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Report to the Ranking Minority Member, Subcommittee on Financial Management, the Budget, and International Security, Committee on Governmental Affairs, U.S. Senate

August 2003

MISSILE DEFENSE

Additional Knowledge Needed in Developing System for Intercepting Long-Range Missiles

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Highlights

Highlights of GAO-03-600, a report to the Ranking Minority Member, Subcommittee on Financial Management, the Budget, and International Security, Committee on Governmental Affairs, U.S. Senate

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MISSILE DEFENSE

Additional Knowledge Needed in Developing System for Intercepting Long-Range Missiles

Why GAO Did This Study

A number of countries hostile to the United States and its allies have or will soon have missiles capable of delivering nuclear, biological, or chemical weapons. To counter this threat, the Department of Defense's (DOD's) Missile Defense Agency (MDA) is developing a system to defeat ballistic missiles.

MDA expects to spend $50 billion over the next 5 years to develop and field this system. A significant portion of these funds will be invested in the Ground-based Midcourse Defense (GMD) element. To field elements as soon as practicable, MDA has adopted an acquisition strategy whereby capabilities are upgraded as new technologies become available and is implementing it in 2-year blocks.

Given the risks inherent to this strategy, GAO was asked to determine when MDA plans to demonstrate the maturity of technologies critical to the performance of GMD's Block 2004 capability and to identify the estimated costs to develop and field the GMD element and any significant risks with the estimate.

What GAO Recommends

GAO is recommending DOD (1) explore options to demonstrate effectiveness of the Cobra Dane radar and (2) establish procedures to help ensure data are reliable from MDA's monitoring system. DOD concurred with GAO's first recommendation and partially concurred with GAO's second.

www.gao.gov/cgi-bin/getrpt?GAO-03-600.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Robert E. Levin at (202) 512-4841 or levinr@gao.gov.

What GAO Found

GMD is a sophisticated weapon system being developed to protect the United States against limited attacks by long-range ballistic missiles. It consists of a collection of radars and a weapon component—a three-stage booster and exoatmospheric kill vehicle—integrated by a centralized control system that formulates battle plans and directs the operation of GMD components. Successful performance of these components is dependent on 10 critical technologies.

MDA expects to demonstrate the maturity of most of these technologies before fielding the GMD element, which is scheduled to begin in September 2004. However, the agency has accepted higher cost and schedule risks by beginning integration of the element's components before these technologies have matured. So far, MDA has matured two critical GMD technologies. If development and testing progress as planned, MDA expects to demonstrate the maturity of five other technologies by the second quarter of fiscal year 2004.

The radar technologies are the least mature. MDA intends to demonstrate the maturity of an upgraded early warning radar in California in the first quarter of fiscal year 2005 and a sea-based radar in the Pacific Ocean in the fourth quarter of that year. Although MDA does not plan to demonstrate the maturity of the technology of the early warning radar in Alaska, which will serve as the primary fire control radar, through its own integrated flight tests, it may be able to do so through the anticipated launch of foreign test missiles.

MDA estimates that it will spend about $21.8 billion between 1997 and 2009 to develop the GMD element. This estimate includes $7.8 billion to develop and field the GMD Block 2004 capability. For example, the funds will be used to install interceptors at two sites, upgrade existing radars and testing infrastructure, and develop the sea-based X-band radar. We found that MDA has incurred a greater risk of cost growth because for more than a year the agency was not able to rely fully on data from its primary tool for monitoring whether the GMD contractor has been performing work within cost and on schedule. In February 2002, MDA modified the prime contract to reflect an increased scope of work for developing GMD. It was not until July 2003 that the agency completed a review to ensure that the data was fully reliable.

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Abbreviations

BMDO	Ballistic Missile Defense Organization
CPR	Cost Performance Report
DCMA	Defense Contract Management Agency
EVM	Earned Value Management
GMD	Ground-based Midcourse Defense
IBR	integrated baseline review
IFT	integrated flight test
MDA	Missile Defense Agency
NMD	National Missile Defense
TRL	technology readiness level

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Accountability * Integrity * Reliability

United States General Accounting Office
Washington, DC 20548

August 21, 2003

The Honorable Daniel K. Akaka
Ranking Minority Member
Subcommittee on Financial Management,
the Budget, and International Security
Committee on Governmental Affairs
United States Senate

Dear Senator Akaka:

Hostile states, including those that sponsor terrorism, are investing significant resources to develop and deploy ballistic missiles of increasing range and sophistication that could be used against the United States, our deployed forces, and our allies. At least 25 countries now have, or are in the process of acquiring, missiles capable of delivering nuclear, biological, or chemical weapons. To counter this threat, the President of the United States in December 2002, directed the Department of Defense (DOD) to begin fielding a ballistic missile defense system in 2004.

The Missile Defense Agency (MDA) within DOD is responsible for developing this system, including the Ground-based Midcourse Defense (GMD) element,[1] which is being developed to protect the United States against long-range ballistic missiles. MDA is also building an integrated testing infrastructure—or "test bed"—with the newly designated GMD element as its centerpiece. MDA expects to spend nearly $50 billion in research and development funds between fiscal years 2004 and 2009 to develop and field a ballistic missile defense system. A significant percentage of the $50 billion will be invested in the GMD element.

GMD is a sophisticated weapon system that will rely on state-of-the-art technologies that have been under development for a number of years. GMD will use space-based sensors to provide early warning of missile launches; ground-based radars to identify and refine the tracks of threatening warheads and associated objects; ground-based interceptors

[1] In January 2002, the Secretary of Defense created the Missile Defense Agency and consolidated all ballistic missile defense programs under the new agency. Former missile defense acquisition programs are now referred to as elements of a single ballistic missile defense system.

(each consisting of a three-stage booster and exoatmospheric kill vehicle) to destroy warheads; and a centralized control system that formulates battle plans and directs the operation of GMD components for carrying out the missile defense mission.

To meet the technical challenge of developing both the integrated system and the GMD element, MDA has adopted a "capabilities-based" acquisition strategy and is implementing it in 2-year development blocks. This approach is designed to field elements as soon as practicable and to improve the effectiveness of fielded elements by upgrading their capability as new technologies become available or as the threat warrants. Block 2004 will be the first block fielded, followed by Blocks 2006 and 2008. Although GMD's Block 2004 capability is expected to be fielded beginning in September 2004, MDA plans to upgrade that capability through the end of 2005.[2]

Because development and fielding of GMD involves substantial technical challenges and a major investment, you asked us to review technical and cost issues related to the GMD element. Specifically, we determined when MDA plans to demonstrate the maturity[3] of technologies critical to the performance of GMD's Block 2004 capability. We also identified the estimated costs to develop and field the GMD element and any significant risks associated with the estimate.

Our scope and methodology are included in appendix I. Although we assessed the maturity of specific GMD critical technologies, the scope of this review did not include an evaluation of MDA's test plans for demonstrating GMD's ability to operate as a system overall. Our detailed assessment of GMD system-level testing is included in a classified report that we issued in June 2003 to other congressional requesters.

[2] The intended performance of the Block 2004 capability is described in a classified annex to this report.

[3] Technological maturity for starting product development or systems integration is achieved when prototype hardware with the desired form, fit, and function has been proven in a realistic operational environment. See U.S. General Accounting Office, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 1999).

Results in Brief

MDA expects to demonstrate the maturity of most of the ten technologies critical to GMD's initial performance before fielding of the element begins in September 2004. However, the agency has accepted a higher risk of cost growth and schedule slips by beginning the integration of the element's components before these technologies have been demonstrated. So far, MDA has matured two critical GMD technologies—the infrared sensors of the kill vehicle[4] and the fire control software of the battle management component.[5] But if development and testing progress as planned, MDA expects to demonstrate the maturity of five others—resident in the kill vehicle, interceptor boosters, and the battle management component—by the second quarter of fiscal year 2004. MDA intends to demonstrate the maturity of an upgraded early warning radar—located at Beale Air Force Base, California—in the first quarter of fiscal year 2005 and a sea-based X-band radar, located in the Pacific Ocean, in the fourth quarter of that year. MDA does not plan to demonstrate through its own integrated flight tests the maturity of a technology resident in the Cobra Dane radar located in Alaska, which will serve as the element's primary radar when GMD is first fielded. Agency officials told us that they may be able to test the radar through the anticipated launch of foreign test missiles. However, it is not clear that testing Cobra Dane in this manner will provide all of the information that a dedicated test provides because MDA will not control the configuration of the target or the flight environment.

