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GAO

Report to the Secretary of Defense

June 1993

ICBM MODERNIZATION

Minuteman III Guidance Replacement Program Has Not Been Adequately Justified

GAO/NSIAD-93-181

GAO

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

National Security and
International Affairs Division

B-241923

June 25, 1993

The Honorable Les Aspin
The Secretary of Defense

Dear Mr. Secretary:

This report examines the adequacy of the Air Force's plans and justification to proceed with the Minuteman III guidance replacement program. It contains a recommendation to the Secretary of the Air Force.

We are sending copies of this report to the Chairmen and Ranking Minority Members of the House and Senate Committees on Armed Services; the Secretary of the Air Force; 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) 512-4199 if you or your staff have any questions concerning this report. Other major contributors to this report are listed in appendix III.

Sincerely yours,

Louis J. Rodrigues
Director, Systems Development
and Production Issues

Executive Summary

Purpose

The Minuteman III weapon system is expected to be the United States' only fielded land-based intercontinental ballistic missile (ICBM) system after 2003. Under current Department of Defense (DOD) and Air Force plans, the Minuteman III will be modified to continue operations through 2020—at which time the weapon system will be 50 years old, far exceeding its 10-year design life goal. From a cost perspective, the most significant program to extend the life of the system is a $4.6 billion (then-year dollars) missile guidance set modification.[1]

Considering the increased reliance on the Minuteman III weapon system, GAO reviewed the adequacy of the Air Force's plans to proceed with that Minuteman III modification.

Background

Air Force Headquarters has directed that the Minuteman III weapon system be maintained through 2020. In response, the organizations responsible for operating and supporting the ICBM force have developed plans, including a guidance replacement program, to sustain an operationally effective Minuteman III force through 2020.

The Air Force's proposed guidance replacement program is a two-phase effort. The first phase consists of a proposal to replace the computer and other electronic components of the missile guidance set at an estimated cost of $1.8 billion in then-year dollars. The second phase is a proposal to replace the guidance set's inertial measurement unit with an advanced inertial measurement system at an estimated cost of $2.8 billion in then-year dollars.

Results in Brief

GAO's review indicates that it would be premature to begin engineering and manufacturing development of the first phase of the guidance replacement program in August 1993, as currently planned. GAO believes that engineering and manufacturing development should be delayed until the Air Force has conducted the necessary studies and analyses to justify proceeding with this proposed program.

The need for the second phase of the guidance replacement program is uncertain at this time, pending a better definition of the post-Strategic Arms Reduction Treaty (START) mix of U.S. and Russian strategic nuclear

[1]In its Minuteman III Life Extension Report, which was submitted to the Congress in July 1992, DOD reported that the electronics replacement program costs were $1.4 billion in 1992 dollars and the inertial measurement unit replacement costs were $1.9 billion in 1992 dollars. Adjusted for inflation, these costs are essentially the same as the program costs that GAO is reporting in then-year dollars.

forces and capabilities. If it is ultimately decided that enhanced operational capabilities are required, and that the Minuteman III guidance set needs to be upgraded to provide those capabilities, it remains to be determined whether the planned advanced inertial measurement system is the most appropriate means of providing those capabilities.

Principal Findings

Guidance Electronics Replacement Program Is Not Adequately Justified

Concerning the $1.8 billion first phase of the guidance replacement program, the available evidence does not support the Air Force's plans to begin engineering and manufacturing development of the guidance electronics replacement effort in August 1993 in order to start fielding modified missile guidance sets in September 1997. The program office's assessment activities, the purpose of which is to evaluate current weapon system and component performance and to detect future problems, are not identifying any Minuteman III missile guidance set system-level performance concerns. To the contrary, for the last several years the Minuteman III missile guidance set flight reliability has improved. Further, missile guidance set failure rates have remained at an acceptable level, with no adverse failure rate trends. In addition, past reliability studies conducted under the auspices of the program office did not identify any missile guidance set problems that could not be corrected on a case-by-case basis.

The results of the assessment program and related studies notwithstanding, the program office, based on engineering judgment and Minuteman II experience, has identified electronic circuitry deterioration within the computer and other electronic components that it believes will become of such magnitude as to cause unacceptable weapon system performance as early as 1997. However, program office documentation does not support that projection. GAO's review showed that the most troublesome concerns identified by the program office are being corrected and the seriousness of the remaining concerns is not apparent. Furthermore, program office documentation did not adequately support the contention that Minuteman II experience is relevant in projecting future Minuteman III performance. For example, program office documentation indicated that the Minuteman III guidance set is more reliable than the Minuteman II missile guidance set. The Minuteman III missile was built on the experience of its predecessor system and

incorporated improved technology. Also, the Minuteman III guidance set has been upgraded to correct some of the problems experienced with Minuteman II electronic circuitry. Further, in GAO's view, the limited number of Minuteman II flight tests during the 1980s provides insufficient information to support a projection of Minuteman III flight reliability.

While engineering judgment and Minuteman II experience may be an acceptable basis for projecting life extension program needs to support long-range planning, GAO believes that the implementation of those plans should be dependent upon sound analytical evidence, which has yet to be developed.

Need for Improved Inertial Measurement Unit Is Unclear

Concerning the $2.8 billion second phase of the guidance replacement program, the Air Force's proposal to replace the existing inertial measurement unit with an advanced inertial measurement system is based on the anticipated need to (1) improve accuracy and thereby increase hard-target damage capability to the level currently being demonstrated by the Peacekeeper missiles, (2) maintain reliability while reducing operations and support costs, (3) enhance nuclear safety, and (4) provide a capability for dormant or semi-dormant operations (not on continuous alert). The Air Force's proposal assumed that engineering and manufacturing development would start in 1997.

However, DOD has decided to examine whether replacement of the inertial instruments with an advanced system is the most appropriate means of attaining the operational needs set forth in the mission need statement. DOD has scheduled a review for the fall of 1993 to determine whether an upgrade of the existing guidance set to provide enhanced capabilities is warranted, and if so, to authorize studies of alternative concepts for enhancing capability. This is Milestone 0 in DOD's acquisition process. The scope and cost of any program to enhance the capability of the current missile guidance set are uncertain, pending the decisions to be made at Milestone 0 and at subsequent DOD acquisition milestones.

