

**Independent Review Team  
Findings And Recommendations**

**Presented to the Director,  
Missile Defense Agency**

**31 March 05**

## GMD Background

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- **National Security Presidential Directive 23, issued on 17 December 2002, called for the initial deployment of a ground-based ballistic missile defense by FY04 using the best technologies available**
  - Responsive to the emerging global strategic environment
- **By the end of September, 2004, the Missile Defense Agency's GMD Program had met the challenge of the Presidential Directive**
  - A major national accomplishment built by the dedication and hard work of the Missile Defense Agency, the GMD Joint Program Office, the Army, and the U.S. Aerospace Industry
  - The GMD system is significantly more complex than most major military systems
- **The rapid development and initial deployment of the GMD system was comparable to other milestones in major military system deployment**
  - The initial deployment of the Minuteman ballistic missile system
  - The initial deployment of the Polaris fleet ballistic missile system

2

In December 2002 the President directed that we begin fielding, and improve, over time, a ballistic missile defense system to defend the United States, our deployed forces, and our allies and friends. His decision was based on the growing ballistic missile and nuclear weapon threats, and the progress we have made in ballistic missile defense technologies.

The Ground-based Midcourse Defense element is one of the most complex military systems that has ever been deployed. The IRT indicated that MDA had successfully demonstrated the "hit-to-kill" technology and other basic Ground-based Midcourse Defense system functionality. The Missile Defense Agency, the Joint Program Office, the Military Services, and U.S. industry have overcome enormous programmatic and technical obstacles in a remarkably short period of time to meet the Presidential Directive for an initial deployment by the end of 2004. The system's complexity and deployment challenges make this achievement comparable to the Manhattan Project to develop an atomic bomb, and the Minuteman and Polaris ballistic missile system deployments.

## **IRT Terms Of Reference And Scope**

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**Dr. Graham, Dr. Ballhaus, MG (R) Nance, assisted by Dr. Widhopf, and Mr. Tosney, shall comprise an IRT of experts that are tasked to accomplish the following:**

- **Review analysis of IFT-10 / 13C / 14 failures including systemic causes**
- **Understand causes of GMD failures**
- **Determine impact of these failures and other problems with GBIs and ground support equipment located at Ft. Greely and Vandenberg AFB**
- **Review pre-flight preparation and test execution process and provide recommendations as appropriate**
- **Review in detail all actions required for a successful launch**
- **Report to the Director, MDA, by 31 MAR 05**

### **IRT Scope**

- **GBI focused to release of EKV**

3

The Independent Review Team was initiated by Lt Gen Obering, the Director of the Missile Defense Agency, on February 14, 2005, and formally established in a directive issued on February 22, 2005. He directed the IRT to review recent Ground-based Midcourse Defense test failures, including a test dating back to December 2002, identify any systemic problems, generate recommendations, and report back to him by 31 March. This briefing is the Independent Review Team's report.

While this report focuses only on specific components of the Ground-based Midcourse Defense element of the Ballistic Missile Defense System, some of its recommendations may have utility for other elements and the overall Ballistic Missile Defense System.

## Executive Summary

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- To achieve a fully operational defense system the GMD Program now needs to enter a new Phase:

### *The Performance and Reliability Verification Phase*

- Key Recommendations
  1. Establish a More Rigorous Flight Readiness Certification Process
    - Make “Test as you fly, fly as you test” the standard
  2. Strengthen Systems Engineering
  3. Perform additional ground-based qualification testing as a requirement for flight testing
  4. Hold contractor functional organizations accountable for supporting prime contract management
  5. Assure that the GMD program is executable

4

After a comprehensive review of the GMD program, and in accord with it having met the Presidential Directive to accomplish an initial Ground-based Midcourse Defense deployment by the end of Fiscal Year 2004, the Independent Review Team recommends that Ground-based Midcourse Defense now move into a new phase: “The Performance and Reliability Verification Phase,” in which mission assurance becomes the highest priority objective.

The Team made five key recommendations to guide the future progress of the Ground-based Midcourse Defense program. Each of these recommendations is discussed in the following charts.

## MDA / GMD Organizations Visited

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- **Arlington, Virginia**
  - **Boeing Missile Def. System**
  - **Missile Defense Agency Headquarters**
- **Huntsville, Alabama**
  - **GMD JPO**
  - **Boeing GMD**
  - **COLSA**
- **Tucson, Arizona**
  - **Raytheon Missile Systems**
- **Chandler, Arizona**
  - **Orbital Sciences GMD**
- **Marshall Islands**
  - **Ronald Reagan Ballistic Missile Defense Test Site**
    - **Kwajalein Atoll**
    - **Meck Island**
- **Fort Greely, Alaska**
- **Portland, Oregon**
  - **Bechtel GMD**
  - **Oregon Iron Works GMD**
- **Vandenberg AFB**
- **Anaheim, California**
  - **Boeing GMD**

*The IRT received outstanding cooperation from all MDA Government and contractor personnel!*

5

The Independent Review Team traveled to numerous government, Prime contractor, and Subcontractor locations over a 31-day period prior to finalizing its recommendations.

