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Report to Congressional Requesters

April 2003

MISSILE DEFENSE

Knowledge-Based Practices Are Being Adopted, but Risks Remain

GAO-03-441

April 2003

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Highlights

Highlights of GAO-03-441, a report to Congressional Requesters

MISSILE DEFENSE

Knowledge-Based Practices Are Being Adopted, but Risks Remain

Why GAO Did This Study

The Department of Defense (DOD) would like to build a capable missile defense system that paces an ever-evolving threat. This is an expensive and risky endeavor because it requires a diverse set of technologies to be quickly developed, integrated, and deployed across an array of platforms. DOD estimates that it will need $50 billion for missile defense research and development over the next 6 years and likely additional funds in subsequent years. GAO was asked to review the Missile Defense Agency's (MDA) strategy for this investment and determine what knowledge-based practices characteristic of successful programs are being adopted by MDA; what significant practices are not being adopted; and whether MDA is following the practices that it has adopted.

What GAO Recommends

GAO is recommending that DOD prepare life cycle cost estimates for missile defense elements before beginning integration activities and explore the option of setting aside funds to produce and operate the missile defense system over the long term.

www.gao.gov/cgi-bin/getrpt?GAO-03-441.

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

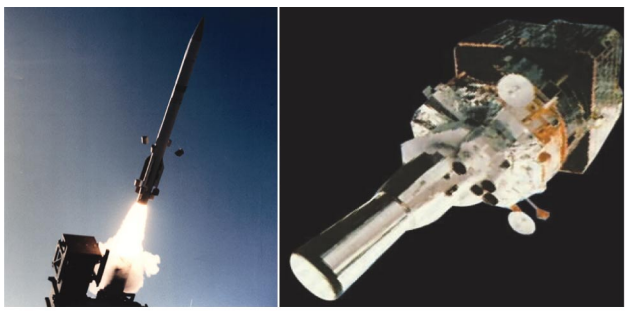
What GAO Found

Our work has shown that programs are most successful when they evolve products over time rather than try to make big leaps in capability and when the programs adopt knowledge-based acquisition processes. Similarly, MDA is taking an evolutionary approach to developing the missile defense system by developing capabilities in spirals or "blocks" rather than attempting to deliver all desired capabilities at one time. The agency intends to facilitate this approach by keeping requirements flexible before beginning activities to integrate technologies into a planned block, following a knowledge-based development plan, and demonstrating that technologies work as intended before beginning system integration of a block. In addition, the agency is seeking to involve stakeholders—such as the military services and operational testers—early in the development effort.

However, MDA has not adopted some knowledge-based practices regarding long-term investment decision making and, as a result, the missile defense program's success could be hampered. First, MDA is not making an early determination of the full cost of a capability. Such an estimate would help decision makers more effectively evaluate which technologies to include because they offer the best capability for the funds invested. Second, DOD is not allocating a "wedge" of funds in its Future Years Defense Plan for system production and operations. Without this wedge, DOD may not have the funds needed to procure and maintain the missile defense system.

In addition, the President's directive to begin fielding a missile defense capability by 2004 places MDA in danger of getting off track early and impairing the effort over the long term. This danger is highlighted by MDA's decision to not follow some of its knowledge-based practices as it develops the first block of the system. For example, MDA is beginning system integration of its first block with immature technology and limited testing. While doing so may help MDA meet the President's deadline, it also increases the potential that some elements may not work as intended.

Examples of Missile Defense Elements



Source: Missile Defense Agency.
Left: ground-based interceptor; right: satellite sensors.

Contents

Abbreviations

BMDS	Ballistic Missile Defense System
DOD	Department of Defense
MDA	Missile Defense Agency

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United States General Accounting Office
Washington, DC 20548

April 30, 2003

The Honorable Carl Levin
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Jack Reed
United States Senate

The threat from foreign ballistic missiles has grown steadily since the end of the Cold War. At least 25 countries now have or are in the process of acquiring missiles capable of delivering nuclear, biological, or chemical weapons. Countering this threat demands not only that the Department of Defense (DOD) develop cutting-edge technology, but also that it acquire and deploy complex systems more rapidly and effectively.

DOD faces significant technical challenges in building a missile defense program. So far, DOD has had mixed results in achieving a "hit-to-kill" capability to destroy enemy warheads reliably, and DOD is still completing development of the components needed to detect and track a missile in all phases of its flight—from the boost phase, through the midcourse, and into the terminal phase. As it works to develop and prove these capabilities, DOD must also make sure that all missile defense elements can work together as an integrated system—a complex task in itself, given the number and diversity of elements involved in missile defense. Once these basic hurdles have been overcome, DOD still faces a far greater technical challenge in achieving target discrimination—that is, the capability to distinguish real warheads from decoys—to defeat more sophisticated threats.

DOD also faces the challenge of delivering a weapon system with the capability promised and within the time and cost promised. For example, previous efforts to develop an airborne laser system and a space-based tracking and surveillance system encountered substantial delays, cost overruns, and other difficulties because DOD undertook these efforts

without fully understanding the effort that would be needed to mature technologies critical to developing the systems' required capabilities.[1]

Lastly, the development of missile defense weapon systems will also be costly. DOD estimates that it will need about $50 billion for missile defense research and development between fiscal years 2004 and 2009, or an average of over $8 billion per year. This investment does not include funding after 2009 to complete development of those systems, let alone the funding needed before and after 2009 to produce and operate the systems.

In January 2002, facing these challenges, the Secretary of Defense directed the Missile Defense Agency (MDA) to orchestrate the integration of DOD's diverse missile defense elements into one layered "system of systems" and to change its acquisition strategy as needed in doing so. In response, MDA has sought to implement practices that have proven successful in other DOD and commercial-sector programs. Taken together, these practices demand a high level of knowledge about a product at key junctures during development and that this knowledge be used to make prudent investment decisions. For example, developers should know that a technology has been demonstrated to work as intended before it is integrated into a product.