MDA estimates that it will spend about $21.8 billion between 1997 and 2009 to develop the GMD element. This estimate includes $7.8 billion to develop and field the GMD Block 2004 capability and to develop the GMD portion of the test bed between 2002 and 2005. For example, the funds will be used to install interceptors at Fort Greely, Alaska, and Vandenberg Air Force Base, California; upgrade existing radars and the test bed infrastructure; and develop the sea-based X-band radar.

MDA has incurred a greater risk of cost growth because for more than a year the agency was not able to rely fully on the data from its primary tool for monitoring whether the GMD contractor was performing work within cost and on schedule—the prime contractor's Earned Value Management

[4] The kill vehicle is the weapon component of the GMD element that attempts to detect and destroy threat warheads through "hit-to-kill" impacts.

[5] The battle management component is the integrating and controlling component of the GMD element. The fire control software plans engagements and tasks GMD components to execute a missile defense mission.

(EVM) system.[6] In February 2002, MDA modified GMD's contract to bring it into line with the agency's new capabilities-based acquisition strategy. It took several months to establish an interim cost baseline[7] against which to measure the contractor's performance and 13 months to complete revisions to the baseline. Also, MDA and the contractor did not complete a review until July 2003 to ensure that the revised baseline was accurate and that contractor personnel were correctly using it to measure performance. This review was of particular importance because an earlier review revealed significant deficiencies in the contractor's development and use of the initial contract baseline. Until this review was completed, MDA did not know for sure whether it could rely fully on the data from its EVM system to recognize and correct potential problems in time to prevent significant cost increases and schedule delays.

We are making recommendations that MDA (1) consider adding a test of the effectiveness of the radar in Alaska; and (2) ensure that procedures are in place that will increase MDA's confidence in data from its EVM system. DOD concurred with our first recommendation and partially concurred with the second. In commenting on the draft report, DOD stated that the feasibility of these procedures will be determined and that a portion of the work is already being accomplished.

Background

The concept of using a missile to destroy another missile (hit-to-kill) has been explored since the mid-1950's, but it was not until 1984 that the first such intercept achieved its objective. Between the mid-1980's and late-1990's the United States conducted a number of experiments designed to demonstrate that it was possible to hit one missile with another. In 1997, the Ballistic Missile Defense Organization (BMDO) established the National Missile Defense (NMD) Joint Program Office. The program office was directed to demonstrate by 1999 a system that could protect the United States from attacks of intercontinental ballistic missiles and to be in a position to deploy the system if the threat warranted by 2003. The

[6] The EVM system is a management tool widely used by DOD to compare the value of contractor's work performed to the work's actual cost. The tool measures the contractor's actual progress against its expected progress and enables the government and contractor to estimate the program's remaining cost.

[7] An interim baseline is often established by the contractor when the government has authorized work, but the requirements and terms of the work have not yet been negotiated. Until negotiations are completed, the contractor develops a baseline using proposed cost that has been divided among work packages with associated budgets and schedule.

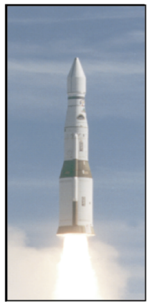
initial system consisted of space- and ground-based sensors, early warning radars, interceptors, and battle management functions.

The program underwent additional changes as the new decade began. In September 2000, the President decided to defer deployment of the NMD system, but development of the system continued with the goal of being ready to deploy the system when directed. This action was followed in 2001 by BMDO's redirection of the prime contractor's efforts from developing and deploying an NMD system to developing an integrated test bed with the newly designated GMD system as its centerpiece. The Secretary of Defense, in January 2002, renamed BMDO as MDA and consolidated all ballistic missile defense programs under the new agency. Former missile defense acquisition programs became elements of a single ballistic missile defense system. These changes were followed in December 2002, by the President's directive to begin fielding in 2004 a ballistic missile defense system, which included components of the GMD element already under development.

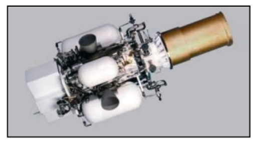
The GMD element is intended to protect the United States against long-range ballistic missiles in the midcourse phase of their flight. This is the point outside the atmosphere where the motors that boost an enemy missile into space have stopped burning and the deployed warhead follows a predictable path toward its target. Compared to the boost and terminal phases, this stage of flight offers the largest window of opportunity for interception and allows the GMD element a longer time to track and engage a target.

As illustrated in figure 1, GMD will rely on a broad array of components to track and intercept missiles. Figure 2 provides a notional concept of how these components will operate once they are fully integrated into the GMD element.

Figure 1: Components of GMD



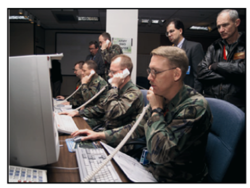
Interceptor booster



Exoatmospheric kill vehicle

Mission: The interceptor consists of a silo-based, three-stage booster stack and “hit-to-kill” exoatmospheric kill vehicle. The kill vehicle is the weapon component of the interceptor that attempts to detect and destroy the threat through a hit-to-kill impact.

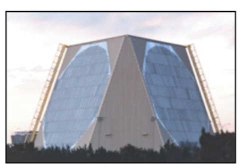
Location: Missile fields in Ft. Greely, Alaska, and Vandenberg Air Force Base, California.



Fire control and communications

Mission: The fire control (battle management) component is the integrating and controlling entity of the GMD element. Its software plans engagements and tasks GMD components to execute a mission. The in-flight interceptor communications system enables the fire control component to communicate with the kill vehicle while in flight.

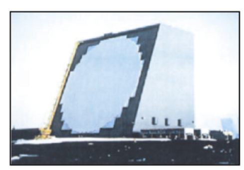
Location: Fire control node, Schriever Air Force Base, Colorado.



Beale radar

Mission: Early warning radar for midcourse tracking in support of the GMD mission.

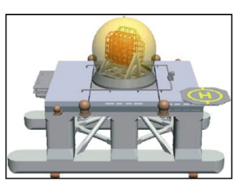
Location: Beale Air Force Base, California.



Cobra Dane radar

Mission: Principal fire control radar for tracking missiles launched out of northeast Asia.

Location: Eareckson Air Station, Alaska.



Sea-based X-band radar

Mission: X-band radar emplaced on a sea-based, mobile platform in the Pacific. It will not be fielded with the initial defensive capability in September 2004 but will be available in late 2005 for use in flight testing or as an operational asset for midcourse tracking and discrimination.

Location: Pacific Ocean.

Source: GAO, based on MDA documents.

Figure 2: Notional GMD Concept of Operations

1	Enemy missile is launched.
2	Space-based satellites detect and report launch to the GMD fire control component; GMD element transitions to alert state.
3	Fire control begins engagement planning based on initial track data from satellites.
4	Primary radars (for example, Cobra Dane) are cued to track enemy missile.
5	Radars provide high-quality track data to fire control, which then develops battle plans to engage the threat.
6	Human operator grants engagement authority to launch interceptors.
7	Interceptor is launched; exoatmospheric kill vehicle deployed to engage the threat.
8	Radars continue to provide updated track data to the fire control.
9	In-flight interceptor communications system of the fire control component sends updated targeting information to the kill vehicle while in flight.
10	Radars classify or discriminate objects of target complex; associated data are communicated to the interceptor via the in-flight interceptor communications system.
11	Kill vehicle acquires, tracks, and discriminates threat complex.
12	Kill vehicle makes final target selection and steers itself for a "hit-to-kill" impact of the designated target.
13	Kill assessment is made from radar data.
14	If threat from attack has been eliminated, GMD element returns to normal state.

Source: GAO, based on MDA documents.

Note: The concept of operations assumes weapons release authority has been previously granted by the President of the United States or the Secretary of Defense. Missile flight times may be too brief to ask for permission to launch interceptors and engage the enemy.

MDA Expects to Demonstrate the Maturity of Most GMD Technologies before September 2004

MDA is gaining the knowledge it needs to have confidence that technologies critical to the GMD Block 2004 capability will work as intended. Two of the ten technologies essential to the Block 2004 capability have already been incorporated into actual prototype hardware and have been demonstrated to function as expected in an operational environment.[8] Other technologies are reaching this level of maturity. If development and testing proceed as planned, MDA will demonstrate the maturity of five additional technologies by the second quarter of fiscal year 2004 and two critical radar technologies during fiscal year 2005. MDA believes that its best opportunity to demonstrate the maturity of the tenth technology, technology critical to GMD's primary radar, may come through the anticipated flight tests of foreign missiles.