The Team drove over 600 miles and flew approx 20,000 Miles in 17 flight segments.

At each location visited, the Team met with both senior Program Managers and individually with key Responsible Engineers and other experts. The Team received outstanding cooperation and candid comments from all government and contractor participants.

## **Phases Of The U.S. Ballistic Missile Defense Program**

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- **BMD**
  - **R&D to determine and demonstrate feasibility of “Hit to Kill”**
  - **Develop and deploy “theater” ballistic missile defense systems**
  
- **Test Bed**
  - **Deploy a limited national missile defense system in the ABM Treaty environment**
  - **Develop a ballistic missile defense system unconstrained by the ABM Treaty**
  
- **GMD Deployment and Operations**
  - **Ballistic Missile threat to U.S. increasing**
  - **NSPD 23 – Initial deployment of operational capability by end of FY04**
  - **Concurrent development, test, production, and deployment of system underway**

6

The US Ballistic Missile Defense Program has gone through several phases prior to the deployment of an initial missile defense capability. The program has built upon technological advances made in earlier U.S. Army missile defense development programs, the Strategic Defense Initiative Organization, and the Ballistic Missile Defense Organization.

Congress passed the National Missile Defense Act of 1999 making it U.S. policy to deploy an effective national missile defense system capable of defending against limited ballistic missile attack. In 2001 and 2002, the ground-based missile program accomplished four out of five intercept tests successfully using prototype interceptors against long-range ballistic missile targets. These tests provided further performance confirmation needed to proceed with the development and fielding of a system that relies primarily on hit-to-kill technologies.

President Bush made it a top priority of his administration to deploy a Ballistic Missile Defense System unconstrained by the Anti-Ballistic Missile Treaty. The Ground-based Midcourse Defense Program has met the challenge of providing an initial ground-based midcourse capability for defense of the U.S. against long-range ballistic missile attack.

## GMD Background (continued)

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- The MDA and the GMD Program have met the challenge of NSPD-23
  - A major accomplishment built on the dedication and hard work of both government and industry
- The U.S. now has substantial GMD assets deployed at Ft. Greely, Vandenberg AFB, Colorado Springs, and Shemya
  - Hostile countries must factor these U.S. assets into their analyses
- The dissuasion and deterrence value of these assets will be
  - Increased by successful flight tests
  - Decreased by unsuccessful flight tests
- System reliability design is based on multiple interceptors per engagement
  - System testing focused on single interceptor performance

*Successful flight testing is a strategic issue as well as a key to system development*

7

The Ground-based Midcourse Defense program has successfully deployed the initial Ground-based Midcourse Defense system, including the emplacement of eight ground-based interceptors in Alaska and California, and will increase the number of deployed interceptors further by the end of 2005. The next challenge is to verify the system operational performance and reliability.

The test program is designed to verify the system performance under increasingly realistic conditions and, over time, should increase confidence in the system's performance. Successful test intercepts will send a strong message to adversaries of the U.S., who may be dissuaded by the effectiveness of the system from investing further in ballistic missile forces and/or be deterred from attacking the U.S., our deployed forces, our allies, and friends. Therefore, successful flight testing is a strategic issue as well as a key to continued successful system development.

The Ground-based Midcourse Defense system performance reliability is based on multiple interceptors for engagement. The ground-based interceptor testing is focused on single interceptor performance, and does not fully reflect the Ground-based Midcourse Defense system's operational capability and reliability. This point is sometimes overlooked in discussions of the Ground-based Midcourse Defense system's capabilities.

## Flight Test Failure Assessment

Test	Failure	Fundamental Issue	IRT Assessment
IFT-10	EKV failed to separate due to an ASIC lead fatigue failure in the Laser Firing Unit	Stiffening foam was removed from board The random vibration test was conducted w/o power-on so the problem could not be detected on the ground had it pre-existed	Incomplete power on vibration test fidelity due to lack of Test-As-You-Fly philosophy Low design robustness for single point flight critical h/w Failure assessment should analyze sibling h/w and apply lessons across the system
IFT-13C	Launch was aborted due to a built-in-test (BIT) anomaly that detected excessive drops of Electronic Control Unit (ECU) messages	Roundoff error propagation caused a timing mismatch. When the SIGI and FC clocks crossover, timing jitter occurs and <i>occasionally</i> data is sent to the ECU when it is busy, resulting in no responses Not until the silo BIT test would h/w interface with appropriate s/w for problem to be detectable	Compatibility flaws remain as evidenced by numerous IFT-14 pre-launch anomalies Corrective actions did not address systemic s/w development discipline, simulation fidelity, and lack of hardware-in-the-loop testing (this would have precluded this failure)
IFT-14	Launch was aborted due to a Lateral Support Group mechanism that failed to fully retract	Corrosion and dissimilar metals (galvanic corrosion) caused one LSG failure The 150° LSG mechanism false positive indication is being investigated One mechanism failed to latch due to wrong crush blocks	Lack of spec/std flowdown for Type II environments (salt fog, temperature) Lack of energy margin analysis after qualification Concern over proximity sensor suitability for harsh environment and reliability