The importance of making the best decisions possible is underscored by the time-critical nature of MDA's efforts. In December 2002, the President directed DOD to begin fielding an initial capability in 2004 to protect the United States against missile attacks. To help ensure that MDA is using its resources wisely to develop the best possible system, you asked us to determine the extent to which the agency's acquisition strategy incorporates the knowledge-based practices characteristic of successful development programs. To better answer your question, we separated it into three parts: (1) What knowledge-based practices are being adopted by MDA? (2) What significant practices are not being adopted? and (3) Is MDA following the knowledge-based practices that it has adopted?

[1] 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.: July 12, 2002). U.S. General Accounting Office, *Defense Acquisitions: Space-Based Infrared System-low at Risk of Missing Initial Deployment Date*, GAO-01-6 (Washington, D.C.: Feb. 28, 2001).

Results in Brief

MDA has adopted practices that offer the best opportunity to develop a complex weapon system successfully. Similar to the successful product development practices of leading commercial organizations, MDA is developing the missile defense system in "blocks," rather than trying to make a big leap in capability. The agency intends to facilitate this evolutionary approach by keeping the system's requirements flexible before beginning activities to integrate technologies into a planned block of the missile defense system, following a knowledge-based development plan, and maturing technology before beginning system integration of a block. In addition, the agency is seeking to involve stakeholders—such as the military services and the operational testers—early in the development effort.

However, MDA has not adopted two significant practices regarding long-term investment decision making, and, as a result, the program's success could be hampered. First, MDA is not making an early determination of the full cost of a capability. Specifically, before beginning system integration, MDA does not estimate the total costs for development, production, operations, and sustainment of that block. Such an estimate would help decision makers in evaluating which technologies to include because they offer the best capability for the funds invested. MDA officials told us that they are considering steps to provide such estimates earlier. Second, DOD is not allocating a "wedge" of funds in its Future Years Defense Plan (fiscal years 2004 through 2009) for system production and operations. MDA officials told us that such a wedge has not been set aside because MDA's acquisition strategy does not presume that a decision will be made to produce and operate the system. DOD risks, however, that when it is ready to procure and maintain the missile defense system, it will not have the funds to do so unless it reduces or eliminates its investment in other important weapon systems. This approach brings little transparency to future investment choices and may constrain options for decision makers.

The President's directive to begin fielding an initial defensive capability in 2004 also places MDA in danger of getting off track early and introducing more risk into the missile defense effort over the long term. This danger is highlighted by MDA's decision to not follow some of its knowledge-based practices as it develops the first block of the missile defense system, which will provide the initial capability. Because of time pressures, MDA must include components that have not been demonstrated as mature and ready for system integration into a particular element, let alone the block overall. For example, MDA has encountered considerable difficulty in developing a new three-stage booster and has yet to flight test interceptor

boosters in configurations planned for fielding in September 2004. Also, MDA's test program has been limited to date and is under considerable schedule pressures. A knowledge-based approach to testing validates whether components (1) work individually, (2) work together as a system in a controlled setting, and (3) work together as a full system in a realistic setting. MDA's integrated flight tests to date have used surrogate and prototype components and have been executed under non-stressing conditions. As a result, testing to date has provided only limited data for determining whether the system will work as intended in 2004. Also, MDA has no plans to demonstrate through flight testing the upgraded primary radar in Alaska that will be used to detect and track enemy missiles.

We are making recommendations to DOD for providing decision makers with more timely information on the cost and funding needs of missile defense. In commenting on a draft of this report, DOD concurred with our recommendations.

Background

In January 2002, the Secretary of Defense refocused the ballistic missile defense program. The Secretary delegated to MDA authority to manage all ballistic missile defense systems under development and shifted such programs controlled by the military services—such as the Army's Theater High Altitude Area Defense program—to the agency. Other programs moved to MDA are highlighted in figure 1. These programs, previously recognized by DOD as major defense acquisition programs, are now considered "elements" and have been consolidated into one overall major program called the Ballistic Missile Defense System (BMDS). Future architectures of the BMDS may also include "stand-alone" components (primarily sensors) that would operate in concert with the various missile defense elements.

Figure 1: Examples of Missile Defense Programs Transferred from Services into MDA

- **Theater High Altitude Area Defense (THAAD)** - Ground-based system designed to intercept short- and medium-range ballistic missiles. Program transferred into MDA from the Army.
- **Medium Extended Air Defense System (MEADS)** - Ground-based system designed to intercept short-range ballistic missiles, cruise missiles, and aircraft. Program transferred into MDA from the Army.
- **Aegis Ballistic Missile Defense (Aegis BMD)** - Ship-based system designed to intercept short and medium-range ballistic missiles. Program transferred into MDA from the Navy.
- **Airborne Laser** - Air-based system designed to intercept ballistic missiles in boost phase through directed-energy (laser) intercepts. Program transferred into MDA from the Air Force.
- **Space Tracking and Surveillance System (STSS)** - Low orbiting satellites designed to track missiles throughout entire flight. Program transferred into MDA from the Air Force.

Source: DOD.

In December 2002, President Bush directed the Department of Defense to begin fielding the first block of the ballistic missile defense system for operational use in 2004. That is, in addition to focusing resources on the development of a testbed for developmental testing of missile defense elements, he instructed MDA to build in an operational capability that would protect the United States against missile attacks. The fielding of such capabilities is referred to as an "initial defensive operations" capability, and, in a statement by the Secretary of Defense, "…would be a very preliminary, modest capability." The initial capability will be based on the testbed and augmented with additional developmental assets.