Our work over the years has found that making a decision to begin system integration of a capability before the maturity of all critical technologies have been demonstrated increases the program's cost, schedule, and performance risks. Because the President directed DOD to begin fielding a ballistic missile defense system in 2004, MDA began GMD system integration with technologies whose maturity has not been demonstrated. As a result, there is a greater likelihood that critical technologies will not work as intended in planned flight tests. If this occurs, MDA may have to spend additional funds in an attempt to identify and correct problems by September 2004 or accept a less capable system.[9]

Importance of Maturing Technology

Successful developers follow "knowledge-based acquisition" practices to get quality products to the customer as quickly and cost effectively as possible. As a part of meeting this goal, developers focus their technology programs on maturing technologies that have the realistic potential for being incorporated into the product under consideration. Accordingly, successful developers spend time to mature technology in a technology setting, where costs are typically not as great, and they do not move forward with product development—the initiation of a program to fully

[8] An operational environment is a real-world environment (e.g., flight demonstration) that addresses all of the operational requirements and specifications demanded of the final product.

[9] U.S. General Accounting Office, *Missile Defense: Knowledge-Based Practices Being Adopted, but Risks Remain*, GAO-03-441 (Washington, D.C.: Apr. 30, 2003). This report presents our analysis of MDA's new approach for developing missile defense technology.

design, integrate, and demonstrate a product for production—until essential technologies are sufficiently mature.

An analytical tool—which has been used by DOD and the National Aeronautics and Space Administration, called technology readiness levels (TRLs),[10] —can assess the maturity level of technology as well as the risk that technology poses if it is included in a product's development. The nine readiness levels are associated with progressing levels of technological maturity and demonstrated performance relative to a particular application—starting with paper studies of applied scientific principles (TRL 1) and ending with a technology that has been "flight proven" on an actual system through successful mission operations (TRL 9). Additional details on TRLs are shown in appendix III.

TRLs provide a gauge of how much knowledge the program office has on the progress or status of a particular technology and are based on two principal factors: (1) the fidelity of demonstration hardware, including design maturity and level of functionality achieved; and (2) the extent and realism of the environment in which the technology has been demonstrated.

MDA recognizes the value of beginning system integration with mature technology and of using TRLs to assess the maturity of technology proposed for a block configuration. In particular, MDA prefers to include new technology in a block configuration only if the technology has reached a TRL 7; that is, only if prototype hardware with the desired form, fit, and function has been proved in an operational environment. However; MDA retains the flexibility to include less mature technology in a block configuration if that technology offers a significant benefit in performance and the risk of retaining it is acceptable and properly managed.

Readiness Levels of GMD Element Technologies

Through technical discussions with the GMD joint program office and its prime contractor, we identified ten critical GMD technologies and jointly assessed the readiness level of each. The critical technologies are resident in the exoatmospheric kill vehicle, the boosters, the battle management, command, and control component, and in the element's

[10] U.S. General Accounting Office, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 1999).

radars. In 7 of 10 cases, we agreed with the program office and the GMD prime contractor on the maturity level of the element's critical technologies. The differences in the remaining three cases, as discussed in detail below, were primarily due to interpretation of TRL definitions. The program office and its contractor rated the two booster technologies and one radar technology at higher readiness levels than, in our opinion, MDA had demonstrated.

Most critical GMD technologies are currently at TRLs 5 and 6. At TRL 5, the technology's development is nearing completion, but it has not been applied or fitted for the intended product. At this point, the technology has been incorporated into a high-fidelity breadboard[11] that has been tested in a laboratory or relevant environment[12]. Although this demonstrates the functionality of the technology to some extent, the hardware is not necessarily of the form and fit (configuration) that would be integrated into the final product. A new application of existing technology is usually assessed at a TRL 5, because the technology has not been demonstrated in the relevant environment for the new application. TRL 6 begins the true "fitting" or application of the technology to the intended product. To reach this level, technology must be a part of a representative prototype that is very close to the form, fit, and function of that needed for the intended product. Reaching a TRL 6 requires a major step in a technology's demonstrated readiness, that is, the prototype must be tested in a high-fidelity laboratory environment or demonstrated in a restricted but relevant environment.

Two of the ten GMD technologies were assessed at a TRL 7, the level that successful developers insist upon before initiating product development. To reach this level, a pre-production prototype of the technology must be demonstrated to its expected functionality in an operational environment. If development and testing proceed as planned by MDA, we judge that most of the technologies (7 of 10) will be at a TRL 7 after the completion

[11] A breadboard is a collection of integrated components that provide a representation of a system/subsystem that can be used to determine concept feasibility and to develop technical data. A breadboard is typically configured for laboratory use to demonstrate the technical principals of immediate interest.

[12] A relevant environment is defined as a testing environment that simulates key aspects of the operational environment.

of integrated flight test (IFT)-14,[13] which is scheduled for the second quarter of fiscal year 2004. Table 1 summarizes our assessment of the TRL for each critical technology as of June 2003 and the date at which MDA anticipates each technology will reach TRL 7. A detailed discussion of each critical technology follows.

Table 1: Technology Readiness Levels of GMD Critical Technologies

Critical technology	TRL (as of June 2003)	Anticipated event/date for achieving TRL 7[a]
Exoatmospheric kill vehicle		
Infrared seeker	7	Achieved
On-board discrimination	6	IFT-14 (2nd quarter FY04)
Guidance, navigation, and control subsystem	6	IFT-14 (2nd quarter FY04)
Boosters		
BV+	6	IFT-13A (1st quarter FY04)
OSC Lite	6	IFT-13B (1st quarter FY04)
Battle management command, control, and communications		
Fire control software	7	Achieved
In-flight interceptor communications system	6	IFT-14 (2nd quarter FY04)
Radars		
Cobra Dane radar	5	Unknown
Beale upgraded early warning radar	5	Radar certification flight (1st quarter FY05)
Sea-based X-band radar	5	IFT-18 (4th quarter FY05)

Source: GAO analysis of GMD data.

Note: Information provided in the table—the configuration of flight test events and associated date—is as of June 2003 and is subject to change.

[a]Assumes technology development and demonstrations will have been successful.

[13] Integrated flight tests of the GMD element are real-world demonstrations of system performance during which an interceptor is launched to engage and intercept a mock warhead above the atmosphere.

Exoatmospheric Kill Vehicle Technologies

The exoatmospheric kill vehicle is the weapon component of the GMD interceptor that attempts to detect and destroy the threat reentry vehicle through a hit-to-kill impact. The prime contractor identified three critical technologies pertaining to the operation of the exoatmospheric kill vehicle. They include the following:

- *Infrared seeker*, which is the "eyes" of the kill vehicle. The seeker is designed to support kill vehicle functions like tracking and target discrimination. The primary subcomponents of the seeker are the infrared sensors, a telescope, and the cryostat that cools down the sensors.
- *On-board discrimination*, which is needed to identify the true warhead from among decoys and associated objects. Discrimination is a critical function of the hit-to-kill mission that requires the successful execution of a sequence of functions, including target detection, target tracking, and the estimation of object features. As such, successful operation of the infrared seeker is a prerequisite for discrimination.
- *Guidance, navigation, and control subsystem*, which is a combination of hardware and software that enables the kill vehicle to track its position and velocity in space and to physically steer itself into the designated target.

All three kill vehicle technologies have been demonstrated to some extent in actual integrated flight tests on near-production-representative kill vehicles. The infrared seeker has reached a TRL 7, because a configuration very much like that to be fielded has been demonstrated in previous integrated flight tests, and only minor design upgrades are planned to reach the Block 2004 configuration. The remaining two kill vehicle technologies are at a TRL 6, because their functionality is being upgraded and the technologies have yet to be incorporated into the kill vehicle and demonstrated in an operational environment.

The on-board discrimination technology has not yet reached TRL 7 because MDA has not tested a "knowledge database" that is expected to increase the kill vehicle's discrimination capability. The purpose of the database is to enable the kill vehicle to distinguish characteristics of threatening from non threatening objects. MDA expects to test the database for the first time in IFT-14.

As a software-intensive technology, on-board discrimination performance under all flight conditions can only be evaluated through ground testing, but flight-testing is needed to validate the software's operation in a real world environment. The discrimination capability that will be tested in IFT-14 is expected to be fielded as part of the Block 2004 capability.

