGW at close and medium ranges. This cost-efficiency advantage would increase after correcting the cost estimates used for MLRS TGW by a factor of 1.67.

Evaluation by the Staff of the Armed Forces

The German Armed Forces Staff replied to the order of the Generalinspekteur by analyzing the planned requirements for ammunition for the weapon systems dedicated to fighting the second echelon. This study also compared MLRS TGW with SMART and concluded that the residual range increase of MLRS TGW over SMART is not substantial.[3] The author doubted that the limited increase in range justified the considerable procurement expenses expected for MLRS TGW. The study recommended terminating the MLRS TGW program in favor of a combination of SMART ammunition, the army's fighting drone, and the MSOW, version C. The limited advantage of MLRS TGW operational capabilities would not justify the expenses.

Recommendations

In view of the evidence presented above and the evaluations done within and for the Ministry of Defense, we believe that a new decision

[3]The ranges of both weapons are classified.

on MLRS TGW development is necessary. This would require a reassessment of the MLRS TGW, considering all other available or planned army and air force weapon systems for fighting the second echelon. The impact of expected conventional armed forces reductions in accordance with the November 1990 treaty should also be taken into account.

We believe, however, that a mere reduction of the procurement quantities for each weapon system would not be sufficient. With a substantial reduction in procurement quantities, the ratio of development costs to procurement costs increases, with the risk that a reasonable cost ratio is no longer feasible.

Our evaluation of Ministry of Defense analyses shows that more cost-efficient alternatives to MLRS TGW, such as SMART, will be available to fulfill overlapping operational requirements and missions.

In addition to these matters, the risk that the United States may not participate in the maturation/full-scale development phase of the program must also be considered. Entering into maturation/full-scale development without U.S. participation would result in (1) an increase in the German share of the remaining development costs, (2) a reduction in the total procurement quantities, and (3) the risk that other nations may terminate their participation in the program.

For these reasons, we recommend that the Minister of Defense develop an alternative concept to MLRS TGW to save substantial development and procurement funds without compromising the necessary defense capability. The Minister should consider an alternative concept that would increase the procurement quantities for more cost-efficient systems such as SMART, if MLRS TGW is cancelled.

Comments From the German Ministry of Defense

I. Details of the Ministry of Defense Comments

(1) The German army and air force are currently undertaking four procurement/development projects for fighting armored targets in the second echelon (SMART, MLRS TGW, KDH fighting drone, and MSOW-C).

(2) SMART is designed to cover target areas up to company size, while TGW is designed to cover target areas the size of a battalion (route column).

(3) TGW, therefore, has a larger footprint and a more sophisticated seeker with a technical risk that is considered to be low.

(4) SMART has a shorter range than TGW.

(5) Logistic support requirements, for example, transportation, are higher for SMART than for TGW.

(6) The BWB cost-efficiency comparison was not officially authorized by BWB, and the study by Industrieanlagen-Betriebsgesellschaft comes to a different conclusion.

(7) To ensure operational availability of artillery within the zone of operation of a division, more artillery guns than MLRS launchers would be required. TGW covers three times the operational area of SMART.

II. Summary

According to the Ministry of Defense, the operational concepts of SMART and MLRS TGW are not identical. SMART does not efficiently fight moving targets at a long range beyond the FLOT. This is confirmed in the study by Industrieanlagen-Betriebsgesellschaft. An increase in the procurement quantities of SMART cannot adequately replace TGW. However, examinations of alternatives are underway. The results of these examinations will enable the Ministry of Defense to reevaluate and decide on the optimum weapons mix by the end of 1992.

III. Further Action

(1) According to the Ministry of Defense, there is no urgent need to make a decision on the program. If the United States terminates its participation in the program, the German position would have to be reconsidered.

(2) The studies currently underway in the Ministry of Defense will provide the necessary data for timely decisionmaking.

(3) Termination of German participation in MLRS TGW at the present stage appears to be unacceptable for economic reasons.

Federal Court of Audit Comments

I. Details of the Federal Court of Audit Comments

(1) In its comments, the Ministry of Defense does not mention the MIX 1 submunition for MW 1, the improved AT-2 antitank rocket, and the replacement for the MAVERICK missile, all of which can be used against armored targets at a long range beyond the FLOT.

(2) According to the phase documents, both SMART and TGW are defined to fight armored vehicle companies.

(3) The larger footprint of TGW is not so much a performance feature but a necessity to use the costly submunition successfully at a long range. In addition, the U.S. General Accounting Office points out in appendix I that the United States considers the MLRS TGW of medium technical risk.

(4) The armored howitzer 2000 is being developed partly to increase the range of artillery ammunition to 40 kilometers. The howitzer will also be used to launch SMART.

(5) According to phase document data, to achieve identical performance, logistical support has to transport 1.44 times the weight for TGW as for SMART.

(6) The BWB cost-efficiency study, of which the Ministry of Defense disapproves, was carried out by the competent experts using correct cost estimates and generally accepted calculation procedures. We have clarified our discussion of the Industrieanlagen-Betriebsgesellschaft study to recognize the cost-efficiency advantage of SMART at close and medium ranges. We also agree that this study shows that the cost-efficiency of SMART decreases at longer ranges (discussed further below). However, as noted previously, the study used an estimated cost for the TGW that was low by a factor of 1.67.

(7) The procurement quantity of MLRS launchers has been reduced from 200 to 150, compared to the 2,705 large caliber artillery guns authorized for the Federal Republic of Germany under the Treaty on Conventional Armed Forces in Europe.

II. Summary

The facts presented in the audit report were taken from Ministry of Defense documents. These documents show that the operational concepts of MLRS and SMART, although not identical, overlap to a great

extent. When using correct cost estimates for MLRS TGW, the study by Industrieanlagen-Betriebsgesellschaft confirms this similarity for targets at medium ranges. In a combat situation, the remaining difference between quasi-stationary and moving targets might be so marginal as to become irrelevant. In addition, the Ministry of Defense should examine whether the gap in defense capability against moving targets at longer range beyond the FLOT might be closed more efficiently by other weapon systems, such as air force systems.

III. Recommendations for Further Action

We have not recommended withdrawing from the MLRS TGW program at this stage. However, because of the significant funds involved, the provisions of the Treaty on Conventional Armed Forces in Europe, the availability of more cost-efficient alternatives, and the U.S. Army's decision to select another system for further development, we believe that the Ministry of Defense should make a decision on the program during 1991. A decision during 1991 would enable the Government to more reliably budget for the next five-year plan.

Objectives, Scope, and Methodology

We examined the requirements, schedule, performance, and costs of the MLRS TGW program. In addition, we compared the MLRS TGW to other army and air force weapon systems—both fielded and in development—intended to fight the second echelon ground forces. We reviewed relevant program documents, such as milestone documents, cost estimates, cost-effectiveness analyses, and Ministry of Defense requirements documentation.

We did our work at the Ministry of Defense (system manager and armaments division) in Bonn, the BWB (MLRS and SMART project offices and technical experts) in Koblenz, the German contractors Diehl (MLRS TGW) and GIWS (SMART) in Nurnberg, and the German commercial organization Industrieanlagen-Betriebsgesellschaft in Munich. We coordinated our work and shared information with the U.S. General Accounting Office. We obtained comments from the Ministry of Defense on a draft of our audit report in June 1991 and have incorporated their comments where appropriate. Our work was performed from November 1990 through February 1991.

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