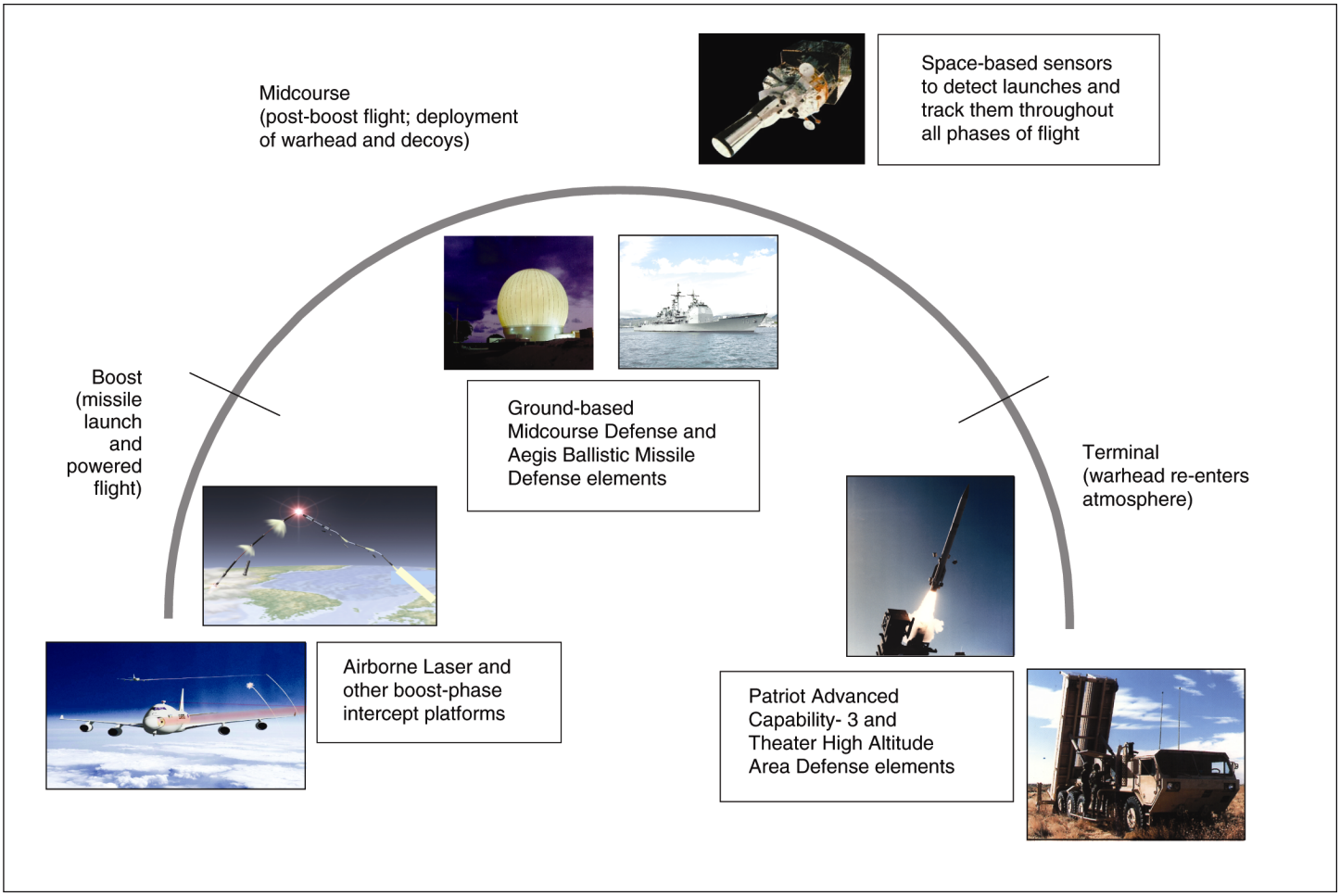
When fully deployed, the BMDS will include (1) space- and ground-based sensors to provide early warning and tracking of missile launches; (2) ground-based radars to identify and refine the tracks of threatening reentry vehicles and associated objects; (3) ground- and sea-based interceptors to destroy enemy missiles through "hit-to-kill" impacts; and (4) fire control nodes for battle management and execution of the ballistic missile defense mission. A notional architecture of future BMDS blocks is illustrated in figure 2. For example, the initial capability for defense of the United States against long-range missiles would come

from the Ground-Based Midcourse Defense element and BMDS sensors, as follows:

- **Ground-Based Midcourse Defense Element.** The principal components of the Ground-Based Midcourse Defense element for defensive operations include interceptors sited at Fort Greely, Alaska, and Vandenberg Air Force Base, California; a fire control node for battle management and execution located at Schriever Air Force Base, Colorado, with a backup node at Fort Greely; an upgraded Cobra Dane radar at Eareckson Air Station in Shemya, Alaska; and an upgraded early warning radar at Beale Air Force Base, California.
- **BMDS Sensors.** Sensors external to the Ground-Based Midcourse Defense element and available for defensive operations include Defense Support Program satellites for missile warning and forward-deployed Aegis AN/SPY-1 radars on existing Navy cruisers.

The above assets comprise the initial configuration, which is scheduled for fielding at the end of September 2004. The agency's near-term intention is to expand this capability by adding more interceptors at Fort Greely, Alaska; a sea-based X-band radar deployed in the Pacific for use in flight testing; and an upgraded early warning radar at Fylingdales, England, by the end of 2005.

Figure 2: Notional Architecture of Future Ballistic Missile Defense System



Source: Missile Defense Agency.

Acquisition Strategy Adopts Many Knowledge-Based Practices

To ensure the delivery of high-quality products on time and within budget, successful developers have adopted acquisition strategies that are anchored in knowledge. Specifically, they establish decision points for moving forward from technology development to product development and on to production.[2] At each decision point, decision makers ask themselves whether they have gained the knowledge they need to proceed into the next acquisition phase. For example, they determine whether the work can be completed with the money and time available and whether the product will be worth the required investment. If any of these questions are answered negatively, the program does not go forward. Other practices that facilitate successful outcomes include developing systems in stages rather than attempting to deliver all desired capabilities at one time, keeping requirements flexible so that the system can be produced within available resources, making sure technology is proven before incorporating it into a development program, and involving the right people at the right time in decision making. Commercial and DOD programs that have successfully implemented these practices have found that they help curb the incentive to rely on immature technologies and to over-promise the capability that can be delivered. Moreover, these programs found that keeping stakeholders involved in decision making ensured that the developed product better met the customers' needs.