8

There were several issues that led to the flight test failures of Integrated Flight Tests-10, -13C, and -14. For each failure, corrective actions were or are being planned to preclude recurrence of the specific failure mechanism. With the focus on rapid deployment of the Ground-based Midcourse Defense system, there was not always adequate opportunity to fully ground test the system prior to each flight attempt.

The cause of failure in each case was not attributable to a systemic design issue, but rather a deficiency in systems engineering and performance verification. Lessons learned from the failures the Independent Review Team investigated can be more effectively applied across Ground-based Midcourse Defense. One such lesson was that encountered in Integrated Flight Test-10, where the tenet to “test-like-you-fly” was intended to be applied, but was not accomplished as a result of a failure in subcontractor communications and configuration control.

The Ground-based Midcourse Defense corrective actions investigated tended to be focused on fixing the problem at-hand and did not fully assess all potential systemic threads. One solution proposed by the Team is to formalize an independent Ground-based Midcourse Defense mission assurance or systems engineering process that rigorously evaluates all potential systemic issues for each major anomaly. A similar process is in place at NASA (e.g., Problem Reporting And Corrective Action system) and elsewhere.

## **Schedule, Cost, And Performance Constraints**

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- **Schedule has been the key challenge that drives daily decision making in the program**
- **While significant budget increase was provided beginning 2001, GMD (and other MDA) programs were still cost constrained**
- **“Hit to Kill” has established system performance capability requirement**

***Program management variables are schedule, cost, performance, and risk***

9

The urgency of countering ballistic missile threats to the nation, initially from Asia, made deployment schedule the primary programmatic imperative that drove decision-making and planning. At the same time, system cost and performance requirements also had to be met. Program risk was driven by the other three program management variables.

## Program Risk Environment

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- **A schedule, cost, and performance constrained program leaves risk as the relief valve**
- **No schedule margin + minimal budget reserve will produce**
  - **A high risk to achieving program objectives**
  - **Examples of increased risk**
    - **Incomplete requirements traceability**
    - **Ground test hardware and qualification tests**
    - **Shipping test flight hardware with open issues**
      - **Work performed out of cycle (e.g., IFT-13C)**
      - **IFT-14: Over 20 constraint-to-launch items two days before launch**
- **Impact: If current situation continues, expect additional test failures**

10

In the development of complex systems, such as Ground-based Midcourse Defense, there are four program management variables--performance, schedule, cost, and risk. The Ground-based Midcourse Defense program has well-defined performance requirements, and to meet the increasing ballistic missile threat, has had essentially no schedule margin, while at the same time proceeding with minimal budget reserve.

As development problems are encountered, which happens on all complex system development efforts, the only remaining variable is risk, which then grows as the system development continues. To achieve mission success, risk in the Ground-based Midcourse Defense system must be constrained such that schedule and/or cost provide the relief. If risk remains the relief valve, additional test failures will likely occur that will result in schedule slips and cost increases.

## The IRT's Bottom Line

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To achieve a fully operational defense system the GMD Program now needs to enter a new Phase:

### *The Performance and Reliability Verification Phase*

- A major leadership initiative to reorient the program such that mission success is job one
  - Mission success will become primary
    - Deployment rate and schedule become secondary
    - Focus on validating technical baseline
    - Directly manage risk
    - Manage to executable schedule and budget (i.e., with adequate reserves)
    - Event driven versus schedule driven test
- The New Initiative will affect all aspects of the GMD Program

11

In view of the success of initial Ground-based Midcourse Defense deployment efforts, the Independent Review Team recommends the Ground-based Midcourse Defense Program enter a new phase focused on Performance and Reliability Verification, in which the Missile Defense Agency makes test and mission success the primary objective. The new phase should validate the technical baseline, and be event-driven rather than schedule-driven.

## **Elements Of The Performance And Reliability Validation Phase**

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- 1. Establish a More Rigorous Flight Readiness Certification Process**
  - Make “Test as you fly, fly as you test” the standard
- 2. Strengthen Systems Engineering**
- 3. Perform additional ground-based qualification testing as a requirement for flight testing**
- 4. Hold contractor functional organizations accountable for supporting prime contract management**
- 5. Assure that the GMD program is executable**

12

Details on these five recommendations are contained in following charts.