Proceeding through the acquisition cycle is predicated on the definition and establishment of firm operational performance requirements. According to DOD and Air Force officials, a mission need statement for a future guidance system for ICBMs was validated by the Joint Requirements Oversight Council in November 1992 identifies, in part, a firm need to preserve ICBM warfighting capability when the Peacekeeper system is deactivated and for ICBMs to have a capability to operate in a dormant or

semi-dormant mode (not on continuous alert). However, these officials stated that specific operational requirements associated with those needs remain to be determined. For example, the validated mission need statement for the guidance replacement program states that there is only a potential requirement for dormant or semi-dormant ICBM operations, depending upon future threat conditions. U.S. Strategic Command personnel advised GAO that dormant or semi-dormant Minuteman III operations would represent a fundamental change in national nuclear weapon systems employment policy that would likely require approval by the President.

In addition, before a final decision can be made on whether improved accuracy for Minuteman III is required, the following questions need to be answered: Is there a need for U.S. nuclear weapons to have a hard-target kill capability and, if so, how many weapons must have that capability? Do both the Trident II submarine-launched ballistic missiles and the land-based ICBMs have to have a hard-target kill capability or does only one of those weapon systems require that capability? If there is a need for U.S. weapons to have a hard-target kill capability, are current demonstrated Peacekeeper and Trident II performance levels sufficient or would improved performance be required?

Recommendations

GAO recommends that the Secretary of the Air Force delay a decision to begin engineering and manufacturing development of the Minuteman III guidance electronics replacement modification until sufficient analytical evidence has been developed to clearly demonstrate that the start of that effort is justified.

Matters for Congressional Consideration

The Congress may wish to consider either not appropriating fiscal year 1994 funds for engineering and manufacturing development of the guidance electronics replacement program or limiting the Air Force's authority to obligate appropriations for the program until studies and analyses have been completed that support the need to proceed with that effort.

Agency Comments and GAO Evaluation

DOD and the Air Force provided oral comments on a draft of this report and disagreed with GAO's conclusions and recommendation. They believe that the mission need statement clearly supports the need for the program. They also believe that collective evidence, engineering judgment, and

Minuteman II experience show that the potential degradation of the Minuteman III guidance set make it inappropriate to wait for a system-level failure to justify going forward with the planned program.

GAO does not question the basic requirement to maintain Minuteman III reliability and supportability. However, DOD's position that there is adequate evidence supporting the projection of reliability degradation runs counter to the results of its assessment program and other special studies. Although requested by GAO, DOD could provide no additional information to support its position.

Additional reasons presented by DOD for not wanting to delay the start of the electronics replacement program, along with GAO'S rebuttal, are as follows. According to DOD, inventories of certain electronic parts are expected to be depleted as early as 1998 at current usage rates. GAO notes, however, that the program office is taking actions that should negate this problem. DOD officials stated that the guidance electronics replacement program is necessary to protect the option to replace the Minuteman III MK 12 reentry vehicle with the Peacekeeper MK 21 reentry vehicle. GAO notes that a final determination to use the MK 21 has not been made and, therefore, does not believe that delaying the start of the electronics replacement program would preclude the future use of that reentry vehicle. DOD officials also stated that currently available ballistic missile industrial base suppliers may not be available if the program is delayed. This has not previously been a justification for the program and, in raising this issue, DOD and Air Force officials did not provide any new documentation supporting their concern. The final area of disagreement is the requirement for dormant or semi-dormant operations. According to DOD officials, the electronics replacement program is required to provide the option to integrate an advanced inertial measurement unit with the Minuteman III missile to provide the capability for dormant or semi-dormant operations. GAO notes, however, that it is not certain when or if this capability will be required. Therefore, GAO believes that it is not necessary to begin the electronics replacement program at this time to protect that option.

Contents

Abbreviations

DOD	Department of Defense
GAO	General Accounting Office
ICBM	Intercontinental Ballistic Missile
START	Strategic Arms Reduction Treaty

Introduction

The Minuteman III weapon system is expected to be the United States' only fielded land-based intercontinental ballistic missile (ICBM) system after 2003. The current land-based ICBM force consists of Minuteman II, Minuteman III, and Peacekeeper missiles. Under current Department of Defense (DOD) and Air Force plans, the Minuteman II and Peacekeeper missiles will be retired and Minuteman III will be modified to sustain operations through 2020. From a cost perspective, the most significant modification program is a $4.6 billion (then-year dollars) missile guidance set modification. This report discusses the adequacy of the Air Force's plans to proceed with that modification.

ICBM Force Restructuring Results in Increased Reliance on Minuteman III

At the beginning of the 1990s, the U.S. land-based ICBM force consisted of 50 ten-warhead Peacekeeper missiles (initially fielded in 1986), 450 one-warhead Minuteman II missiles (initially fielded in 1965), and 500 three-warhead Minuteman III missiles (initially fielded in 1970). The Air Force had planned to modernize the ICBM force by developing and fielding the one-warhead Small ICBM weapon system, with improved target damage capability and survivability, to augment the existing ICBM force. In addition, the Air Force had planned to develop the Rail Garrison weapon system, which was intended to improve survivability of the 50 Peacekeeper missiles by taking them out of their silos and putting them on train cars.

However, the President terminated both the Small ICBM and Rail Garrison programs. In addition, to comply with Strategic Arms Reduction Treaty (START) I and II agreements, DOD now plans to change the U.S. ICBM force structure. The Minuteman II and Peacekeeper missiles will be retired by 1997 and 2003, respectively, and the number of reentry vehicles/warheads on each Minuteman III missile will be reduced from three to one by 2003. Accordingly, as currently planned, the U.S land-based ICBM force will consist of 500 one-warhead Minuteman IIIs after 2003.

As a planning baseline, Air Force Headquarters has directed its subordinate commands to assume that the Minuteman III system will remain operational through 2020. Responding to that direction, the Air Force organizations responsible for operating and supporting the Minuteman III weapon system have developed plans and programs within the context of an established long-range planning process that they believe will keep the Minuteman III force in operation, with no degradation in current operational effectiveness, until 2020. By then, the Minuteman III system will have been in operation for 50 years—far exceeding its 10-year design life goal.

Minuteman III Description

The Minuteman III weapon system is comprised of missiles deployed in underground silos and controlled by underground launch control centers located at remote sites away from the silos. The missile consists of a three-stage propulsion system and a post-boost vehicle with its own propulsion system rocket engine, a missile guidance set, and a reentry system that can carry up to three warheads.

The missile guidance set is the focus of this report. This set is programmed to direct the flight of the missile to its target. It contains (1) inertial instruments that measure missile acceleration and attitude, (2) an electronic computer to process data provided by the instruments and to provide signals to control missile flight, and (3) other electronic components to provide power for the inertial instruments and computer and to provide an interface to other missile flight control devices. When the missile is on-alert, the guidance set operates continuously. This enables the missile to be launched in less than 1 minute. Appendix I contains a more detailed description of the Minuteman III missile guidance set.