MDA realizes the value of these practices and is seeking to incorporate them into its acquisition strategy. Specifically, as discussed below, MDA plans to evolve the missile defense system over time, rather than trying to make a big leap in its capability. MDA is also planning to keep the system's requirements flexible before beginning system integration and to follow a knowledge-based development plan. In addition, MDA is seeking to involve stakeholders—such as the military services and the operational testers—early in the development effort.

[2] The three acquisition phases are distinguished by the activities that occur during each of the three phases. During technology development, scientists apply scientific knowledge to a practical engineering problem and demonstrate that components with desired capabilities can be developed. Product development includes integrating those components into a stable system design and demonstrating that the design will result in a product that meets the customer's needs and can be produced with the time and money available. Production is the manufacturing of the product.

Evolutionary Development

Historically, many new development programs in DOD have sought to achieve a great leap ahead in capabilities. Because the technology was often not available to make such leaps, programs were often in development for years while engineers tried to develop and mature the needed technologies. As the time required to develop a system increased, so did the cost of the system.

In contrast, development programs are most successful when they take an evolutionary, or phased, approach. In doing so, they establish time-phased plans to develop new products in increments. The first increment often has a limited capability because it incorporates technology that is already mature or can be matured quickly. As new technology is developed, it is incorporated into subsequent increments so that the product's capability evolves over time. This approach reduces risks by introducing less new content and technology into a program's design and development effort. An evolutionary strategy also enables developers to deliver a series of interim capabilities to the customer more quickly. Recognizing the benefits of evolving systems, DOD recently revised its acquisition system policy to encourage evolutionary development.

The Missile Defense Agency's new strategy for developing the ballistic missile defense system adopts evolutionary development. At the beginning of each block, the agency intends to predict the capability that can be developed given a "tool box"[3] of currently available technology and then to design that system. As additional technology matures, the agency can incorporate it into the next block being developed.

Two key practices adopted by MDA can be expected to help the agency in taking an evolutionary approach. They include (1) keeping requirements flexible and (2) following a knowledge-based development plan with specific decision points and criteria for moving forward.

Flexible requirements

Customers generally want new products that are high performance at low cost, delivered as soon as possible. But developing and producing such a product may exceed the developer's technology or engineering expertise, or may be too costly and time-consuming for the customer to accept. Therefore, what a customer needs in a product and what a developer can produce given available resources must be matched to

[3] All possible elements/components and interfaces that could be used in a ballistic missile defense system.

form an achievable set of product requirements before development begins. To make this match, both the customer and the developer must be flexible so that potential gaps between needs and resources can be closed. Flexibility represents the customer's ability and willingness to lower product expectations, coupled with the product developer's willingness and ability to invest more resources to reduce technical risks before beginning system integration. Without flexibility, resources and needs can still be matched, but the options for closing the gaps between the two are limited to additional investments on the developer's part. In fact, our past reviews have found that many traditional DOD acquisition programs incurred substantial cost increases and schedule delays because requirements by the military services were unrealistic and inflexible.

Because of its flexibility, MDA's new "capabilities-based approach" for the development of missile defense elements provides a greater opportunity to resolve this potential gap between resources and needs.[4] Instead of proceeding with the development of a solution based on firm operational requirements set by the services, the agency, in coordination with the warfighter, considers a number of system architectural options that can be developed given the mature technologies that are available. Decision makers evaluate the alternative architectures according to the potential military utility that each offers, given the constraints of cost and schedule. For example, decision makers would compare the regions of the world that each architecture could defend from missile launches (defended area) or each architecture's probability of engagement success. This acquisition approach eliminates any possible gap between resources and needs; the customer (warfighter) accepts the best capability that the developer can deliver given available resources and assumes enhanced capabilities will be built into future blocks.

Knowledge-based development plan

In the early stages of a major defense acquisition program, DOD establishes a master schedule for moving through development and into production. Historically, once these milestones have been established, they have often been an impetus for moving forward even if requisite knowledge had not been attained—an action that invariably caused schedules to slip and costs to rise. By contrast, we have found that successful developers place more importance on capturing specific

[4] At the beginning of systems integration, MDA plans to establish system capability specifications. As in any organization, these specifications may change if testing shows that they are unattainable or that meeting them will be too costly or take too much time.

technology, design, and manufacturing knowledge than meeting milestones and they use this knowledge to make investment decisions. Moreover, these developers identify and use specific markers or criteria—such as technology readiness levels, percentage of engineering drawings released to the manufacturer, or the percentage of manufacturing processes under statistical control—to ensure that the program has sufficient knowledge to move forward.

MDA has similarly adopted a structured plan, called the Integrated Master Plan, for moving forward with requisite knowledge. Every block would move through eight formal "events," each of which would include an identified set of accomplishments that should be completed before the program moves on to the next event. (See table 1 for a list of events and their associated accomplishments.) As a block moves through the events, MDA plans to use quantitative criteria whenever possible to enhance decisions on whether to continue developing the block as it is or to make changes. At the end of a block's development, MDA expects to recommend one of four alternative actions to decision makers. Officials could recommend that the elements be (1) transferred to the services to be produced and fielded in its current configuration, (2) further developed in a subsequent block, (3) retained as a test asset in the missile defense testbed, with some capability available for operational use, or (4) terminated.