First, increase rigor in the flight test certification process to include the addition of a concurrent and accountable independent assessment of test readiness. Second, strengthen system engineering by tightening contractor configuration management, enforcing process and workmanship standards, and ensuring complete specification flow-down. Third, add ground test units and expand ground qualification testing. Fourth, hold the prime contractor’s functional organizations (such as engineering, quality control, and mission assurance experts) fully accountable for supporting the program. And finally, ensure program executability by stabilizing baselines and establishing event-driven schedules focused on mission assurance.

## **Recommendation 1**

### **Establish a More Rigorous Flight Readiness Certification Process**

*Make “Test as you fly, fly as you test” the standard*

13

Each of the five recommendations will be addressed sequentially in detail.

## Establish a Rigorous Flight Readiness Certification Process

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### Findings

- Current mindset appears to be “Prove why should not fly”
- Significant number of “open items” have been rolled forward “bow waving” risk
- Need to conduct a more rigorous flight certification
  - Must be based on comprehensive flight readiness verification process
- Independent review process is informal, ad hoc, not comprehensive or proactive

### Impact

- Increased risk of flight test failure

### Recommendations

- Change mindset to “Prove why should fly” vs. “Prove why should not fly”
- JPO establish a concurrent peer level certification process with Prime for program and launch execution (Similar to contractor Responsible Engineer “sign off” accountability)
- GMD JPO administers and controls Flight Readiness Certification process
  - Close constraints to ship or test at the appropriate review level.
  - Do not allow risk to be “rolled forward”
- Require Prime conduct and report President Council Review of flight readiness
- Establish and formalize an accountable Independent Readiness Review Team (IRRT)
  - Participate in comprehensive reviews at all levels to assess risk
- FRR decision authority should be Director, MDA
  - Conduct Flight Readiness Review no later than ten days prior to launch
  - JPO, Prime, and IRRT provide presentations and are polled

14

The Independent Review Team recommends the mindset now be changed to assure all “open items” are addressed and closed before the interceptor proceeds to the next stage of flight-test processing. Other key changes recommended are to give the Government (Ground-based Midcourse Defense Joint Program Office) control of the Flight Readiness Review process and schedule, require both prime and sub-contractors have Reviews where their business unit Presidents “sign off” and be accountable for readiness to fly, formalize an accountable Independent Review Team, and have the final Flight Readiness Review chaired by the Director of the Missile Defense Agency.

During the President’s Launch Vehicle Broad Area Review (LV BAR) in 1999, for example, that Independent Review Team found that five major failures could likely have been prevented with more thorough “independent” review processes and analyses:

<u>Vehicle</u>	<u>Mission</u>	<u>Failure Cause</u>	<u>Comments</u>
Delta 259	Commercial Control	Dynamics Mismatch	Independent Control Stability Analysis
Delta 242	Iridium	Unaccounted Structural Resonance Mode	Same as above
Pegasus	Step-1	Unstable (wrong Aero-coeff.)	Same as above
Conestoga	Commercial	Guidance Software Error	Incomplete Software IV&V
Titan IVB32	Milstar 2-F1	Error in G&C Data Set Input	Flawed IV&V Process

## **Recommendation 2**

# **Strengthen Systems Engineering**

## Strengthen Systems Engineering

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### Finding

- The need exists to establish a formal “Test As You Fly/Fly As You Test” policy and process. Numerous escapes indicate a need to rigorously assess the verification plan and detailed test execution with regard to these tenets

### Impact

- Without a disciplined process to assess the lapses in testing as you fly, the program is at risk of not meeting mission success goals on future launch attempts and test flights

### Recommendations

- Establish a core GMD “Test As You Fly/Fly As You Test” policy leveraging off National Security Space initiatives
- Establish a formal JPO process that includes a well defined set of criteria to independently assess the deviations from the established tenets of the policy
  - Include as part of the process a rigorous assessment of the risk of not testing as you fly and mitigation for each identified deviation
- Evaluate design to ensure that safety features do not overly restrict successful launch

16

Complex space systems have repeatedly demonstrated the need to adhere to a verification strategy that places significant emphasis on “test as you fly” or demonstration of “operations” in the intended conditions of usage prior to actual operation. Billions of dollars in lost assets during the 1990s caused government and industry leaders to devise a process that required adherence to test-as-you-fly and to assess the risk of not adhering to these tenets when such action is unavoidable. Experience with Ground-based Midcourse Defense-specific failures provides ample reason to adopt these tenets from the space industry and apply them to Ground-based Midcourse Defense for future flight testing.

National Security Space, under the sponsorship of the National Reconnaissance Office, has established a working group to define the basic tenets of this strategy for the Space and Missile Systems Center and the National Reconnaissance Office. Included in this effort is a rigorous process to assess the risk of deviating from test-as-you-fly tenets. The Joint Program Office should review the National Security Space initiatives and establish a formal test process that provides a rigorous risk assessment. Ground-based Midcourse Defense has an opportunity to leverage the National Reconnaissance Office-sponsored initiative.