Therefore, IFT-14 should demonstrate the technology's maturity if the test shows that the kill vehicle achieves its discrimination objective.[14]

Similarly, the guidance, navigation, and control technology will also increase to a TRL 7 if the technology achieves its objectives in IFT-14. The inertial measurement unit, an important component of the guidance, navigation, and control subsystem that enables the kill vehicle to track its position and velocity, has not yet been tested in the severe environments (e.g., vibrations and accelerations) induced by the operational booster. This will be first attempted when one of the new operational boosters is used in IFT-14. In addition to testing the inertial measurement unit, IFT-14 will also test the upgraded divert hardware (used to actively steer the kill vehicle to its target) that is expected to be part of the Block 2004 configuration.

Booster Technologies

The integrated booster stack is the part of the GMD interceptor that is composed of rocket motors needed to deliver and deploy the kill vehicle into a desired intercept trajectory. For all flight tests to date, a two-stage surrogate booster called the payload launch vehicle has been used.

In July 1998, the GMD prime contractor began developing a new three-stage booster for the GMD program, known as the "Boost Vehicle", from commercial off-the-shelf components. However, the contractor encountered difficulty. By the time the booster was flight tested in August 2001, it was already about 18 months behind schedule. The first booster flight test met its objectives, but the second booster tested drifted off course and had to be destroyed 30 seconds after launch.

Subsequently, MDA altered its strategy for acquiring a new booster for the interceptor. Instead of relying on a single contractor, MDA authorized the GMD prime contractor to develop a second source for the booster by awarding a subcontract to another contractor. If development of the boosters proceeds as planned, both boosters will be part of the Block 2004 capability. One booster is known as BV+ and the other as "OSC Lite."

The BV+ Booster

The prime contractor ultimately transferred development of the boost vehicle to a subcontractor who is currently developing a variant—known as "BV+"—for the GMD element. The program office and GMD

[14] See classified annex for further details.

contractor rated the BV+ at a TRL 7. The prime contractor reasoned that the extent of the legacy program and its one successful flight test should allow for this rating. However, given the limited testing to date, we assessed the BV+ booster currently at a TRL 6; that is, the technology has been demonstrated in a restricted flight environment using hardware close in form, fit, and function to that which will be fielded in 2004. We believe the contractor's assessment is too high at this time, because the step from TRL 6 to TRL 7 is significant in terms of the fidelity of the demonstration environment. However, the first test of a full configuration BV+ booster will occur with IFT-13A, which is scheduled for the first quarter of fiscal year 2004. In our opinion, the BV+ booster will reach TRL 7 at this time if the booster works as planned.

The "OSC Lite" Booster

The second booster under development is referred to as "OSC Lite". This booster, which is essentially the Taurus Lite missile that carries satellites into low-earth orbit, will be reconfigured for the GMD element. Despite the fact that the booster was recently tested under restricted flight conditions, GMD's prime contractor believes that the legacy development of the Taurus Lite missile is sufficient to prove that the OSC Lite has reached TRL 7. However, in our opinion, because the test was conducted with hardware configured as it was in the Taurus missile, not as it will be configured for GMD's Block 2004, the booster's maturity level is comparable to that of the BV+. The first flight test of a full configuration OSC Lite booster is scheduled for IFT-13B in the first quarter of fiscal year 2004. We believe that if the booster performs as intended in this test, it will reach TRL 7.

Battle Management Command, Control, and Communications Technologies

The battle management component is the integrating and controlling component of the GMD element. Prime contractor officials identified and assessed the following sub-components as critical technologies:

- *GMD fire control software*, which analyzes the threat, plans engagements, and tasks components of the GMD element to execute a mission.
- *In-flight interceptor communications system*, which enables the GMD fire control component to communicate with the exoatmospheric kill vehicle while in flight.

The two battle management technologies have been demonstrated to some extent in actual integrated flight tests, and both are near their Block 2004 design. We determined that the GMD fire control software has currently achieved a TRL 7 and the in-flight interceptor communications system has reached a TRL 6. Prime contractor officials concur with our assessment.

The fire control software is nearing expected functionality and prior software builds have been demonstrated in GMD flight tests. Only minor design changes will be made to address interfacing issues (linking the fire control component with other GMD components) before the software reaches the operational configuration of Block 2004. As a software-intensive technology, the performance of the fire control software throughout the entire “flight envelope” can only be evaluated through ground testing. Ground testing is well underway at both the Joint National Integration Center at Schriever Air Force Base, Colorado, and at the prime contractor’s integration laboratory in Huntsville, Alabama.

The second technology associated with the battle management component is the in-flight interceptor communications system. Even though the pointing accuracy and communications capability of this technology were demonstrated in previous flight tests, the operational hardware to be fielded by 2004 is expected to operate at a different uplink frequency than the legacy hardware used in these past flight tests.[15] Accordingly, we assessed the in-flight interceptor communications system at a TRL 6. The first integrated flight test to include an operational-like build of this technology is IFT-14, and if the technology meets its objectives in this flight test, TRL 7 would be achieved.

Radar Technologies

The GMD contractor initially identified the sea-based X-band radar as the only radar-related critical technology. Since its initial assessment in September 2002, the contractor has now agreed with us that the Beale upgraded early warning radar and the Cobra Dane radar are also critical technologies of the GMD element. The contractor and the GMD program office assessed the Beale and Cobra Dane radars at a TRL 5, because the technology, especially mission software, is still under development and has not yet been demonstrated in a relevant flight environment.[16] The contractor assessed the sea-based X-band radar at a TRL 6. As discussed below, we agree with their assessment of the Beale and Cobra Dane radars but rated the sea-based X-band radar as a TRL 5.

[15] See classified annex for further details.

[16] The hardware of the Beale and Cobra Dane radars is mature since both are currently in operation for other missions, namely, integrated tactical warning and technical intelligence, respectively. Adding the ballistic missile defense mission to these radars requires primarily software-related development and testing.

The early warning radar at Beale Air Force Base has participated in integrated flight tests in a missile-defense role using legacy hardware and developmental software. Design and development of operational builds of the software are progressing, but such builds have only been tested in a simulated environment. Therefore, we assessed the Beale radar technology at a TRL 5—an assessment driven by software considerations. The conversion of the early warning radar at Beale to an upgraded early warning radar, which consists of minor hardware and significant software upgrades, is planned for completion sometime during the middle of fiscal year 2004. After this time, the Beale radar can take part in flight-testing in its upgraded configuration. MDA currently plans to demonstrate the upgraded Beale technology in a non intercept flight test, known as a radar certification flight,[17] in the first quarter of fiscal year 2005. The Beale radar will be demonstrated at a TRL 7 if the objectives of this flight test are achieved.

The Cobra Dane radar is currently being used in a surveillance mode to collect data on selected intercontinental ballistic missile test launches out of Russia and does not require real-time data processing and communications capabilities. To achieve a defensive capability by September 2004, the Cobra Dane radar is being upgraded to perform both of these tasks. This upgrade, which requires a number of software modifications, is designed to enable Cobra Dane to detect and track enemy targets much as the Beale upgraded early warning radar does. Although the hardware component of the Cobra Dane radar is mature and will undergo only minor updating, Cobra Dane's mission software is being revised for this application. The revision includes reuse of existing software and development of new software so that the Cobra Dane radar can be integrated into the GMD architecture.

Upgrades to the Cobra Dane radar are due to be completed at the beginning of 2004. After the software is developed and ground tested, the radar can reach a TRL 6, but it is uncertain when the radar will reach a TRL 7. Because of other funding and scheduling priorities, MDA has no plans through fiscal year 2007 for using this radar in integrated flight tests; such tests would require air- or sea-launched targets that are not currently part of the test program. Unless the current test program is modified, the only opportunities for demonstrating Cobra Dane in an operational environment would come from flight tests of foreign missiles. MDA

[17] Ground testing of interim software builds to be mounted on the Beale radar is ongoing.

officials anticipate that such opportunities will occur. However, it is not clear that testing Cobra Dane in this manner will provide all of the information that a dedicated test provides because MDA will not control the configuration of the target or the flight environment.