One such quantitative criterion adopted by MDA is technology readiness levels. Our reviews have found that successful developers often use technology readiness levels as an analytical tool to assess the maturity of technology being considered for inclusion in a product. There are nine levels of maturity. The level increases as the technology becomes closer in form, fit, and function to the actual system and is demonstrated in more realistic environments. For example, technology is least mature, or least ready for inclusion in a product, when it is an idea being explored in paper studies. Conversely, technology is most mature when it has been incorporated into the intended product and that product has been demonstrated in its intended environment. The lower the level of technology readiness, the more ground that must be covered to bring the technology to the point at which it can meet the intended product's cost, schedule, and performance requirements with little risk. We found that most successful developers insert new technology into a product only when the technology has been incorporated into prototype hardware and that hardware has been demonstrated to work in the environment in which it is expected to be used.

MDA's knowledge-base development plan incorporates the use of technology readiness levels at Event 1 to assess the maturity of technology proposed for a block configuration. The strategy calls for including new technology at system integration (Event 4) if that technology has been proven in prototype hardware that works in the environment in which it is expected to be used. While the incorporation of mature technology at system integration is MDA's preferred approach, the strategy retains the flexibility to include less mature technology if it offers a significant benefit and the risk of including it is acceptable. In such instances, MDA expects to develop a plan for reducing the risk of moving forward with immature technology and to remove the technology from the block if the risk has not been reduced at subsequent decision points.

Table 1: Events and Accomplishments within MDA's Integrated Master Plan

Event 0–Block Capability Alternatives
Block planning process completed
Long lead targets, tests, and exercises identified
Affordability Analysis completed
Preliminary block plan approved
Event 1–Preliminary Configuration Definition
Preliminary block description approved
Technology readiness levels assessed
Performance assessments updated
Preliminary concept of operations and operational architecture drafted
Risks assessed and mitigation programs established
Detailed cost estimates for elements/components available
Cost/benefit analysis updated
Integration/test objectives defined
Element/component preliminary design reviews completed
Required funding identified
Integrated master schedule completed
Event 2–Configuration Definition
Critical design reviews for all element/component/targets programs completed
Performance/cost assessments updated
Risks assessed and mitigation programs updated
Military utility characterized and concept of operations refined
Preliminary integration test plan available
Funding available and resources allocated
Block definition updated
Integrated master schedule updated
Event 3–First Development Article
First development article built and initial tests completed
Targets built and initial tests completed

Test range and support planning completed
Concept of operations defined and operational architecture available
Funding and Estimate at Completion assessed
Event 4–Integrated Test Readiness Review
Block integration test planning completed
Element/component test and checkout completed
Target test and checkout completed
Ballistic missile defense system tactics, techniques, and procedures for designated user defined
Funding and Estimate at Completion updated
Operational characterization of each element completed
Operational certification of element completed
Event 5–Interim Test and Progress Review
50 percent of system test objectives accomplished
Support systems defined
Training systems defined
Funding updated and Estimate at Completion verified
Initial transition plans completed
Initial operational characterization completed
Event 6–Element/component transition decision points
System/element/component testing completed
Operational characterization completed
Support systems planned and budgeted
Training systems planned and budgeted
Transition plans completed and funded
Production plans available
Updated block definition available
Element/component certification of military utility completed
Service total obligation authority available
Event 7–Block Certification of military utility
Military utility assessed and system element/component offered for transition
Ballistic missile defense system capability demonstrated
Life cycle cost estimate indicates long-term affordability
Reliability, maintainability, and availability, and support requirements characterized
Block certification of military utility completed
Integration of declared block capability of ballistic missile defense system

Source: DOD.

Note: The events and accomplishments in MDA's Integrated Master Plan are being revised. This set was in effect as of February 2003.

Involvement of Stakeholders

Developers have found that if they are to be successful, all groups that have a stake in the product should be involved at all appropriate stages in the development effort. For example, cost analysts are needed to accurately estimate the cost of the product, experts in test and evaluation are needed to objectively assess the performance of product prototypes,

and others are needed to enhance understanding of the customer's needs. By involving these groups from the time a product design is created and keeping them involved throughout the product integration and demonstration phases, a program can ensure that it has a complete perspective.

A key forum for stakeholder input is the Missile Defense Support Group, which includes representatives from the Joint Air and Missile Defense Organization; the Comptroller's Office; the Director, Operational Test and Evaluation; and other units across DOD. The support group provides advice on such subjects as policy, operations, testing, acquisition, and resources to the Director of the Missile Defense Agency and the Under Secretary of Defense for Acquisition, Technology and Logistics, and supports the Senior Executive Council[5] in decision making. In addition, an analytical working group remains in close contact with MDA management so that it can collect information for the Missile Defense Support Group as well as conduct independent analyses of the missile defense program's work.

Initially, not all members of the Missile Defense Support Group and its working group believed that MDA's approach to stakeholder involvement would be successful. Soon after the support group was established, members voiced concern that they were not getting sufficient access to agency information. Members said that communication with MDA was poor and that access to knowledgeable MDA individuals was limited, all of which made it difficult to provide timely advice. For example, in April 2002, the agency presented options to the support group to address capability shortfalls in sea-based terminal defense caused by the loss of the Navy Area missile defense program.[6] Members of the group questioned why a successor to the Navy Area program was needed. MDA planned additional briefings pertaining to this issue; however, the group was never briefed and MDA, without additional group input, went directly to the Under Secretary of Defense for Acquisition, Technology and Logistics to obtain approval for a particular approach to sea-based terminal missile

[5] The Senior Executive Council is led by the Deputy Secretary of Defense, and its members are the Under Secretary of Defense for Acquisition, Technology and Logistics, and the Secretaries of the Army, Navy, and Air Force. The Council provides oversight of MDA's activities and is responsible for making program adjustments and deciding to transition or transfer a capability to the services. Furthermore, the Council approves MDA's investment strategy and decisions.