The Independent Review Team recommends that the Ground-based Midcourse Defense program implement a “test-as-you-fly, fly-as-you-test” policy and risk assessment process for the program to assure that the end-to-end interoperability of ground/launch/mission hardware, software, and operating scenarios have been verified prior to launch, and establish as part of this process a disciplined risk assessment process to mitigate exceptions to these tenets. The test-as-you-fly policy must assure risk is not “rolled forward,” and the plan should direct that a flight test not be carried out until mitigation for each identified deviation is resolved.

## Strengthen Systems Engineering (continued)

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### Finding

- Need exists for a more disciplined post flight assessment process that comprehensively analyzes all data, including flight-to-flight trending, and disseminates and utilizes results in a timely fashion
- Upcoming flights are planning to scale back on the amount of flight instrumentation. GBI models and simulations have not yet been sufficiently validated and require additional flight data to improve confidence in models and simulations

### Impact

- Without a comprehensive closed-loop design feedback process, design and quality escapes can impact mission success

### Recommendations

- Assure post flight assessment process comprehensively reviews all performance data, flight-to-flight trends, and data reduction related to models and simulations. Process should include a strong focus on “in spec” and “out of family” pedigree data correlations
- Consider the modeling and simulation functional domain user needs for pre-flight instrumentation on near-term flights

17

The Ground-based Midcourse Defense system has a very complex architecture comprised of hardware, software, and ground and sea-based facilities. The initial deployment of the Ground-based Midcourse Defense system was intended to be the start of an iterative, spiral-type development process. Due to a need to deploy rapidly, there has not yet been an opportunity to complete the verification of a number of key components of the architecture, and some will be “phased-in” over time.

The Independent Review Team members brought a perspective to the Ground-based Midcourse Defense assessment that included extensive experience in the high-reliability spacecraft and space launch industries, and the compelling need to ensure that a strong closed-loop design process exists for these industries. During the late 1990s, the U.S. experienced a large number of space launch vehicle failures in a relatively short period of time. Later assessment of the systemic root causes of a number of the major anomalies showed that subtle evidence was often present in flight telemetry or ground test data that was indicative of a weak design or process deficiency. Consequently, the Launch Vehicle Broad Area Review recommended that a strong post-flight and flight-to-flight assessment be institutionalized.

The Team found a similar situation unfolding in Ground-based Midcourse Defense, underscored by the fact that plans are already underway, without having launched the first Exo-atmospheric Kill Vehicle, to start to cut back on the flight test instrumentation. The Team feels strongly that this is premature. For the near-term, all due diligence should be focused on enhancing both the flight- and ground-test instrumentation configurations to help anchor or validate the large number of complex models that have not yet been fully verified. In addition, a disciplined post-flight analysis working group supported by all key subcontractors should exist to ensure that all anomalies are closed out and that all “out of family” telemetry data is understood prior to the next flight.

## Strengthen Systems Engineering (continued)

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### Finding

- **Based on the extent and nature of ground test, launch abort, and flight failures on GMD, the need exists to establish a set of core specifications and standards.**
  - Provides a disciplined and validated set of processes and guidelines to improve the consistency in practices between subcontractors and improve mission success

### Impact

- **Lack of adherence to industry best practices as embodied in specifications and standards presents an unnecessary degree of risk (e.g., IFT-10, IFT-14)**

### Recommendations

- **Establish a core GMD design, verification, and process specifications and standards for new contracts and modify existing contracts as appropriate**
- **Leverage off of the high-reliability National Security Space Mission Assurance Improvement Task Force initiatives underway to update critical specs and standards for technical relevancy (e.g., AIAA, military, industry)**

18

Acquisition reform in the 1990s led to reduced usage of military specifications and standards on government contracts. After considerable cost, schedule, performance problems with major systems in the late 1990s, independent government-sponsored reviews have led to the elective revitalization of specifications and standards. As a result of the acquisition environment when the Ground-based Midcourse Defense system's antecedents were established, Ground-based Midcourse Defense has very few hardware and software development specifications and standards in effect. Evidence the Independent Review Team found suggests strongly that the Ground-based Midcourse Defense Joint Program Office should adopt an expanded set of specifications and standards related to the design and development of the Ground-based Midcourse Defense hardware and software. Due to the lack of application of a few well-known verification specifications and standards by the Ground-based Midcourse Defense program, (e.g., thorough environmental testing on the ground), failure evidence suggests that some problems might have been found earlier in the development cycle and before launch. The Team feels that considerable opportunity exists to improve the confidence in the reliability of the hardware and software by adopting industry best practices that exist as specifications and standards.

The National Security Space community has recently established a core set of specifications and standards for space systems that in many cases have direct application to Ground-based Midcourse Defense. The Joint Program Office should review these high-reliability specifications and standards, some of which are new, and many older ones that have been completely rewritten to reflect industry best practices. The rigor required to build and test space systems requires technically sound and relevant specifications. The Ground-based Midcourse Defense program should establish a set of core specifications to improve its probability of mission success.