Minuteman III Life Extension Programs

The Silo-Based ICBM System Program Office at the Ogden Air Logistics Center, Hill Air Force Base, Utah, has prepared a Logistics Program Management Plan, dated April 1992, that identifies the programs and related costs associated with extending Minuteman III operations through 2020. The proposed life extension programs include those modifications necessary to extend the operational life of the Minuteman III missile at its current capability levels, such as:

- A program to replace the electronic components in the missile guidance set—the first phase of a guidance replacement program—to correct projected unacceptable degradation in flight reliability and operational readiness as early as 1997. Appendix II contains a more detailed description of this program.
- A program to remanufacture the solid rocket propulsion motors. Both Stage II and Stage III motors must be remanufactured every 17 years because of age-related deterioration of motor materials. The first remanufacturing cycle is almost completed, and another cycle will be necessary by about 2000.

The proposed missile life extension programs also include those that change the capability of the missile such as:

- A program to replace the missile guidance set's inertial measurement unit—the second phase of a guidance replacement program—to improve accuracy and thereby preserve ICBM warfighting when the Peacekeeper system is deactivated, provide a capability for dormant or semi-dormant (not on continuous alert) operations, maintain reliability and sustainability while reducing operations and support costs, and enhance nuclear safety. Appendix II also contains a more detailed description of this program.
- A program to reduce the number of MK 12 or MK 12A reentry vehicles that each missile carries from three to one. This modification is planned to comply with terms of the START I and II accords.
- A program to replace the MK 12 reentry vehicles with either the MK 12A reentry vehicle or the Peacekeeper's MK 21 reentry vehicle to provide enhanced performance and improved nuclear safety.

Minuteman III Life-Cycle Costs

The most recent long-range planning estimate (June 1992) shows that the life-cycle costs of sustaining a force of Minuteman III missiles on continuous alert from 1992-2020 is $36 billion in then-year dollars. Operations and support costs for day-to-day operations activities account for $24.9 billion and are funded with operations and maintenance appropriations ($13.3 billion), military personnel appropriations ($10.6 billion), and missile procurement appropriations ($1 billion). Acquisition costs for life extension programs account for $11.1 billion—$7.5 billion for sustaining current capability and $3.6 billion for enhancing capability—and are funded with missile procurement appropriations ($8.3 billion), research and development appropriations ($1.6 billion), and operations and maintenance appropriations ($1.2 billion).

At an estimated cost of $4.6 billion in then-year dollars ($1.8 billion for electronics replacement and $2.8 billion for inertial measurement unit replacement)[1] the proposed guidance replacement program is the most costly life extension program. The $4.6 billion estimate is comprised of $3.3 billion for procurement and $1.3 billion for research and development. To begin the electronics replacement program in fiscal year 1993, the Air Force approved $49.7 million for research and development. The Air Force has requested $87.4 million for research and development in fiscal year 1994 to continue the electronics replacement program.

[1]In its Minuteman III Life Extension Report, which was submitted to the Congress in July 1992, DOD reported that the electronics replacement program costs were $1.4 billion in 1992 dollars and that the inertial measurement unit replacement costs were $1.9 billion in 1992 dollars. Adjusted for inflation, these costs are essentially the same as the program costs that we are reporting in then-year dollars.

These costs represent individual estimates prepared by several organizations involved in operating and supporting the Minuteman III force. The individual estimates were prepared to support the Minuteman long-range planning process and not necessarily to support annual budget requests. Accordingly, these life-cycle cost estimates are subject to change as operational requirements and life extension costs become more definite. The estimates are integrated into a single data base by the Silo-Based ICBM System Program Office and reported by the program office in a cost annex to its Logistics Programs Management Plan.

Objective, Scope, and Methodology

Our objective was to assess the adequacy of the Air Force's plans and programs for sustaining an operationally effective Minuteman III weapon system through 2020, with specific emphasis on the status and issues related to the guidance replacement program.[2]

We interviewed appropriate officials and examined pertinent documents at the Silo-Based ICBM System Program Office, Ogden Air Logistics Center, Hill Air Force Base, Utah; the Ballistic Missile Organization, Norton Air Force Base, California; the Air Combat Command Headquarters, Langley Air Force Base, Virginia; the U.S. Strategic Command Headquarters, Offutt Air Force Base, Nebraska; and the Office of the Secretary of Defense and Air Force Headquarters, Washington, D.C.

We performed our work from June 1992 to May 1993 in accordance with generally accepted government auditing standards. DOD and the Air Force provided oral comments on a draft of this report. The comments are presented and evaluated in chapters 2 and 3.

[2]GAO testimony entitled The U.S. Nuclear Triad: GAO's Evaluation of the Strategic Modernization Program (GAO/T-PEMD-93-5, June 1993) discusses Minuteman III's operational performance.

Beginning Engineering and Manufacturing Development of an Electronics Replacement Program Is Not Justified

As part of its plans to extend the effective service life of the Minuteman III through 2020, the Silo-Based ICBM System Program Office is proposing a two-phase guidance replacement program. The first phase involves replacing the computer and other electronic components of the missile guidance set and rewriting operational software at a cost of $1.8 billion in then-year dollars. Current Air Force plans are to begin engineering and manufacturing development of a guidance electronics replacement program in August 1993 in order to begin initial fielding of modified missile guidance sets in September 1997.

The plan to replace electronic components is based on the program office's projection that current reliability and supportability concerns with electronic circuitry anomalies within those components will continue to evolve and become of such magnitude as to cause an unacceptable degradation in weapon system flight reliability and operational readiness as early as 1997. The program office developed this projection based upon engineering judgment and experience with the Minuteman II weapon system.

We question the program office's projection. At the present time, assessments of the missile guidance set show that it is demonstrating acceptable flight and ground reliability with no adverse trends. Also, program office documents show that the most troublesome electronic circuitry concerns identified by the program office are being corrected and the seriousness of the remaining concerns is not apparent. In addition, program office documentation did not support the contention that Minuteman II experience is relevant to projected Minuteman III performance. Further, while engineering judgment and Minuteman II experience may be an acceptable basis for projecting life extension program needs to support long-range planning, we believe that implementation of those plans should be dependent upon sound analytical evidence, which has yet to be developed.

Assessments Do Not Indicate Degradation in Missile Guidance Set Performance

Assessment program results are not indicating a current or future degradation of missile guidance set system-level performance. Furthermore, special studies are not indicating a degradation of the missile guidance set components of sufficient magnitude to warrant a complete replacement of electronic components.