[6] DOD cancelled the Navy Area program in 2001 due to cost overruns.

defense. DOD officials told us that they did not seek further input from the group because there was insufficient time for it to fully understand and evaluate the issue before a decision had to be made.

Shortly after this, support group members provided comments and suggestions to the Under Secretary and the MDA director on increasing communication, obtaining access to MDA personnel, and receiving timely information. Subsequently, MDA made progress in addressing the support group's suggestions and concerns relating to these issues. As a result, according to support group members, the level of interaction, communication, and involvement has improved. In particular, support group members attend weekly system and element review meetings and have regular interaction with agency personnel outside of the Missile Defense Support Group forum.

Two Knowledge-Based Practices Have Not Been Adopted

While MDA has adopted many of the practices of successful acquisition programs, it has not incorporated two particularly significant ones. Specifically, before beginning system integration, successful developers reduce their investment risk by estimating total costs and determining that funding is available for developing, producing, and operating the system. (We recently reported on the significance of DOD's costs for operating its weapon systems and keeping them ready for action over many years.[7])

In MDA's case, decision makers would benefit from having this knowledge available before MDA begins system integration because decision makers would be better positioned to consider whether to delay until subsequent blocks those elements that currently have unaffordable production, operation, or maintenance costs and whether costs might be lowered in the future by inserting new technology or implementing better engineering solutions. The information would also help decision makers to compare all elements' costs and decide which elements should be included in a planned block of the missile defense system because they offer the best capability for the funds invested.

As of February 2003, MDA's draft Integrated Master Plan did not call for an element's life cycle cost to be estimated at the beginning of system

[7] U.S. General Accounting Office, *Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs*, GAO-03-57 (Washington, D.C.: Feb. 11, 2003).

integration (Event 4) but rather at the point when that element is considered for transfer to a military service for production, operation, and maintenance (Event 7). Moreover, MDA may never estimate the full cost of some elements because, according to officials, some elements may never be transferred to a military service for production and operation. For example, MDA plans to continually upgrade elements such as the Ground-Based Midcourse Defense element in the missile defense test bed even though it would be available for combat use. In such cases, MDA plans to estimate only the element's development costs—not its production, operation, and maintenance costs.

Also, DOD has not allocated funds in its Future Years Defense Plan (fiscal years 2004 through 2009) for the production, operation, and maintenance of any elements that might be transferred in the future to the military services. MDA has established optional decision points called "off ramps" where elements such as Theater High Altitude Area Defense could be transferred to the military services, but DOD has not set aside a "wedge" of funding for the element's production and operating costs.

MDA officials told us that the agency is considering revisions to its Integrated Master Plan so that it can provide decision makers with complete life cycle cost information on each element prior to beginning system integration activities for each block of the missile defense system. For example, MDA anticipates defining each element's training and support systems before it begins system integration activities. The officials said that that they are still, however, in the process of determining the cost information that needs to be collected and the timing of its collection. In terms of setting aside a wedge of funding in the Future Years Defense Plan for production and operations costs, MDA officials told us that no such action is planned at this time because MDA's acquisition strategy does not presume that a decision will be made to transfer the element to the military service. They told us that they expect funding would be made available.

However, we believe that unplanned operation and maintenance costs could be a particular problem for DOD because its budget for these expenses is already stressed by the rising cost to operate and maintain many aging weapon systems. Also, when DOD is at the point of deciding whether to transfer elements of the missile defense system to a military service for production and operation, DOD could find that it does not have the funds available for missile defense without reducing or eliminating funding for other important weapon systems.

MDA Is Not Following Some Knowledge-Based Practices in Developing 2004 Capability

Because the President directed that a missile defense capability be fielded beginning in 2004, MDA will not be able to follow some knowledge-based practices in developing the initial capability in this brief time. As noted earlier, MDA's draft Integrated Master Plan recommends that when a block enters system integration it include mature technology but the plan allows for the inclusion of less mature technology if the benefits are significant and if risks can be mitigated. Given the Presidential direction, MDA must include components in the block that have not been demonstrated as mature and ready for integration into a particular element, let alone the block overall. MDA's plan also calls for rigorous testing before the agency recommends that the system or its elements be available for fielding. However, MDA's test program has been limited to date and is under considerable time pressures.

System Integration of Block 2004 Begins with Some Immature Technologies

Our past reviews of DOD and commercial product development programs have shown that programs are in a much better position to succeed if components that incorporate new technologies are matured to a high level before being integrated into a product. Conversely, developers that initiated product developments with immature technology increased the risk that their products would fail tests and that some aspects of the products' design would have to be reworked because components did not perform as predicted. The overall impact of such problems was often that products did not deliver the promised capability or the developers had to spend additional time and money to develop that capability.

While its draft Integrated Master Plan recommends that system integration begin with mature technologies (Event 4), MDA has begun including components into the Block 2004 configuration that are not yet mature. Two examples are the Cobra Dane radar and the boosters for the Ground-Based Midcourse Defense interceptors.

- The Cobra Dane radar is located at Eareckson Air Station in the western end of the Aleutian Islands chain in Alaska. Planned hardware and software upgrades intended to provide the radar with real-time acquisition and tracking capabilities are expected to be completed in fiscal year 2004. MDA has no plans, however, to demonstrate the expected functionality of the radar through integrated flight tests.
- MDA has encountered considerable difficulty in developing a three-stage booster for the Ground-Based Midcourse Defense element and has yet to flight test interceptor boosters in configurations planned for fielding in September 2004. By the time the new booster was flight tested in August 2001, it was already about 18 months behind schedule. The first booster

flight test was successful, but the second booster drifted off course and had to be destroyed 30 seconds after launch. Subsequently, the agency authorized two new contracts for developing boosters for use in the Block 2004 capability. While this strategy should reduce risk in the program, the first demonstrations of these boosters will occur in the flight tests scheduled later this year.