## Strengthen Systems Engineering (continued)

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### Finding

- **There is a need to validate the design and reliability of the system as currently deployed**
- **Escapes have occurred in configuration management and the requirements verification processes and their flow-down to subcontractors**
  - IFT-10 and IFT-13C verification escapes (e.g., no power during vibration, minimal silo testing)
  - Enhanced launch environments measured during flight test BV(5), BV(6), and IFT-13B
  - Deferral of Operational Aging Requirements (i.e., a large number of serious issues do not yet have a mitigation plan)
  - LSC Environmental Controls (i.e., Meck Island corrosion)

### Impact

- **Hardware and software may not accomplish mission with predictable performance and reliability**

### Recommendations

- **JPO establish an independent assessment of the requirements and verification flow-down and traceability to established benchmarks (e.g., MIL-STD-1540E)**
- **Assess the adequacy of the Boeing configuration management (CM) processes in light of the CM escapes in both hardware and software**
- **Commission a system-level Failure Modes and Effects Analysis (FMEA)**
- **Focus attention on mission critical single point failures**

19

Inconsistencies were identified in the flow-down of requirements to subcontractors and configuration control. The reliability of the current system should be verified through an independent assessment, where Configuration Management processes and Failure Modes and Effects Analysis identify single-point failure areas, and plans can be developed to mitigate their effects on mission reliability.

## Strengthen Systems Engineering (continued)

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### Finding

- Need end-to-end ground testing of all hardware / software to verify and validate the design performance in a fully operational mode
- Ground test flight assets
  - SM-3 – 6
  - THAAD – 6
  - D5 Fleet Ballistic Missile – 13
  - GMD OBV – 1
  - GMD BV+ – 1
  - GMD EKV – 2

### Impact

- Potential for continued launch aborts and flight test failures

### Recommendations

- Independent assessment team should perform a detailed assessment of the fidelity of the end-to-end “test as you fly, fly as you test” test process
- Redirect hardware in production flow to increase ground test system hardware inventory

20

There are not enough ground test assets available to verify/validate system operational performance and reliability. The Joint Program Office should consider redirecting some production assets for ground test to gain a higher confidence in the Ground-based Midcourse Defense system performance.

## Strengthen Systems Engineering (continued)

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### Finding

- **There are deficiencies in the test program as current planned. Insufficient ground test assets (quantity and fidelity). Does not allow major sub-contractors to do adequate hardware in the loop end-to-end testing**
  - One EKV shared between GDIL (Huntsville) and Raytheon (Tucson). One Engineer Design Unit (EDU) at Raytheon
  - One booster flight computer for Pre-Mission Testing (PMT) software checkout
  - Sub-contractors did not have adequate Command Launch Equipment (CLE) available for development, qualification, and testing
  - One ground test missile for GMD versus six for THAAD and six for SM-3

### Impact

- **Transfers complete test of subcontractor's HW / SW product to Boeing GDIL which results in both increased schedule and technical risk**

### Recommendations

- **Need to identify specific prioritized list or ask contractor to provide**
- **Prime work with subs to develop technical and schedule risk mitigation plan with recognized list of test assets needed**
- **Take assets from production to provide needed hardware for HW-in-the-loop testing at the major subcontractors.**

21

There are insufficient ground test assets in the Ground-based Midcourse Defense program. This situation reduces the amount and fidelity of subcontractor testing. The Joint Program Office should consider redirecting some production assets for ground testing.

## Strengthen Systems Engineering (continued)

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### Finding

- Assess the service life, storage requirements, testing, and analysis adequacy to assure the design meets operational system requirements.
- Aging surveillance program and storage condition assessment were deferred
  - Prime contractor did not have a contingency plan in place (e.g., list of age sensitive materials incorporated into the existing configuration)

### Impact

- System or components may fail well before end of service life and require replacement, substantive design changes, and/or retrofitting (i.e., IFT-14 failure)

### Recommendations

- JPO establish and lead a formal working group to assess all immediate and anticipated service and storage life concerns
- Prime should establish service life requirements and flow them down to subs as appropriate

22

An aging surveillance program should be established by the Ground-based Midcourse Defense Program to assess service and storage life requirements and performance.

## **Recommendation 3**

**Perform additional ground-based qualification testing as a requirement for flight testing**

## Perform Added Qualification Testing

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### Findings

- **The system requires further qualification testing and analysis to assure the design meets operational system requirements**
- **Program approach to qualification testing and screening varied among subcontractors and suppliers**
  - Found deficient in terms of Test-As-You-Fly
- **Max Predicted Environment (MPE) was flowed down to subcontractors**
  - Qualification approach and margins not uniform
- **Software analysis and testing not sufficiently detailed to validate that software meets design requirements**
  - More rigorous software / hardware in the loop testing could have prevented IFT-13C abort
- **Some key subcontractors have limited experience in building space qualified hardware**
  - Lack of experience demands a more rigorous test program
  - Subcontractors partially applied a MIL-STD-1540E qualification strategy
  - Equipment not always powered and functioning during qual testing
  - No integrated EKV/adaptor or BAM thermal vacuum testing

24

The Ground-based Midcourse Defense system requires further testing and analysis to verify its performance and reliability, including space qualification testing. Some key subcontractors have limited experience in building and testing space-qualified hardware, and should be given rigorous guidance and supervision.