Assessment Testing

The Silo-Based ICBM System Program Office is responsible for managing an assessment program to test, monitor, analyze, evaluate, and report the operational effectiveness of ICBM weapon systems. Assessment results are presented in annual Weapon System Effectiveness Reports. The indicators used by the program office in monitoring and reporting weapon system effectiveness are (1) operational readiness rate—the percent of deployed missiles that are available for launch, (2) countdown and flight reliability—the likelihood that a missile will be successfully launched and will deliver its warheads to the intended target area, and (3) accuracy—how close a missile can get its warheads to the intended target or targets.

As reported in the Silo-Based ICBM Weapon System Effectiveness Annual Report, dated November 1992, assessment program results show that weapon system reliability and operational readiness is acceptable in terms of specification. Further, the results of assessment testing show no adverse trends in system-level missile guidance set performance that would impact future weapon system reliability or operational effectiveness—the assessment program has been designed to detect changes in the performance of missile systems 6 years in advance to allow corrective actions to be taken before unacceptable degradation occurs. Examples demonstrating the results of assessment testing follow.

- Flight tests are primary data sources for assessing launch and flight reliability. Since mid-1987, the missile guidance set has performed successfully in 24 consecutive flight tests. The successful results of these tests have resulted in an upward trend in weapon system and missile guidance set flight reliability since mid-1987.
- Shock and vibration tests of missile guidance sets were developed as a means to detect degradation of flight reliability. Shock and vibration are the components of the flight environment that are expected to induce most flight failures; therefore, this test provides a means to detect degradation that might permit missile guidance sets to operate in an on-alert environment, but which would otherwise cause failure during flight. The missile guidance set has successfully performed in all shock and vibration tests conducted since 1989.
- Missile guidance set failure rate is one factor used in assessing weapon system operational readiness rates. Failure rate analyses show that the missile guidance set is not experiencing any adverse failure rate trends at the overall system-level or at the individual component-level. Since 1980, the guidance set's semi-annual mean-time-between-failure rate has averaged 11,800 hours, ranging from 11,200 hours to 12,490 hours. While

the mean-time-between-failure rate requirement is classified, according to the program office, the 11,800 hours is within acceptable limits. In addition, the guidance set's major components, such as the guidance computer and the gyro-stabilized platform, have maintained similar mean-time-between-failure stability.

Special Studies

In addition to the assessment program, reliability studies conducted by the program office have not shown that electronic circuitry deterioration is of such magnitude as to warrant a complete replacement of electronic components. For example, the most recent study of Minuteman III reliability was conducted in 1987 under the auspices of the Silo-Based ICBM System Program Office. In reporting the results of its study in September 1987, the program office concluded that there had been a statistically significant decline in the reliability of the weapon system during the period 1982-87. No specific problems for the decline were identified, but the missile guidance system appeared to be the primary contributor. Since mid-1987, however, the results of Minuteman assessment testing have been positive and flight reliability has improved.

Another study, referred to as the "Ten-System Test Degradation Assessment," was conducted by a program office contractor in 1987 and 1988. That study was specifically intended to determine the existence and magnitude of missile guidance set degradation in order to define the scope of a Minuteman III guidance set upgrade. The study included assessments of the digital computer and inertial measurement unit electronics. The study did not identify any significant concerns relative to the computer. Regarding the inertial measurement unit electronics, the study indicated concerns about degraded wet slug tantalum capacitors, but no other serious potential near-term electronic problems were identified. While the degradation of some capacitors was so severe that replacement actions were being taken, the degradation of other capacitors did not warrant replacement. In this latter case, the study recommended periodic reviews and tests, similar to the Ten-System Assessment, be conducted to ensure that identified degradation does not worsen. Program officials stated that no further studies were conducted in anticipation of the current plan to replace all guidance set electronics.

After reviewing the results of the 1987 Minuteman III reliability study and the Ten-System Assessment, our conclusion is similar to a program office position stated in its August 1988 Minuteman Weapon System Integrated Program Management Plan. In that document, the program office stated

that "There is no conclusive evidence of degradation within the Minuteman III missile guidance set that cannot be corrected on a case-by-case basis, but the circumstantial evidence for potential force-wide degradation warrants advance planning and continuing study."

Projected Deterioration of Electronic Circuitry Is Not Supported

The program office believes that serious age-related deterioration of the circuitry within the guidance set electronic components is occurring. While the results of assessment testing do not show adverse trends in system-level missile guidance set performance, the program office is, nevertheless, projecting that circuitry deterioration will cause an unacceptable degradation in flight reliability and operational readiness as early as 1997, based on engineering judgment and Minuteman II experience.

As discussed below, the seriousness and impact of the electronic circuitry anomalies is not apparent and the relevance of Minuteman II experience is not clear. We asked the program office for any additional documentation supporting its projection. However, they were unable to provide any.

Seriousness of Electronic Circuitry Anomalies Is Not Apparent

The program office has identified eight electronic circuitry anomalies that it projects will collectively result in an unacceptable degradation in weapon system flight and/or ground reliability after 1997. However, our review indicates that the most troublesome electronic problems are in the process of being corrected as units are returned to the guidance repair facility for maintenance or other reasons, and the seriousness of the remaining anomalies is not apparent.

- Dry out of wet slug tantalum capacitors: A capacitor is a basic component of an electronic circuit that, similar to a battery, stores an electronic charge. It is used to pass signals from one electronic component to another. The liquid inside the capacitors has begun to dry out, causing a loss of capability to store an electrical charge. This age-related phenomena has been a concern for several years and has been observed frequently in both Minuteman II and III. The more troublesome capacitors in Minuteman III guidance sets are being replaced. The flight reliability impact of the dry out of wet slug tantalum capacitors is unknown.
- Formvar transformer shorts: The degradation of the insulation inside a transformer within the missile guidance set controller results in electrical shorts that destroy the transformers and interconnected circuitry. This condition has been a frequent and long-standing problem within both the

Minuteman II and Minuteman III guidance sets. The program office has already replaced some transformers and has implemented plans to replace others.