The sea-based X-band radar is being built as part of the Block 2004 capability and scheduled for completion in 2005. It will be built from demonstrated technologies—a sea-based platform and the prototype X-band radar currently being used in the GMD test program. Prime contractor officials told us that they consider the risk associated with the construction and checkout of the radar as primarily a programmatic, rather than technical risk, and believe that the sea-based X-band radar has reached a TRL 6. The contractor also stated that the initial operational build of the radar software is developed and currently being tested at the contractor's integration laboratory. We assessed the sea-based X-band radar as a TRL 5 because the radar has not yet been built and because constructing a radar from an existing design and placing it on a sea-based platform is a new application of existing technology. For example, severe wind and sea conditions may affect the radar's functionality—conditions that cannot be replicated in a laboratory. As a result, developers cannot be sure that the sea-based X-band radar will work as intended until it is demonstrated in this new environment. However, both we and the contractor agree that the maturity level of the sea-based X-band radar will increase to a TRL 7 if it achieves its test objectives in IFT-18 (scheduled for the fourth quarter of fiscal year 2005).

MDA Has Risked Cost Growth Because It Could Not Fully Rely on Data from Its System for Monitoring Contractor Performance

From the program's inception in 1997[18] through 2009, MDA expects to spend about $21.8 billion to develop the GMD element. About $7.8 billion of the estimated cost will be needed between 2002 and 2005 to develop and field the Block 2004 GMD capability and to develop the GMD portion of the test bed.[19] However, MDA has incurred a greater risk of cost increases because for more than a year MDA was not sure that it could rely fully upon data from the prime contractor's Earned Value Management (EVM) system,[20] which provides program managers and others with early warning of problems that could cause cost and schedule growth.

GMD Development Costs

Before the restructuring of the GMD program in 2002, about $6.2 billion was spent (between 1997 and 2001) to develop a ground-based defense capability. MDA estimates it will need an additional $7.8 billion between 2002 and 2005 to, among other tasks, install interceptors at Fort Greely, Alaska, and at Vandenberg Air Force Base, California; upgrade existing radars and test bed infrastructure; and develop the sea-based X-band radar that will be added in the fourth quarter of fiscal year 2005. In addition, MDA will invest an additional $7.8 billion between fiscal year 2004 and 2009 to continue efforts begun under Block 2004, such as enhancing capability and expanding the test bed. Table 2, below, provides details on the funding requirements by block and by fiscal year, and figure 3 provides examples of specific Block 2004 tasks.

[18] We calculated program cost from 1997 forward because the National Missile Defense program was established at that time.

[19] The cost to develop and field the initial GMD capability and the ballistic missile defense test bed is funded in MDA's budget within the Defense Wide Research, Development, Test and Evaluation appropriation. MDA is not requesting any procurement, military construction, or military personnel funds for this effort.

[20] The EVM system is a management tool widely used by DOD to compare the value of contractor's work performed to the work's actual cost. The tool measures the contractor's actual progress against its expected progress and enables the government and contractor to estimate the program's remaining cost.

Table 2: Estimated Cost to Develop and Field GMD

Then-year dollars in billions

	Fiscal years									
	1997-2001	2002	2003	2004	2005	2006	2007	2008	2009	Subtotal
Sunk Cost	6.2									6.2
GMD Initial Capability and Block 2004 Test Bed		3.1	2.6	1.2	.9					7.8
GMD Block 2006				1.6	1.8	1.4	1.2			6.0
GMD Block 2008								.9	.9	1.8
Total	**6.2**	**3.1**	**2.6**	**2.8**	**2.7**	**1.4**	**1.2**	**.9**	**.9**	**21.8**

Source: Ballistic Missile Defense Budget, Midcourse Defense Segment, February 2003.

Figure 3: Tasks GMD Plans to Accomplish for the GMD Block 2004 Project

- Initiation of Cobra Dane radar hardware and software upgrades.
- Upgrade of range assets at the Reagan Test Site and other locations to enhance launch capabilities and range safety.
- Design and construction efforts of the Block 2004 test bed.
- Purchase of an additional data terminal in the northeastern part of the United States.
- Construction and testing of the sea-based X-band radar.
- Continue engineering, simulations, ground tests,and integrated flight tests.
- Continue development of alternate boosters and silo.
- Continue development and testing of sea-based X-band radar and upgraded early warning radar software.
- Continue development of the exoatmospheric kill vehicle.
- Fund community programs such as school assistance, an additional fire truck and ambulance, upgrades to recreation center, library, and city hall at Fort Greely, Alaska.

Source: MDA.

MDA did not include the following costs is its Block 2004 estimate:

- The cost to recruit, hire, and train military personnel to operate the initial defensive capability and provide site security at various locations, which MDA estimates to be an additional $13.4 million (half in fiscal year 2003 and half in 2004 each), will be needed to operate GMD and provide physical security. Additional costs to cover these personnel throughout the life of the program beginning in 2005 and beyond were also omitted.
- The cost to maintain equipment and facilities was not included.
- Systems engineering and national team costs—which benefit all elements, including GMD and cannot be divided among the elements—were not included in MDA's budget.

MDA's Insight into Potential Cost Growth Was Limited by the Agency's Inability to Rely Fully on Data from Earned Value Management System

Because a significant portion of MDA's Block 2004 GMD cost estimate is the cost of work being performed by the element's prime contractor, MDA's ability to closely monitor its contractor's performance is critical to controlling costs. The tool that MDA, and many DOD entities, have chosen for this purpose is the EVM system. This system uses contractor reported data to provide program managers and others with timely information on a contractor's ability to perform work within estimated cost and schedule. It does so by examining variances reported in contractor cost performance reports between the actual cost and time of performing work tasks and the budgeted or estimated cost and time. While this tool can provide insightful information to managers, MDA's use of it has been hampered by several factors. Principally, although major contract modifications were made in February 2002, it took until July 2003 for MDA to complete a review to confirm the reliability of data from the EVM system. An earlier review of a similar nature revealed significant deficiencies in the contractor's formulation and collection of EVM data. Until a new review was completed, MDA could not be sure about its ability to rely fully upon this data to identify potential problems in time to prevent significant cost growth and schedule delays.

Baseline Revised over 13-Month Period

An accurate, valid, and current performance management baseline is needed to perform useful analyses using EVM. The baseline identifies and defines work tasks, designates and assigns organizational responsibility for each task, schedules the work task in accordance with established targets, and allocates budget to the scheduled work. According to DOD guidance,[21] a performance management baseline should be in place as early as possible after the contractor is authorized to proceed. Although the guidance does not define how quickly the contractor should establish a baseline, experts generally agree that it should be in place, on average, within 3 months after a contract is awarded or modified.

About a year before the Secretary of Defense directed MDA to adopt an evolutionary acquisition strategy, the agency awarded a new contract for the development of a National Missile Defense system. In February 2002, MDA modified this contract to redirect the contractor's efforts. Instead of developing a missile defense system that met all of the requirements of the war fighter, as the initial contract required, the modification directed the contractor to develop the first GMD increment, or block, which was to be a ballistic missile test bed with GMD as its centerpiece.

Following the contract's modification, the contractor in June 2002 established an interim baseline. This baseline was developed by adding budgets for near-term new work to the original baseline. Because the cost of the work being added to the baseline had not yet been negotiated, the contractor based the budgets on the cost proposed to MDA, as directed by DOD guidelines. The contractor implemented the baseline almost within the 3-month time frame recommended by experts. In the time between the modification and the development of the interim baseline, MDA authorized the contractor to begin work and spend a specified amount of money, and MDA paid the contractor about $390 million during this period.

An option that MDA could have used to help validate the interim baseline was to have the Defense Contract Management Agency (DCMA)[22] verify contractor work packages and track the movement of funds between the unpriced work account and the baseline. However, neither MDA nor DCMA initiated these actions. In its technical comments on a draft of this report, DOD pointed out that during the negotiation process, MDA reviews prime and subcontractor proposal data that include engineering labor hours, material, and cost estimates. DOD further noted that these estimates eventually form a basis for the work packages that make up the data for the performance management baseline. We agree that these costs

[21] Department of Defense, *Earned Value Management Implementation Guide* (Washington, D.C.: Dec. 1996, as revised, p. 10).

[22] DCMA is the agency that DOD has given responsibility for validating contractors' Earned Value data.

will eventually be associated with the work packages that make up the baseline. However, a joint contractor and MDA review of the initial GMD baseline concluded that even though these costs were otherwise fair and reasonable, some work packages that the contractor developed for the original contract's baseline did not correctly reflect the work directed by MDA. An independent review of work packages included in the interim baseline would have increased the likelihood that the work packages were being properly developed and that their budget and schedule were appropriate.