MDA officials told us that they could not deploy an initial capability in the timeframe directed by the President if they did not continue to develop the technology while designing the system. MDA officials told us that they expect to follow their knowledge-based development plan as they develop the next block (Block 2006) of the missile defense system.

Testing under Pressure and Limited to Date

The fundamental purpose of testing is to gauge the progress being made when an idea or concept is translated into an actual product and, ultimately, to make sure the product works as intended. Leading commercial firms conduct testing to discover potential developmental problems early. The firms focus on validating that their products have reached increasing levels of product maturity at given points in time. The firms' products have three maturity levels in common: components work individually, components work together as a system in a controlled setting, and components work together as a full system in a realistic setting. Testing in this systematic manner helps ensure that problems are identified and corrected early, when the cost of solving problems is lower and more options are available. Over time, disciplined testing helps confirm that the product eventually produced will meet the customer's needs.

In the past, when DOD programs have been schedule—rather than event—driven, program managers have found it difficult to slow the program if problems were identified during testing. MDA has been placed in a similar, pressured position as it prepares to field an initial capability by September 2004. Also, only limited test data is available for determining whether a credible capability will be available at that date.

One system-level test is planned prior to fielding

The capability that MDA expects to deploy is essentially a collection of elements that are connected by battle management software. Initially, the mission of the software will be to hand off data from the radars that detect and track enemy missiles to the shooters that launch interceptors to kill the missiles. For example, the battle management software could communicate to the Ground-Based Midcourse element data on the position of an intercontinental ballistic missile being tracked by the Aegis

Ballistic Missile Defense radar. MDA has begun the development of battle management hardware/software and has completed some ground tests of its capability. However, MDA plans to deploy the block although the battle management software's ability to interoperate with the elements as an integrated missile defense system will not be flight tested until the Spring of 2004.

Element flight-test data is limited

Integrated flight tests to date have demonstrated that the Ground-Based Midcourse Defense and Aegis Ballistic Missile Defense elements can defeat a mock warhead in a test environment. However, the tested elements did not include all of the same components that will be part of the elements deployed in 2004. Instead these elements were tested using some surrogate and prototype components. For example, all tests of the Ground-Based Midcourse element have included a surrogate booster and a prototype kill vehicle. In addition, tests of this element have not included the Cobra Dane radar that will be used in September 2004 to detect and track intercontinental ballistic missiles. The Cobra Dane radar will not actively participate in integrated flight tests at least through September 2007.

Element flight tests have also been executed under nonstressing conditions that are not fully representative of the environments that the elements would experience in combat. All flight tests completed to date have been limited to a single corridor and intercept region, that is all targets have been launched from Vandenberg Air Force Base, California, and interceptors have been launched from the Reagan Test Site in the Marshall Islands. As a result, flight-test engagement conditions are limited to those with slower closing velocities and shorter intercept ranges. Testing under conditions such as these significantly limit the data MDA can collect on system effectiveness and readiness.

Operational test data is limited

An operational test assesses the effectiveness of the system against the known threat and its suitability for combat use. U.S. law requires that such tests be carried out on major defense acquisition programs and assessed by DOD's Director, Operational Test and Evaluation, before a full-rate production decision is made. The purpose of the Director's assessment is to advise the Secretary of Defense and Congress on the effectiveness of the system against the known threat and its suitability for combat use.

MDA does not plan to operationally test the Block 2004 Ground-Based Missile Defense element before it is available for initial defensive operations. The September 2004 fielding is not connected with a full-rate production decision that would clearly trigger statutory operational testing

requirements. Nonetheless, according to DOD officials, MDA plans to incorporate both developmental and some operational test requirements in integrated flight tests.

The Director, Operational Test and Evaluation, will provide comments on an element's operational effectiveness and suitability as demonstrated in these tests.[8] However, Operational Test and Evaluation officials said that because developmental tests are scripted, planned events, they do not provide the opportunity to assess how the equipment and its operators will function under unforeseen conditions.

Conclusion

MDA is attempting to build a ballistic missile defense capability that paces an ever-evolving threat. This is an expensive and risky endeavor, because it requires a diverse set of technologies that must be quickly developed, integrated, and deployed across an array of land-, air-, sea-, and space-based platforms. Whether MDA can successfully meet the challenge of quickly developing an effective and suitable missile defense system depends in large part on its willingness to adopt practices that have made other developers successful and to implement those practices as it develops each block.

Certainly, the presidential directive has already caused MDA to not follow some of the knowledge-based practices that it had adopted as it develops Block 2004. Giving up this approach opens the door to greater cost and performance risks. Beginning system integration of Block 2004 with immature technology increases the potential that some element may not work as intended. If this happens, MDA will be faced either with fielding a less than credible system or likely spending more money in an attempt to develop the desired capability within the time allowed. In addition to the challenge it faces in Block 2004, MDA faces the challenge of getting its acquisition program back on track. Because the ballistic missile threat is

[8] The National Defense Authorization Act for Fiscal Year 2002 (P.L. 107-107) requires the Director of Operational Test and Evaluation to (1) annually assess, and report to Congress on, the adequacy and sufficiency of MDA's test program during the preceding fiscal year, (2) monitor the development of MDA's plan for ensuring that each critical technology for a missile defense program is successfully demonstrated in an appropriate environment before that technology enters into operational service (and provide the Director of MDA with appropriate comments), and (3) review, on an ongoing basis, the development of MDA's annual program goals (including testing goals) and annual program plan (including schedules for flight tests and other significant testing activities) and provide any resulting comments on the plans to the Secretary of Defense and the Director of MDA.

rapidly increasing, MDA could always believe it is operating in an emergency environment. Yet, it has never been proven that it takes longer to acquire a weapon system if a knowledge-based acquisition plan is followed. Instead, the opposite should be true, because such a plan decreases the likelihood that deadlines will be missed because critical elements do not work as intended.