- Conductive particles in integrated circuits: This involves small, entrapped particles that were not thoroughly cleaned from the semiconductor surfaces of integrated circuits during the manufacturing process. There is a possibility that these particles could relocate and create an electrical short and, in turn, a part failure. This was a problem with Minuteman II. Concerning some Minuteman III missiles, this condition was corrected during the manufacturing process by placing a glass film over the semiconductor (referred to as glass passivation) to insulate the parts and hold the particles in place. About half of the Minuteman III missile guidance sets incorporate this improvement. Moreover, the decline in the reliability of the sets without the improvement is statistically insignificant, as reported in the 1987 Minuteman III Reliability Assessment Report.
- Kirkendahl voiding: This is an age-related phenomena that occurs when dissimilar surface metals are bonded together. In the case of Minuteman II, both transistor and integrated circuits had gold leads bonded to aluminum pads; but, in Minuteman III, only the transistors had gold leads bonded to an aluminum pad. While kirkendahl voiding was a pervasive problem with Minuteman II, it has only been observed once in the Minuteman III guidance set.
- Increased usage of spare integrated circuits: This concerns the accelerated depletion of the inventory of a particular integrated circuit in the computer caused by replacing the circuit during repair. The program office's 1991 Weapon System Effectiveness Report indicates that the increased usage of such integrated circuits was due, in part, to faulty test equipment that has now been repaired. As a result of the repair, the replacement of integrated circuits has declined. In addition, the program office's 1992 Weapon System Effectiveness Report stated that a faulty part on the integrated circuit had been identified. However, according to the report, actions are underway that should provide for long-term availability of this integrated circuit.
- Part and wiring vibration fatigue: This was identified as the possible cause of a 1991 failure of a missile guidance set controller that occurred during post-repair vibration testing. Further testing is underway to confirm that part and wiring vibration fatigue was the actual cause of the failure. This is the only occurrence of possible fatigue failure that has been identified.
- Heat sink shorts: This involves corrosion between leads and the metallic casing on integrated circuits within the guidance computer. The corrosion, which is created during repairs by handling and atmospheric exposure, causes electrical shorts and logic faults in the computer. This condition

was observed in Minuteman II often enough to cause concern about degrading flight reliability. This condition has been observed only once in an operational Minuteman III guidance set. This problem has been minimized in the Minuteman III guidance set design by changing 30 percent of the integrated circuit cases from metal to ceramic. In addition, according to the program office's 1992 Weapon System Effectiveness Report, the low incidence of Minuteman III guidance computer failures, along with modifications to guidance set repair procedures, will reduce the likelihood of corrosion.

- Delaminated circuit boards: Delamination caused by heat or soldering during repeated repairs was observed in Minuteman II but has not been observed in Minuteman III.

Relevance of Minuteman II Experience Is Not Clear

The documentation provided by the program office contained little analytical evidence to support its assertion that the Minuteman III missile is expected to demonstrate "similar" flight and ground reliability degradation as experienced with Minuteman II. For example:

- Program office documentation indicates that the ground reliability of the Minuteman III guidance set is better than the Minuteman II missile guidance set. The Minuteman III missile was built on the experience of its predecessor and incorporated the improved technology of its day. Also, as previously discussed, the Minuteman III guidance set was upgraded to correct some of the problems experienced with Minuteman II electronic circuitry. Considering the Minuteman III design improvements, Minuteman II experience may not be relevant as a basis for projecting that Minuteman III flight reliability will decline and become unacceptable as early as 1997. The program office had no analytical evidence to corroborate its assertion that Minuteman II experience is relevant.
- Flight testing is a primary source of data for determining flight reliability and detecting changes that could have future impact. However, according to the program office's 1988 Minuteman II Reliability Assessment Report, there had been insufficient flight tests conducted during the 1980s to characterize or detect future changes in Minuteman II reliability. In our opinion, this limited number of test flights would also provide insufficient information to support a credible prediction of future Minuteman III reliability.
- The ground reliability experience of the guidance computer suggests that Minuteman III guidance sets may not be experiencing a similar rate of degradation as the Minuteman II guidance sets. A downward trend in the Minuteman II guidance computer ground reliability began in

1980—15 years after the Minuteman II missiles were initially deployed. According to the 1992 Weapon System Effectiveness Report, the Minuteman III guidance computer ground reliability is not showing a negative trend 22 years after the Minuteman III missiles were first deployed.

Conclusions

It is premature to begin engineering and manufacturing development of the proposed $1.8 billion guidance electronics replacement program in August 1993, as currently planned. Although electronic replacement may eventually be needed, the Air Force has not conducted the necessary studies and analyses to justify proceeding with this proposed program.

Recommendation

We recommend that the Secretary of the Air Force delay a decision to begin engineering and manufacturing development of the Minuteman III guidance electronics replacement program until sufficient analytical evidence has been developed to clearly demonstrate that the start of that effort is justified.

Matters for Congressional Consideration

The Congress may wish to consider either not appropriating fiscal year 1994 funds for engineering and manufacturing development of the guidance electronics replacement program or limiting the Air Force's authority to obligate appropriations for the program until studies and analyses have been completed that support the need to proceed with that effort.

Agency Comments and Our Evaluation

In commenting on a draft of this report, DOD and Air Force officials disagreed with our conclusions and recommendation to delay the start of engineering and manufacturing development of the guidance electronics replacement program. They believe the need for the program has been clearly stated in a mission need statement that was validated by the Joint Requirements Oversight Council on November 5, 1992. They also believe that collective evidence and engineering judgment show that the Minuteman III guidance set could face in-flight reliability degradation as early as 1997 and that waiting for a system-level failure to justify the program is inappropriate.

We do not question the basic requirement for maintaining Minuteman III reliability and supportability as stated in the mission need statement and

have made appropriate clarifications in our report. However, DOD's position that there is adequate evidence supporting the projection of reliability degradation runs counter to the results of its assessment program and other special studies. As we have discussed in our report, the Air Force has an assessment program to identify adverse performance trends in sufficient time to allow actions to be taken to preclude degraded system-level performance. At the present time, the missile guidance set is demonstrating acceptable system-level flight and ground reliability with no adverse reliability trends. Further, available documents show that the most troublesome electronic circuitry concerns identified by the program office are already being corrected. Also, these documents do not indicate that the remaining concerns are serious. The relevance of Minuteman II experience is questionable. Several times during our audit, we discussed our position with DOD and Air Force officials, and we asked for any additional analytical evidence, such as studies and analyses, to support their projection. However, no additional information was provided.

DOD and Air Force officials said they had four other reasons why they wanted the engineering and manufacturing development of the guidance electronic replacement program to proceed as currently planned. As discussed in the following sections, we do not find the reasons to be persuasive.

Their first reason involves pending unsupportability of the Minuteman III guidance and control system. According to DOD and Air Force officials, inventories of certain electronic parts, many of which are not longer procurable, are projected to be depleted as early as 1998 at current usage rates. However, our review showed that, of the eight circuitry anomalies concerns identified by the program office, only one involved the continued availability of an electronic part (integrated circuit), and according to the November 1992 Silo-Based ICBM Weapon System Effectiveness Report, the program office is taking actions that should provide continued availability of this part.