The contractor completed all revisions to the baseline for the prime contractor and all five subcontractors by March 2003, 3 months after negotiating the cost of the modification and 13 months after authorizing the work to begin. The contracting officer explained that it took until December 2002 to negotiate the 2002 contract change because the additional work was extremely complex, and, as a result, the modification needed to be vetted through many subcontractors that support the prime.

Baseline Review Completed in July 2003

The DOD guidance states that an integrated baseline review (IBR) is to be conducted within 6 months of award of a new contract or major change to an existing contract.[23] The review verifies the technical content of the baseline. It also ensures that contractor personnel understand and have been adequately trained to collect EVM data. The review also verifies the accuracy of the related budget and schedules, ensures that risks have been properly identified, assesses the contractor's ability to implement properly EVM, and determines if the work identified by the contractor meets the program's objectives. The government's program manager and technical staff carry out this review with their contractor counterparts.

Completing an IBR of the new baseline has been of particular importance because the July 2001 IBR for the initial contract identified more than 300 deficiencies in the contractor's formulation and execution of the baseline. For example, the contractor had not defined a critical path for the overall effort, many tasks did not have sufficient milestones that would allow the contractor to objectively measure performance, and contractor personnel who were responsible for reporting earned value were making mistakes in measuring actual performance against the baseline.

[23] *Earned Value Management Implementation Guide*, pp. 34 and 36.

MDA began a review in March 2003 of the contractor's new baseline, which reflected the contract modification,. Completing this IBR took until July 2003 because of the complexity of the program and the many subcontractors that were involved. Although the review team found fewer problems with the contractor's formulation and execution of the new baseline, problems were identified. For example, the IBR showed that in some cases the baseline did not reflect the new statement of work. Also, both the prime contractor and subcontractors improperly allocated budget to activities that indirectly affect a work product (known as level of effort activities) when they could have associated these activities with a discrete end product. Because of the way these activities are accounted for, this designation could mask true cost variances.

Management Reserve Used to Offset Expected Cost Overruns at Contract Completion

Before the IBR was underway, DCMA recognized another problem with the contractor's EVM reports. In its December 2002 cost performance report, the contractor reported that it expected no cost overrun at contract completion. This implied that the program was not experiencing any problems that could result in significant cost or schedule growth. However, DCMA stated that October 2002 was the second month in a row that the contractor had used management reserve funds to offset a significant negative cost variance.[24] DCMA emphasized that this is not the intended purpose of management reserves. (Management reserves are a part of the total project budget intended to be used to fund work anticipated but not currently defined.) DCMA officials told us that while this is not a prohibited practice most programs wait until their work is almost completed, that is 80 to 90 percent complete, before making a judgment that the management reserve would not be needed for additional undefined work and could be applied to unfavorable contract cost variances.

[24] Defense Contract Management Agency, *Ground-Based Midcourse Defense Monthly Assessment Report Contract No. HQ0006-01-C-0001 for Missile Defense Agency* (Seal Beach, Calif.: Dec. 2002, p. 10). DCMA reported that cost performance reports were giving "… a misleading feeling that everything in the program is OK. For the 2nd month in a row, [the prime contractor] has covered up a significant Variance-at-Completion (-$107,800K) … by taking money out of Management Reserve (MR). This is not the intended purpose of using MR funds. [The prime contractor] is reporting a $0 Variance-At-Completion [VAC] by subtracting $107,800K from MR to reduce VAC to $0. Based on prior performance to date, this could be an indication of a trend for growth of the EAC [estimate-at-completion]."

Conclusions

Because of the President's direction to begin fielding a ballistic missile defense system in 2004, the MDA took a higher risk approach by beginning GMD system integration before knowing whether its critical technologies were mature. If development and testing progress as planned, however, MDA expects to have demonstrated the maturity of 7 of the 10 critical GMD technologies before the element is initially fielded in September 2004 and 2 others during fiscal year 2005. If technologies do not achieve their objectives during testing, MDA may have to spend additional funds in an attempt to identify and correct problems by September 2004 or accept a less capable system.

Because of other funding and scheduling priorities, MDA does not plan to demonstrate through integrated flight tests whether the Cobra Dane radar's software can process and communicate data on the location of enemy missiles in "real time." Although tests using sea- or air-launched targets before September 2004 would provide otherwise unavailable information on the software's performance, we recognize those tests would be costly and funds have not been allocated for that purpose. We also recognize that the most cost efficient means of testing the Cobra Dane radar is through launches involving foreign test missiles. However, we believe it would be useful for MDA to consider whether the increased confidence provided by a planned test event outweighs other uses for those funds.

MDA is investing a significant amount of money to achieve an operational capability during the first block of GMD's development, and the agency expects to continue investing in the element's improvement over the next several years. Because MDA is also developing other elements and must balance its investment in each, it needs an accurate GMD cost estimate. If it is used as intended, the EVM system can be an effective means of monitoring one of GMD's largest costs, the cost of having a contractor develop the GMD system. It is understandable that the dynamic changes in MDA's acquisition strategy led to major contract modifications, which made it more difficult for the contractor to establish a stable baseline. However, in this environment, it is even more important that MDA find ways to ensure the integrity of the interim baselines and to quickly determine that revised baselines can be fully relied on to identify potential problems before they significantly affect the program's cost.

Recommendations for Executive Action

To increase its confidence that the Ground-based Midcourse Defense element fielded in 2004 will operate as intended, we recommend that the Secretary of Defense direct the Director, Missile Defense Agency, to explore its options for demonstrating the upgraded Cobra Dane radar in its new ballistic missile defense role in a real-world environment before September 2004.

To improve MDA's oversight of the GMD element and to provide the Congress with the best available information for overseeing the program, we recommend that the Secretary of Defense direct the Director, Missile Defense Agency, to:

- ensure that when a contractor is authorized to begin new work before a price is negotiated that DCMA validate the performance measurement baseline to the extent possible by (1) tracking the movement of budget from the authorized, unpriced work account into the baseline, (2) verify that the work packages accurately reflect the new work directed, and (3) report the results of this effort to MDA; and
- strive to initiate and complete an integrated baseline review (IBR) of any major contract modifications within 6 months.

Agency Comments and Our Evaluation

DOD's comments on our draft report are reprinted in appendix II. DOD concurred with our first recommendation. DOD stated that MDA is exploring its options for demonstrating, prior to 2004, the upgraded Cobra Dane radar in a real-world environment. However, DOD noted that because it takes considerable time to develop and produce targets and to conduct safety and environmental assessments, completing a Cobra Dane radar test before September 2004 would be very challenging. DOD concluded that "targets of opportunity" (flight tests of foreign missiles) and ground testing may provide the best means to demonstrate the radar's maturity in the near term.

DOD partially concurred with our second recommendation. In responding to the first part of recommendation two, DOD stated that MDA and the DCMA will jointly determine the feasibility of tracking the budget for authorized, unpriced work into the baseline and will concurrently assess work package data while establishing the formal performance measurement baseline. DOD also stated that a selected portion of this work is already being accomplished by DCMA. We continue to believe in the feasibility of our recommendation. DCMA officials told us that they could monitor the movement of budget into the baseline and verify the work packages associated with the budget. In addition, the guidelines state that surveillance may be accomplished through sampling of internal and external data. We believe that if DCMA sampled the data as it is transferred into the baseline, the implementation of this recommendation should not be burdensome.

In responding to the second part of recommendation two, DOD stated that MDA will continue to adhere to current DOD policy by starting an IBR of any major contract modification within 6 months. MDA correctly pointed out that DOD's *Interim Defense Acquisition Guidebook* only requires a review be initiated within 6 months (180 days) after a contract is awarded or a major modification is issued. However, DOD's *Earned Value Management Implementation Guide* states that such a review is conducted within 6 months. Similar language is found in the applicable clause from the GMD contract,[25] which states that such reviews shall be scheduled as early as practicable and should be conducted within 180 calendar days after the incorporation of major modifications. While we understand the difficulty of conducting reviews within 180 days when the contract is complex and many subcontractors are involved, we believe that it is important for the government to complete an IBR as soon as possible to ensure accurate measurement of progress toward the program's cost, schedule, and performance goals.