MDA and DOD also need to address the long-term implications of their investment strategy. Both are assuming increased investment risk by not having the right information available for decision makers at the right time. The level of anticipated spending magnifies this risk. MDA officials told us they are considering changes to MDA's Integrated Master Plan to identify life cycle costs at the beginning of system integration activities so that tradeoff decisions can be made in a more timely manner. However, because DOD has not yet set aside funds to cover its long-term costs, the department could find that it cannot afford to procure and maintain that system unless it reduces or eliminates its investment in other important weapon systems. By setting aside funds in the Future Years Defense Plan, we believe DOD would bring needed visibility to the impending trade-offs between missile defense and other weapon system spending for procurement and operations.

Recommendations for Executive Action

To assist MDA and DOD decision makers in determining which elements or components should be included in each new block of the Ballistic Missile Defense System, we recommend that the Missile Defense Agency, before beginning integration activities, prepare a life cycle cost estimate for configuring the element or component that the agency is considering including in the block.

To help ensure that funds are available to produce and operate the elements of the missile defense system when a decision is made to transfer elements to the military services, we recommend that the Secretary of Defense explore the option of requiring the services to set aside funds for this purpose in the Future Years Defense Plan.

Agency Comments and Our Evaluation

In commenting on a draft of this report, the DOD concurred with our recommendations.

Regarding our recommendation that MDA prepare life cycle cost estimates before beginning integration activities, DOD said that MDA will prepare its best estimate of life cycle costs based upon projected hardware life, operational cost drivers, and initial capability quantities prior to integration activities for each block.

Regarding our recommendation that DOD set aside funds in its Future Years Defense Plan in anticipation of the transfer of missile defense system elements to the military services, DOD said that there is benefit in budgeting funds when such a transfer is anticipated. Doing so would promote budget stability and improve the likelihood that an element or component would actually be fielded.

DOD also suggested technical changes, which we incorporated as appropriate. DOD's comments are reprinted in appendix I.

Scope and Methodology

To address our objectives, we analyzed documents that detailed the Missile Defense Agency's new acquisition practices and compared the practices to those of successful development programs. We also obtained detailed briefings from Missile Defense Agency officials regarding the agency's plan for the implementation of these practices and contrasted that plan to the implementation plan of successful programs. In addition, we discussed the challenges and risks that the agency faces as it implements its new plan with the Institute of Defense Analyses, Alexandria, Virginia. We also discussed these issues with all members of the Missile Defense Support Group, including the Office of the Undersecretary for Acquisition, Technology and Logistics; Office of the Undersecretary for Policy; Office of the Undersecretary (Comptroller); General Counsel; Office of the Assistant Secretary (Command, Control, Communications, and Intelligence); Office of the Director, Operational Test and Evaluation; Office of the Director, Program Analysis and Evaluation; Office of the Director, Cost Analysis Improvement Group, in Washington, D.C.; and the Joint Staff; Department of the Army; Department of the Air Force; Department of the Navy; and the Missile Defense Agency in Arlington, Virginia.

We conducted our review from March 2002 to March 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 the Chairmen and Ranking Minority Members of the Senate Committee on Armed Services; the Senate Committee on Appropriations, Subcommittee on Defense; the House Committee on Armed Services; the House Committee on Appropriations, Subcommittee on Defense; 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 were Katherine Schinasi, Barbara Haynes, Cristina Chaplain, David Hand, Alan Frazier, Randy Zounes, Adam Vodraska, Jose Ramos, and Greg Lagana.

R. E. Levin
Director
Acquisition and Sourcing Management

Appendix I: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

17 APR 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: Knowledge-Based Practices Are Being Adopted but Risks Remain," dated March 18, 2003 (GAO Code 120135/GAO-03-441). The Department appreciates the opportunity to comment on the draft report.

The Department concurs with the recommendations it contains. 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 CAPT Michael J. Cregge, USN, (703) 695-8815, michael.cregge@osd.mil.

We appreciate the opportunity to comment on the draft report.

Sincerely,

Glenn F. Lamartin
Director
Defense Systems

GAO DRAFT REPORT – DATED MARCH 18, 2003
GAO CODE 120135/GAO-03-441

"MISSILE DEFENSE: Knowledge-Based Practices Are Being Adopted but Risks Remain"

DEPARTMENT OF DEFENSE COMMENTS
TO THE RECOMMENDATIONS

RECOMMENDATION 1: To assist MDA and DoD decision makers in determining which elements or components should be included in each new block of the Ballistic Missile Defense System, the GAO recommended that the Missile Defense Agency, before beginning integration activities, prepare a life-cycle cost estimate for the configuration of the element or component that the agency is considering including in the block. (p. 23/GAO Draft Report)

DOD RESPONSE: Concur. MDA will prepare its best estimate of life-cycle costs based upon projected hardware life, operational cost drivers, and initial capability quantities prior to integration activities for each block. As indicated in the Integrated Master Plan, MDA considers system costs throughout the knowledge-based development process. Cost analysis begins at the earliest prototype development and continues through any potential off-ramps and/or transition to the Services. Relevant construction requirements, production ramp-ups, training, and other support functions are considered, with most costs analyzed prior to integration activities.

RECOMMENDATION 2: To help ensure that funds are available to produce and operate the elements of the missile defense system when a decision is made to transfer elements to the Military Services, the GAO recommended that the Secretary of Defense explore the option of requiring the Services to set aside funds in the Future Years Defense Plan for this purpose. (p. 23/GAO Draft Report)

DOD RESPONSE: Concur. Clearly, there is benefit in budgeting funds within the Future Years Defense Plan when a procurement/fielding action can be anticipated. Doing so would not only promote the stability of the overall defense budget, but would also significantly improve the likelihood that an element or component would actually be fielded. The Department will certainly consider this option for elements and components that have demonstrated sufficient maturity to enter into production.

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Jeff Nelligan, managing director, NelliganJ@gao.gov (202) 512-4800
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