Their second reason involves protecting the option to replace the MK 12 reentry vehicle with the Peacekeeper missile's MK 21 reentry vehicle. According to DOD and Air Force officials, the guidance electronics replacement program is necessary to protect this option. However, a final determination to use the MK 21 has not been made. Even if it is decided to use the MK 21, those reentry vehicles will not be available until about 2000, when the Air Force plans to begin retiring Peacekeeper missiles. Therefore, we do not believe that delaying the start of engineering and

manufacturing development precludes the use of the MK 21 reentry vehicle.

Their third reason involves the declining availability of the ballistic missile industrial base suppliers. According to DOD and Air Force officials, the qualified suppliers may not be available if engineering and manufacturing development is delayed. In all the documentation provided to us during this review, the declining availability of suppliers had not been identified by the Air Force as justification for proceeding with engineering and manufacturing development. Further, in raising this issue when commenting on our report, DOD and Air Force officials did not provide any new documentation supporting their concern.

Their fourth reason involves the potential need for operating the Minuteman III system in dormant or semi-dormant modes. According to DOD and Air Force officials, the electronics replacement program is required to provide the option to integrate an advanced inertial measurement unit with the Minuteman III missile to provide the capability for dormant or semi-dormant operations. However, as discussed in chapter 3 of this report, it is not certain when or if dormant or semi-dormant operations will be required. Consequently, it does not appear necessary to begin engineering and manufacturing development at this time to protect that option.

Justification and Plans for Replacement of Inertial Instruments Remain to Be Finalized

The second phase of the guidance replacement program is intended to upgrade the capability of the 500 deployed Minuteman III missiles by replacing the guidance set's inertial measurement unit with an advanced inertial measurement system. This Air Force proposal, estimated to cost $2.8 billion in then-year dollars, is intended to improve accuracy, provide a capability for dormant or semi-dormant operations, improve ground reliability, and improve nuclear safety of the weapon system. The need for enhanced guidance set capability is contained in a mission need statement validated by the Joint Requirements Oversight Council on November 5, 1992. It is uncertain, however, whether the Air Force's proposal to upgrade the guidance set to provide these capabilities will be implemented. DOD and Air Force officials stated that DOD plans to conduct a review in the fall of 1993 to determine whether studies of alternative concepts for enhancing guidance capability are warranted (Milestone 0—the first step in DOD's acquisition process).

Justification and Plans for Inertial Instrument Replacement

The Air Force's reasons for providing enhanced capability are as follows:

- An improvement in Minuteman III accuracy to the level currently being demonstrated by the Peacekeeper missile would allow the land-based ICBM force to retain Peacekeeper target damage capability after retirement of the Peacekeeper missiles in 2003 (the current plan assuming ratification of START I and II). Software modifications made during the 1980s have improved Minuteman III accuracy, bringing it closer to Peacekeeper accuracy, but further improvement is needed to match Peacekeeper accuracy. Silo-Based ICBM System Program Office personnel have advised us that it is not possible to improve accuracy further without upgrading the Minuteman III guidance set inertial instruments.
- An ability to remove some or all of the Minuteman III force from an on-alert status while retaining the capability to rapidly restore it to a full-alert posture (referred to in this report as capability for dormant or semi-dormant operations) would enhance operational flexibility in responding to an evolving threat. According to Air Force personnel, the Minuteman III guidance set was not designed to support a rapid restoration to a full-alert posture—the current process of restoring missile accuracy to full-alert readiness after being taken off-alert is lengthy and manpower intensive.
- A decrease in guidance set failure rates resulting from dormant or semi-dormant operations would reduce Minuteman III repair costs.
- A decrease in guidance set failure rates will reduce the number of times the reentry vehicles will have to be removed (to remove a failed guidance

set from a missile the reentry vehicles must also be removed). According to DOD and Air Force officials, this will significantly enhance nuclear safety.

To gain those capabilities, Air Force Headquarters reviewed several alternatives and decided, in February 1992, to replace the current inertial instruments on all 500 operational missiles with an advanced inertial measurement system (as discussed in appendix II). The Air Force, however, stated that it had not ruled out the option of equipping less than 500 missiles with an advanced system, if future requirements or budget dictate. As of May 1992, the Air Force had planned to initiate engineering and manufacturing development of the advanced inertial measurement system in 1997.

However, DOD has decided to examine whether replacement of the inertial instruments with an advanced system is the most appropriate means of attaining the operational needs set forth in the mission need statement. According to DOD officials, they plan to conduct a review in the fall of 1993 to determine whether studies of alternative concepts for enhancing Minuteman III guidance capability were warranted (Milestone 0—the first step in DOD's acquisition process). The studies, if done, would then serve as the basis for developing an acquisition strategy and cost, schedule, and performance objectives of viable alternatives to support the next decision point in DOD's acquisition process—Milestone I, Concept Demonstration. Only after a favorable Milestone I decision would the scope of this modification be defined and preliminary cost, schedule, and performance objectives identified. Furthermore, an upgrade of the guidance set to provide enhanced capabilities would not be considered a new acquisition program until after a favorable Milestone I decision.

Firm Operational Requirements Remain to Be Determined

Proceeding through the acquisition cycle is predicated on the definition and establishment of firm operational performance requirements. According to DOD and Air Force officials, the validated mission need statement for a future guidance system for ICBMs, in part, identifies a firm need to preserve ICBM warfighting capability when Peacekeeper is deactivated and for ICBMs to have a capability to operate in a dormant or semi-dormant mode. However, these officials stated that specific Minuteman III operational requirements associated with those needs remain to be determined. For example, the validated November 1992 mission need statement for the guidance replacement program states that there is only a potential requirement for dormant or semi-dormant

operations depending upon future threat conditions. U.S. Strategic Command personnel advised us that dormant or semi-dormant Minuteman III operations would represent a fundamental change in national nuclear weapon systems employment policy that would likely require approval by the President. In addition, a final determination on whether improved accuracy for Minuteman III is required awaits several decisions. For example:

- Is there a need for U.S. nuclear weapons to have a hard-target kill capability and, if so, how many weapons must have that capability?
- Do both the Trident II submarine-launched ballistic missiles and the land-based ICBMs have to have a hard-target kill capability or does only one of those weapons require hard-target kill capability?
- If there is a need for U.S. nuclear weapons to have a hard-target kill capability, is current demonstrated Peacekeeper and Trident II performance sufficient or would improved performance be required?

DOD, Air Force, and U.S. Strategic Command personnel advised us that the need for accuracy and/or dormant or semi-dormant capability depends, in part, on the ratification and implementation of START I and II, as currently defined, and the resulting mix and capabilities of U.S. and Russian strategic nuclear forces.