## **Perform Added Qualification Testing (continued)**

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### **Impact**

- **Premature failure and continued workmanship issues**

### **Recommendations**

- **Perform qualification testing consistent with MIL-STD-1540E on all flight hardware**
- **Conduct a detailed assessment of the software development and verification processes at the contractor / subcontractor level**
- **Complete detailed software requirements analysis and testing to specifications on OBV prior to next flight**
  - Current completion date – late June 2005

25

The Independent Review Team recommends that qualification testing be conducted in a manner consistent with MIL-STD-1540E, and complete detailed software assessment be performed prior to the next flight test.

## **Perform Added Qualification Testing (continued)**

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### **Findings**

- **The system requires qualification test in the stressed thermal vacuum condition**
  - To assure the design meets operational system requirements
  - To identify potential synergistic design and workmanship defects that are not tested at the lower level of assembly
- **Thermal / Vacuum test cycling on functioning hardware needed**
  - EKV with target scene generation
  - PAM

### **Impact**

- **High potential for design, quality and workmanship defects to escape detection**
- **Hardware not verified operationally through critical temperature/pressure regimes and operational scenarios**

### **Recommendation**

- **Perform Thermal / Vacuum testing in accordance with MIL-STD 1540E**
  - After high cycle stress vibration testing

26

The Exo-atmospheric Kill Vehicle and Payload Avionics Module are required to operate in a space environment, and therefore the Independent Review Team recommends that thermal/vacuum testing consistent with MIL-STD-1540E be performed on the Exo-atmospheric Kill Vehicle and the Payload Avionics Module.

## **Perform Added Qualification Testing (continued)**

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### **Findings**

- A review of flight test data from BV5(BV+), BV6(OBV), and IFT 13-B (OBV) shows the Prime Item Development Specs (PIDS) for both shock and vibration requires modification (e.g. original spec was exceeded in low frequency region)
- EKV adapter module modified and tested to accommodate OBV environment

### **Impact**

- EKV, Adapter, and Boost Avionics may require additional shock and vibration qualification testing or design modification to address BV+ low frequency exceedances

### **Recommendation**

- Timely approval of the combined specification change that envelopes both the OBV and BV+ booster environments
  - Flow environments to subcontractors

27

The Independent Review Team recommends that Prime Item Development Specifications be modified for both shock and vibration environments that encompass the Orbital Booster Vehicle and BV+ booster launch environments under the condition that the BV+ booster is a viable launch option. Later inclusion of BV+ launch environments that are currently not included in the revised Prime Item Development Specifications could result in added cost and schedule delays for new Exo-atmospheric Kill Vehicles.

## **Recommendation 4**

**Hold Contractor Functional  
Organizations Accountable For  
Supporting Prime Contract  
Management**

## **Hold Contractor Functional Organizations Accountable**

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### **Finding**

- **Background: Contractor functional leadership (Engineering, Supplier Management, Quality Assurance, and Mission Assurance) should be accountable for**
  - Maintaining processes that provide predictable, repeatable results and assuring that standards are met in the execution of those processes across a business unit's programs
  - Quality of the technical workforce
  - Technical check and balance on programs, providing an independent path (from the program management) for assuring technical risk issues are addressed in a timely fashion
- **Prime Contractor's functional organizations need to be properly staffed, structured, and held accountable**
- **Functional staff must be proactive**
- **There are seams in the Engineering functional accountability. Engineering VP's at Anaheim and Huntsville do not report to Engineering Director in Missile Defense System's Business Unit**

29

The Independent Review Team recommends that the Prime Contractor's functional leadership (Engineering, Supplier Management, Quality Assurance, and Mission Assurance) should be held fully accountable for mission success, and staffed and managed accordingly.

## Hold Contractor Functional Organizations Accountable

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### Impact

- Lack of clear flow of accountability coupled with lack of engagement at business unit level leads to a *reactive* rather than *proactive* approach to functional support check and balance – less likely to prevent quality escapes
  - Missing a key line of defense for Mission Success

### Recommendation

- Prime Contractor report to JPO and MDA Directors how they intend to assure a continuous flow of accountability in engineering, quality assurance, supplier management and mission assurance
- To reinforce their accountability, relevant business unit functional leads (engineering, quality assurance, mission assurance) should be polled at major SRRs and at Prime Contractor President's review prior to FRR's
- Missile / launch experience from the broader Boeing enterprise should continue be to be drawn into the GMD program

30

The Independent Review Team recommends that the Prime Contractor should provide to the Joint Program Office a plan for reinforcing the accountability of unit functional leads (Engineering, Supplier Management, Quality Assurance, Mission Assurance) and their input on the Flight Readiness Review process.