DOD also provided technical comments to this report, which we considered and implemented as appropriate. In its technical comments, for example, DOD expressed particular concern that our draft report language asserting MDA's inability to rely on the EVM system was unsupported and misleading. DOD also stated that its prime contractor's EVM system is reliable. It stated, for example, that MDA has reviewed, and continues to review on a monthly basis, the contractor's cost performance reports and that the prime contractor's EVM system and accounting systems have been fully certified and validated by DCMA. We modified our report to better recognize MDA's ability to use and trust the EVM system. However, we still believe that MDA would benefit from taking additional measures to increase its confidence in the accuracy of its interim baselines. Also, when the revised baseline is in place, a review of its formulation and execution is necessary before MDA can confidently and fully rely on data from the EVM system.

[25] Defense Federal Acquisition Regulation Supplement clause 252.234-7001, EVM System (March 1998).

We conducted our review from December 2001 through August 2003 in accordance with generally accepted government auditing standards. As arranged with your staff, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from its issue date. At that time, we plan to provide copies of this report to interested congressional committees, the Secretary of Defense, and the Director, Missile Defense Agency. We will make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov/.

If you or your staff have any questions concerning this report, please contact me on (202) 512-4841. Major contributors to this report are listed in appendix V.

Sincerely yours,

Robert E. Levin
Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To determine when MDA plans to demonstrate the maturity of technologies critical to the performance of GMD's Block 2004 capability, we reviewed their critical technologies using technology readiness levels (TRLs) developed by the National Aeronautics and Space Administration and used by DOD. We did so by asking contractor officials at the Boeing System Engineering and Integration Office in Arlington, Virginia, to identify the most critical technologies and to assess the level of maturity of each technology using definitions developed by the National Aeronautics and Space Administration. We reviewed these assessments along with program documents, such as the results of recent flight tests and discussed the results with contractor and agency officials in order to reach a consensus, where appropriate, on the readiness level for each technology and identify the reasons for any disagreements.

In reviewing the agency's current cost estimate to develop the first block of the GMD element and its test bed, we reviewed and analyzed budget backup documents, cost documents, and selected acquisition reports for the GMD program extending over a period of several years. We also met with program officials responsible for managing the development and fielding of the GMD Block 2004 capability. For example, we met with officials from the GMD Joint Program Office in Arlington, Virginia, and Huntsville, Alabama; and the Office of the Deputy Assistant for Program Integration at the MDA, Arlington, Virginia.

To determine whether there were any significant risks associated with the estimate, we met with agency officials responsible for determining the cost of the GMD element to find out if there were costs that were omitted, but should have been included, in the estimate. We also analyzed data from cost performance reports that the GMD contractor developed for the MDA. We reviewed data from the GMD element and contracting officials and conducted interviews to discuss the data. Although we did not independently verify the accuracy of the cost performance reports we received from MDA, the data were assessed independently by DCMA.

Appendix II: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION, TECHNOLOGY AND LOGISTICS

16 JUL 2003

Mr. R. E. Levin
Managing Director, Acquisition and Sourcing Management
U.S. General Accounting Office
441 G Street, NW
Washington, D.C. 20548

Dear Mr. Levin:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "MISSILE DEFENSE: Additional Knowledge Needed in Developing System for Intercepting Long-Range Missiles," dated June 19, 2003 (GAO Code 120109/GAO-03-600). The Department appreciates the opportunity to comment on the draft report.

The Department concurs with the first recommendation and partially concurs with the second. MDA will continue to adhere to current DoD policy by starting an integrated baseline review of any major modification within six (6) months after contract definitization. Specific comments for each recommendation are enclosed. We are also providing recommendations for factual corrections in a separate enclosure. My point of contact for this report is Lt Col Christina N. Walton, USAF, (703) 697-5385, christina.walton@osd.mil.

Sincerely,

Mark D. Schaeffer
Principal Deputy
Defense Systems

Enclosures:
As Stated

GAO DRAFT REPORT – DATED JUNE 19, 2003
GAO CODE 120109/GAO-03-600

"MISSILE DEFENSE: ADDITIONAL KNOWLEDGE NEEDED IN DEVELOPING SYSTEM FOR INTERCEPTING LONG-RANGE MISSILES"

DEPARTMENT OF DEFENSE COMMENTS TO THE RECOMMENDATIONS

RECOMENDATION 1: GAO recommends that "To increase its confidence that the Ground-based Midcourse Defense element fielded in 2004 will operate as intended, we recommend that MDA explore its options for demonstrating the upgraded Cobra Dane radar in its new ballistic missile defense role in a real-world environment before September 2004."

DOD RESPONSE: Concur. MDA is considering the addition of an integrated flight test prior to September 30, 2004, that would prove-out the upgrades that are underway to the Cobra Dane radar at Shemya, Alaska. However, the lead time for adding radar tests with dedicated targets is considerable and depends on the time needed for target development and/or production, as well as the requisite safety and environmental assessments. As a result, accomplishing such testing before September 2004 would be very challenging. Consequently, targets-of-opportunity and ground testing may provide the best avenue for demonstrating the radar in the near term.

RECOMENDATION 2: To improve MDA's oversight of the Ground-based Midcourse Defense element and to provide Congress with more reliable information for overseeing the program, we recommend that MDA

- Ensure that when a contractor is authorized to begin new work before a price is negotiated that DCMA validate the performance measurement baseline to the extent possible by (1) tracking the movement of budget from the authorized, un-priced work account into the baseline, (2) verify that the work packages accurately reflect the new work directed, and (3) report the results of this effort to MDA.
- Strive to initiate and complete an integrated baseline review of any major contract modifications within 6 months.

DOD RESPONSE: Partially Concur. MDA and DCMA will jointly determine the feasibility of performing reviews of the transfer of budget for authorized, un-priced work into the baseline and assess work package data concurrently with the establishment of the formal performance measurement baseline. A selected portion of this work is already being accomplished by DCMA contractor surveillance activities. During the period that the contractor is establishing the Performance Measurement Baseline (PMB), there are reviews of contractor estimating and accounting processes including earned value management. MDA will continue to adhere to current DoD policy by starting an integrated baseline review of any major modification within six (6) months after contract definitization.

1

<u>DCMA Boeing Anaheim Comments</u>: DCMA early activities to validate the PMB included participation in all IBR activities (both at Prime and at Subcontractors), membership in all cost and financial Integrated Process Teams, attended program management reviews, reviewed prime and subcontractor's proposals, appointment of warranted Administrative Contract Officer, Certification of all the contractors ticketed system including; Accounting System, Anaheim Site Billing System, Anaheim Site, Estimating System, and Indirect & ODC System.

2

Appendix III: Technology Readiness Level Assessment Matrix

Technology readiness level (TRL)	Description	Hardware /software	Demonstration environment
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	None (paper studies and analysis)	None
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative, and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis)	None
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytical studies and demonstration of nonscale individual components (pieces of subsystem).	Lab
4. Component and/or breadboard. Validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.	Low fidelity breadboard. Integration of nonscale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab

Technology readiness level (TRL)	Description	Hardware /software	Demonstration environment
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	High fidelity breadboard. Functionally equivalent but not necessarily form and/or fit (size, weight, materials, etc). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight-demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.	Prototype. Should be very close to form, fit, and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, on a vehicle or in space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative operational environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight-qualified hardware	Developmental test and evaluation in the actual system application

Technology readiness level (TRL)	Description	Hardware /software	Demonstration environment
9. Actual system "flight proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	Operational test and evaluation in operational mission conditions

Source: GAO and its analysis of National Aeronautics and Space Administration data.

Note: GAO information based on U.S. General Accounting Office, *Missile Defense: Knowledge-Based Decision Making Needed to Reduce Risks in Developing Airborne Laser*, GAO-02-631 (Washington, D.C.: June 2002).

Appendix IV: Importance of Earned Value Management

Pulling together essential cost, schedule, and technical information in a meaningful, coherent fashion is always a challenge for any program. Without this information, management of the program will be fragmented, presenting a distorted view of program status. For several decades, DOD has compared the value of work performed to the work's actual cost. This measurement is referred to as Earned Value Management (EVM). Earned value goes beyond the two-dimensional approach of comparing budgeted costs to actuals. It attempts to compare the value of work accomplished during a given period with the work scheduled for that period. By using the value of completed work as a basis for estimating the cost and time needed to complete the program, the earned value concept should alert program managers to potential problems early in the program.