Conclusions

At the present time, the need for enhanced Minuteman III operational capabilities is uncertain pending a better definition of the post-START mix of U.S. and Russian strategic nuclear forces and capabilities. If it is ultimately decided that enhanced operational capabilities are needed and that the Minuteman III guidance set needs to be upgraded to provide those capabilities, it remains to be determined if the planned advanced inertial measurement system is the most appropriate means of providing those capabilities.

Agency Comments and Our Evaluation

In a draft of this report, we had proposed that the Secretary of Defense delay the Milestone 0 review for Phase II of the guidance replacement program. In commenting on our draft report, DOD and Air Force officials stated that proceeding with the Milestone 0 review was the necessary first step to assessing the alternative means for satisfying the validated need as stated in the mission need statement. According to these officials, if, as a result of the Milestone 0 review, a decision was made to proceed with this phase of the guidance replacement program, specific Minuteman III

operational performance requirements would then be studied. Based on our evaluation of these comments, we have deleted our earlier proposal from the final report.

Missile Guidance Set Description

The Minuteman III missile guidance set is an inertial guidance system that directs the flight of the missile to its target. Minuteman III missiles are maintained in a continuous on-alert status, and the missile guidance sets operate 24 hours a day, 7 days a week, thus enabling the missile to be launched in less than 1 minute. The Minuteman III guidance set was designed between 1966 and 1969, produced between 1970 and 1978, and has been in operational use since 1970. In 1992, the average age of the guidance units produced for operational use was 17 years, which exceeds the guidance set's 10-year design life.

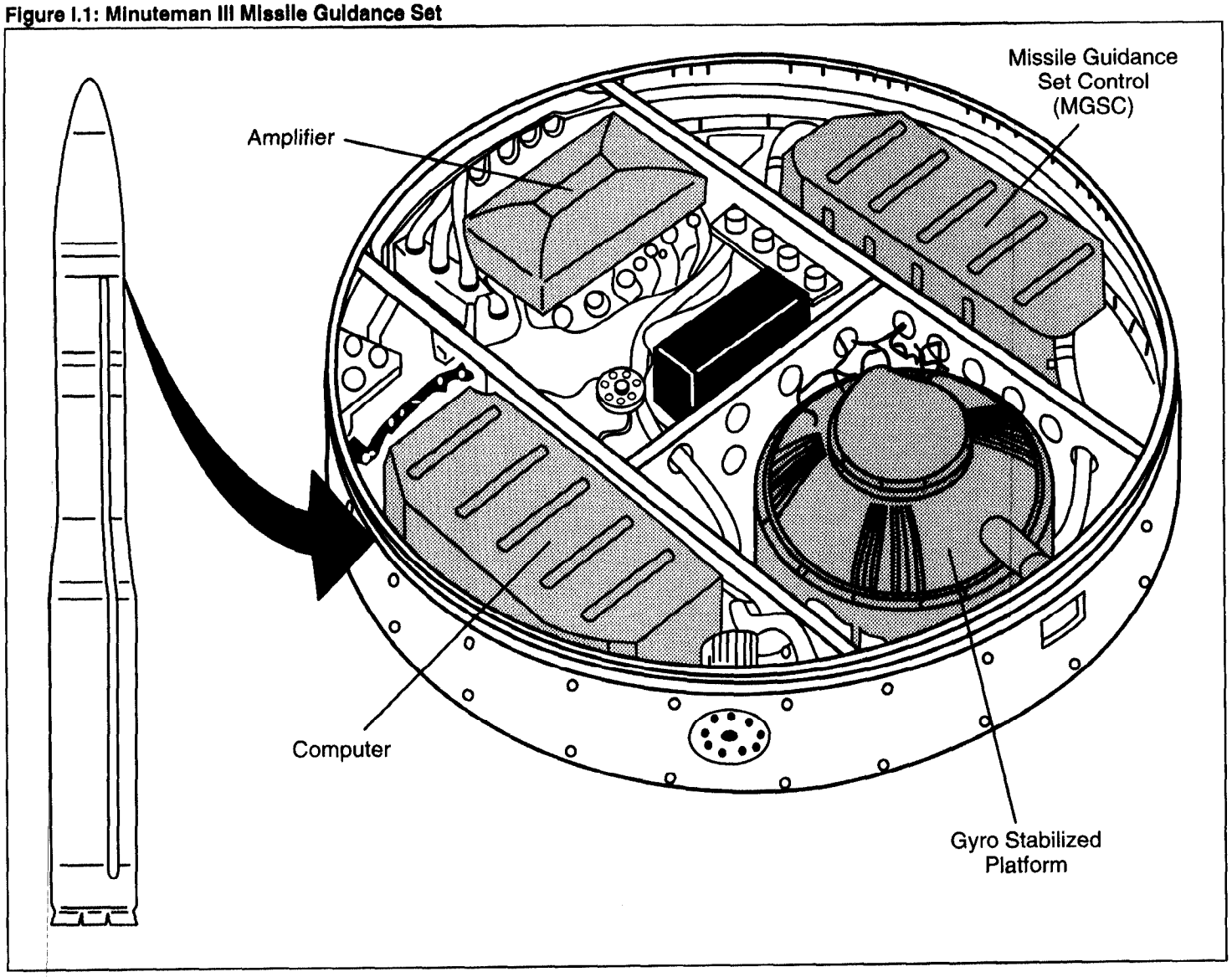
The Minuteman III missile guidance set is the third generation of Minuteman guidance systems designed and produced by the Autonetics Division of Rockwell International. Incorporation of current technology with each generation has resulted in a smaller, more capable, and less vulnerable system. The Minuteman III guidance set is located on a wafer that is placed on the missile just below the reentry system—removal of the set for maintenance also requires removal of the reentry system. The guidance set has four major components: the guidance digital computer unit, the gyro-stabilized platform, the missile guidance set control, and the amplifier assembly. Each is a separate component on the guidance set wafer, as illustrated in figure I.1. A synopsis of the function of each of the four guidance set components is as follows:

- The computer is a miniaturized general purpose digital computer designed and programmed to control the missile throughout the powered portion of flight. After thrust termination, it also controls the post-boost vehicle in a multiple independently retargetable reentry vehicle deployment mission. While the missile is on-alert, the computer also provides missile readiness status information.
- The gyro-stabilized platform measures acceleration and provides acceleration and attitude information to the guidance computer. This data is required so that flight of the missile is accurate and proper. The platform contains some electronic circuitry and inertial instruments, including three pendulous integrating gyroscopic accelerometers and one gyrocompass assembly. The accelerometers measure missile velocity and the gyrocompass assembly provides data for aligning the platform before missile launch.
- The missile guidance set control provides power to the inertial instruments in the gyro-stabilized platform. It contains electronics to control and sense these instruments in accordance with commands from the computer. Information sensed by the missile guidance set control is

relayed to the computer. This component and the gyro-stabilized platform comprise the inertial measurement unit.