## **Recommendation 5**

**Assure GMD Program  
Is Executable**

## Assure GMD Program Is Executable

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### Finding

- Program executability is challenged by aggressive schedules and lack of management reserve, leading to program baseline perturbations and compounding of risk

### Impact

- Schedule driven program with inadequate management reserve to buy down technical and schedule risk likely to result in test failures

### Recommendation

- **Stabilize baselines**
  - High confidence schedules (event driven)
  - Appropriate management reserve
  - Reprioritized budget to manage risk
  - Contract incentives focused on mission success
- **Mitigate Risk**
  - Program culture should focus on mission success
    - Do not “bow wave” risk
    - Manage quality first and then schedule – leads to optimum cost performance by doing things right the first time
  - Formalize well staffed proactive Independent Review Process with accountability

32

The Independent Review Team recommends that the Ground-based Midcourse Defense program move to a performance and reliability verification phase. This phase must have adequate resources and reserves to stabilize the baseline, mitigate risk, and adjust the schedule to ensure mission success.

## **Assure GMD Program Is Executable (continued)**

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### **Finding**

- Lack of critical spares
- Lack of resident on-site responsible engineering support

### **Impact**

- Lack of on-site responsible engineering and spares increases technical and schedule risk

### **Recommendation**

- Program assess and prioritize needed spares and on-site responsible engineering support requirements

33

The Independent Review Team recommends that the Ground-based Midcourse Defense Program obtain adequate inventories of critical spares and assign on-site responsible engineering support at all required sites.

## Next Flight Test Recommendations

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- **Make Next Flight an Interceptor Functional Test (Non-intercept)**
- **Objective – Fly the interceptor to evaluate**
  - **Flight characteristics**
  - **Flight environment**
  - **Fidelity of the required qualification tests**
  - **Future planned improvements**
  - **Validity of models and simulations**
  - **Hardware-in-the-loop testing**

34

The Independent Review Team recommends that the next flight test be a non-intercept flight focused on obtaining data on flight characteristics. It should also obtain data for use in verifying and refining specifications and qualification environments/parameters, and in improving and verifying modeling and simulation capabilities.

## **Next Flight Test Recommendations (continued)**

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- **Accomplish the following prior to an IFT-14B launch**
  - **Develop a comprehensive check list of flight test functions and ensure each is tested prior to flight**
  - **Add ground test instrumentation for Silo and SIV to characterize ground equipment launch environments**
  - **Execute a comprehensive Flight Readiness Certification by JPO, Prime, and IRRT**
  - **Replace stage one and two Thrust Vector Control boards with qualified components**
  - **Complete detailed software specification verification analysis and testing for the booster**
  - **Retract Launch Support Group and silo doors prior to initiating simulated target launch. Remove risk of GSE impacting mission success**
  - **Complete comprehensive Heritage Review of the Ground Support Equipment (emphasis on design adequacy)**
  - **Establish rigorous post test analysis team for timely dissemination of critical information**

35

The Independent Review Team recommends accomplishing the activities listed prior to the next non-intercept flight test.

## **Next Intercept Flight Test Recommendations**

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- **Next Intercept Flight Test**
- **Objective: “Hit-to-Kill”**
  - **Assure 80% mission success probability**
  - **Institute a system-wide “test as you fly, fly as you test” test program (see Boeing Satellite Systems (BSS) Policy as an example) and require documentation of approval of exceptions**
  - **Immediately take an interceptor and configure for component/system qualification testing**
    - Conduct to MIL-STD-1540E requirements and test-as-you-fly, fly-as-you-test tenets
    - Prioritize test plan at Raytheon that includes the EKV and PAM
    - Tests should encompass appropriate EMI / EMC, shock, vibration, and thermal vacuum (appropriate scene generation) under launch and operational environments
    - Establish a consistent policy for retest and fatigue life assessment for vibration and thermal testing
  - **Ground testing should be done with hardware, emulators and simulators at prime and subs in the same configuration**

36

The Independent Review Team recommends that a successful non-intercept test should be followed by an intercept (hit-to-kill) flight test. Prior to that test, the actions listed should be taken to ensure mission success.

## Summary

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- To achieve a fully operational defense system the GMD Program now needs to enter a new Phase:

### ***The Performance and Reliability Verification Phase***

- **Key Recommendations**
  - 1. Establish a More Rigorous Flight Readiness Certification Process**
    - Make “Test as you fly, fly as you test” the standard
  - 2. Strengthen Systems Engineering**
  - 3. Perform additional ground-based qualification testing as a requirement for flight testing**
  - 4. Hold contractor functional organizations accountable for supporting prime contract management**
  - 5. Assure that the GMD program is executable**