In 1996, in response to acquisition reform initiatives, DOD reemphasized the importance of earned value in program management and adopted 32 criteria for evaluating the quality of management systems. These 32 criteria are organized into 5 basic categories: organization, planning and budgeting, accounting considerations, analysis and management reports, and revisions and data maintenance. The 32 criteria are listed in table 1. In general terms, the criteria require contractors to (1) define the contractual scope of work using a work breakdown structure; (2) identify organizational responsibility for the work; (3) integrate internal management subsystems; (4) schedule and budget authorized work; (5) measure the progress of work based on objective indicators; (6) collect the cost of labor and materials associated with the work performed; (7) analyze any variances from planned cost and schedules; (8) forecast costs at contract completion; and (9) control changes.

Table 3: 32 Criteria for Earned Value Management Systems

Categories of Criteria	Criteria
Organization	1. Define the authorized work elements for the program. A work breakdown structure, tailored for effective internal management control, is commonly used in this process.
	2. Identify the program organizational structure, including the major subcontractors responsible for accomplishing the authorized work, and define the organizational elements in which work will be planned and controlled.
	3. Provide for the integration of the company's planning, scheduling, budgeting, work authorization, and cost accumulation processes with each other and, as appropriate, the program work breakdown structure and the program organizational structure.
	4. Identify the company organization or function responsible for controlling overhead (indirect costs).
	5. Provide for integration of the program work breakdown structure and the program organizational structure in a manner that permits cost and schedule performance measurement by elements of either or both structures as needed.

Categories of Criteria	Criteria
Planning and Budgeting	6. Schedule the authorized work in a manner that describes the sequence of work and identifies significant task interdependencies required to meet the requirements of the program.
	7. Identify physical products, milestones, technical performance goals, or other indicators that will be used to measure progress.
	8. Establish and maintain a time-phased budget baseline, at the control account level, against which program performance can be measured. Budget for far-term efforts may be held in higher-level accounts until an appropriate time for allocation at the control account level. Initial budgets established for performance measurement will be based on either internal management goals or the external customer-negotiated target cost including estimates for authorized but undefinitized work. On government contracts, if an over target baseline is used for performance measurement reporting purposes, prior notification must be provided to the customer.
	9. Establish budgets for authorized work with identification of significant cost elements (labor, material, etc.) as needed for internal management and for control of subcontractors.
	10. To the extent it is practical to identify the authorized work in discrete work packages, establish budgets for this work in terms of dollars, hours, or other measurable units. Where the entire control account is not subdivided into work packages, identify the far term effort in larger planning packages for budget and scheduling purposes.
	11. Provide that the sum of all work package budgets plus planning package budgets within a control account equals the control account budget.
	12. Identify and control level of effort activity by time-phased budgets established for this purpose. Only that effort which is unmeasurable or for which measurement is impractical may be classified as level of effort.
	13. Establish overhead budgets for each significant organizational component of the company for expenses that will become indirect costs. Reflect in the program budgets, at the appropriate level, the amounts in overhead pools that are planned to be allocated to the program as indirect costs.
	14. Identify management reserves and undistributed budget.
	15. Provide that the program target cost goal is reconciled with the sum of all internal program budgets and management reserves.
Accounting Considerations	16. Record direct costs in a manner consistent with the budgets in a formal system controlled by the general books of account.
	17. When a work breakdown structure is used, summarize direct costs from control accounts into the work breakdown structure without allocation of a single control account to two or more work breakdown structure elements.
	18. Summarize direct costs from the control accounts into the contractor’s organizational elements without allocation of a single control account to two or more organizational elements.
	19. Record all indirect costs which will be allocated to the contract.
	20. Identify unit costs, equivalent units costs, or lot costs when needed.
Accounting Considerations	21. For EVMS, the material accounting system will provide for: (1) Accurate cost accumulation and assignment of costs to control accounts in a manner consistent with the budgets using recognized, acceptable, costing techniques. (2) Cost performance measurement at the point in time most suitable for the category of material involved, but no earlier than the time of progress payments or actual receipt of material. (3) Full accountability of all material purchased for the program including the residual inventory.

Categories of Criteria	Criteria
Analysis and Management Reports	22. At least on a monthly basis, generate the following information at the control account and other levels as necessary for management control using actual cost data from, or reconcilable with, the accounting system: (1) Comparison of the amount of planned budget and the amount of budget earned for work accomplished. This comparison provides the schedule variance. (2) Comparison of the amount of the budget earned and the actual (applied where appropriate) direct costs for the same work. This comparison provides the cost variance.
	23. Identify, at least monthly, the significant differences between both planned and actual schedule performance and planned and actual cost performance, and provide the reasons for the variances in the detail needed by program management.
	24. Identify budgeted and applied (or actual) indirect costs at the level and frequency needed by management for effective control, along with the reasons for any significant variances.
	25. Summarize the data elements and associated variances through the program organization and/or work breakdown structure to support management needs and any customer reporting specified in the contract.
	26. Implement managerial actions taken as the result of earned value information.
	27. Develop revised estimates of cost at completion based on performance to date, commitment values for material, and estimates of future conditions. Compare this information with the performance measurement baseline to identify variances at completion important to company management and any applicable customer reporting requirements including statements of funding requirements.
Revisions and Data Maintenance	28. Incorporate authorized changes in a timely manner, recording the effects of such changes in budgets and schedules. In the directed effort prior to negotiation of a change, base such revisions on the amount estimated and budgeted to the program organizations.
	29. Reconcile current budgets to prior budgets in terms of changes to the authorized work and internal replanning in the detail needed by management for effective control.
	30. Control retroactive changes to records pertaining to work performed that would change previously reported amounts for actual costs, earned value, or budgets. Adjustments should be made only for correction of errors, routine accounting adjustments, effects of customer or management directed changes, or to improve the baseline integrity and accuracy of performance measurement data.
	31. Prevent revisions to the program budget except for authorized changes.
	32. Document changes to the performance measurement baseline.

Source: *Interim Defense Acquisition Guidebook*, app. 4.

Note: In the *Interim Defense Acquisition Guidebook*, DOD states that these guidelines are reproduced from the American National Standards (ANSI) Institute/Electronic Industries Alliance (EIA) EVM System Standard (ANSI/EIA-748-98), Chapter 2 (May 19, 1998).

The criteria have become the standard for EVM and have also been adopted by major US government agencies, industry, and the governments of Canada and Australia. The full application of EVM system criteria is appropriate for large cost reimbursable contracts where the government bears the cost risk. For such contracts, the management discipline described by the criteria is essential. In addition, data from an EVM system have been proven to provide objective reports of contract status, allowing numerous indices and performance measures to be calculated. These can then be used to develop accurate estimates of anticipated costs at completion, providing early warning of impending schedule delays and cost overruns.

The standard format for tracking earned value is through a Cost Performance Report (CPR). The CPR is a monthly compilation of cost, schedule and technical data which displays the performance measurement baseline, any cost and schedule variances from that baseline, the amount of management reserve used to date, the portion of the contract that is authorized unpriced work, and the contractor's latest revised estimate to complete the program.

As a result, the CPR can be used as an effective management tool because it provides the program manager with early warning of potential cost and schedule overruns. Using data from the CPR, a program manager can assess trends in cost and schedule performance. This information is useful because trends tend to continue and can be difficult to reverse. Studies have shown that once programs are 15 percent complete the performance indicators are indicative of the final outcome. For example, a CPR showing a negative trend for schedule status would indicate that the program is behind schedule. By analyzing the CPR, one could determine the cause of the schedule problem such as delayed flight tests, changes in requirements, or test problems because the CPR contains a section that describes the reasons for the negative status. A negative schedule condition is a cause for concern, because it can be a predictor of later cost problems since additional spending is often necessary to resolve problems. For instance, if a program finishes 6 months later than planned, additional costs will be expended to cover the salaries of personnel and their overhead beyond what was originally expected. CPR data provides the basis for independent assessments of a program's cost and schedule status and can be used to project final costs at completion in addition to determining when a program should be completed.

Examining a program's management reserve is another way that a program can use a CPR to determine potential issues early on.

Management reserves, which are funds that may be used as needed, provide flexibility to cope with problems or unexpected events. EVM experts agree that transfers of management reserve should be tracked and reported because they are often problem indicators. An alarming situation arises if the CPR shows that the management reserve is being used at a faster pace than the program is progressing toward completion. For example, a problem would be indicated if a program has used 80 percent of its management reserve but only completed 40 percent of its work. A program's management reserve should contain at least 10 percent of the cost to complete a program so that funds will always be available to cover future unexpected problems that are more likely to surface as the program moves into the testing and evaluation phase.

Appendix V: GAO Contact and Staff Acknowledgments

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