- The flight control amplifier electronically couples the computer with the missile downstage and reentry system, providing missile attitude and event control during flight. Acting on commands from the computer, it amplifies signals to downstage valves, actuators, and ordnance devices.

Figure I.1: Minuteman III Missile Guidance Set



Guidance Replacement Program Description and Status

The Air Force is proposing a two-phase guidance replacement program to modify the Minuteman III missile guidance set at a cost of $4.6 billion in then-year dollars, as of June 1992. Program objectives are to first replace guidance set electronic components and, then, replace guidance inertial instruments with an advanced inertial measurement system to provide enhanced capabilities to meet anticipated future operational needs. The operational needs for the guidance replacement program are based upon a "Mission Need Statement for Future Guidance System for Intercontinental Ballistic Missiles," prepared by the Air Combat Command. This mission need statement was validated by the Joint Chiefs of Staff's Joint Requirement Oversight Council on November 5, 1992.

While both phases of the guidance replacement program are being proposed to meet operational needs identified in a common mission need statement, DOD has decided to designate each phase as a separate major acquisition program. As such, each phase will be subject to separate acquisition milestone reviews at either the Air Force or DOD level. In August 1993, the Air Force plans to conduct a Milestone II review for engineering and manufacturing development of the electronics replacement program (Phase I). In the fall of 1993, DOD plans to conduct a Milestone 0 review (concept exploration and definition) of the proposed inertial instrument replacement program (Phase II).

Guidance Replacement Program Evolution

The guidance replacement program began in 1991 as a guidance electronics upgrade program only. Appropriations for the program were first requested in DOD's fiscal year 1992 budget, which was submitted to the Congress in February 1991. In February 1992, the Air Force added the inertial measurement unit replacement component to the program. This component was added following an assessment of guidance sets for future ICBM's that was requested by DOD's Strategic Systems Committee in October 1991. According to the Air Force, this assessment involved an extensive analysis of technical and cost tradeoffs among more than a dozen different configurations of guidance systems for both the Small ICBM and Minuteman missile systems—the Peacekeeper inertial measurement unit, the Trident system of components, the Advanced Inertial Measurement System, and Minuteman III guidance set upgrades. After reviewing the various alternatives, the Air Force recommended the current two-phased guidance replacement program. Implementation of this recommendation was directed by the Air Force in Program Management Directive 2313 (1), entitled "ICBM Integrated Weapon System Management," dated April 28, 1992.

Air Force Headquarters personnel advised us that the Air Force initially expected that the complete guidance replacement program would be a major acquisition program with DOD retaining authority for defense acquisition milestone decisions. In December 1992, however, the Under Secretary of Defense for Acquisition delegated milestone decision authority for Phase I to the Air Force (a Category 1C acquisition program) and retained milestone decision authority for Phase II (a Category 1D acquisition program).

Phase I Description and Status

Phase I of the proposed guidance replacement program is expected to ensure reliability and supportability of the missile guidance set through 2020. This phase involves the design, development, test, and production of new electronic components to replace the computer, control amplifier assembly, missile guidance set control, and the electronics within the gyro-stabilized platform. In addition, Phase I involves rewriting the guidance set's operational software in ADA—the Air Force's designated programming language. The program office estimates that the electronics replacement modification will cost $1.8 billion in then-year dollars.

Phase I design requirements also protect options for replacing the existing inertial instruments with an advanced inertial measurement system (Phase II of the guidance replacement program) and for replacing the Minuteman III MK 12 and MK 12A reentry vehicles with the Peacekeeper MK 21 reentry vehicle, a proposal that is being considered by the Air Force. According to the program office, an upgrade of the existing guidance computer is needed before the Peacekeeper MK 21 reentry vehicle can replace the Minuteman III MK 12 and MK 12A reentry vehicles.

The formal internal Silo-Based ICBM System Program Office acquisition process for accomplishment of the electronics replacement program began in August 1991 and is continuing. During this process, alternative solutions for corrective action were considered, such as (1) replacing only those parts that were deteriorating, (2) reusing electronic components that were initially acquired to upgrade Minuteman II inertial measurement unit electronics, and (3) a complete replacement of electronic components with new hardware. The third alternative was the solution selected by the program office. The internal acquisition process has progressed to the point of issuing a March 26, 1993, solicitation of contractor proposals for executing the modification.

The award of a contract is predicated on a favorable decision following the Milestone II review, scheduled for August 1993. The purpose of that review is to determine whether engineering and manufacturing should begin and, if so, to establish a development baseline containing refined program cost, schedule, and performance objectives. According to a program official, to achieve first article delivery of this modification in September 1997, the Air Force needs to award the contract for engineering and manufacturing development by about August 1993. Milestones leading to a first article delivery in September 1997 are as follows:

August 1993	Begin engineering and manufacturing development
September 1995	Complete critical design review
July 1996	Begin low-rate initial production
November 1996	First flight test
July 1997	Begin full-rate production

Phase II Description and Status

Phase II of the guidance replacement program is intended to improve accuracy, provide a capability for dormant or semi-dormant operations, improve reliability, and improve nuclear safety. Phase II involves a replacement of the inertial measurement unit (inertial instruments and associated electronics) with an advanced inertial measurement system. Phase II is estimated by the program office to cost $2.8 billion in then-year dollars.

The technologies for an advanced inertial measurement system are being developed and demonstrated by the Air Force's Advanced Strategic Missile Systems Program Office. This effort started in August 1991 and is planned to be completed in the third quarter of fiscal year 1995. The Air Force initially planned to begin engineering and manufacturing development of Phase II in fiscal year 1995, after completion of the technology demonstration effort. In May 1992, however, the Air Force decided to delay the initiation of engineering and manufacturing development until fiscal year 1997.

However, DOD has decided to examine whether replacement of the inertial instruments with an advanced system is the most appropriate means of attaining the operational needs set forth in the mission need statement. A Milestone 0 review is scheduled for the fall of 1993 to consider approving studies and analyses of alternative approaches for enhancing the performance of the current Minuteman III missile guidance set. Approving the initiation of studies and analyses is the first step in DOD's acquisition process. These studies and analyses must be conducted and a favorable decision rendered at the next acquisition milestone (Milestone I—Demonstration and Validation) before a Phase II program will be defined and initial cost, schedule, and performance objectives are established.

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