Report No. DODIG-2015-037

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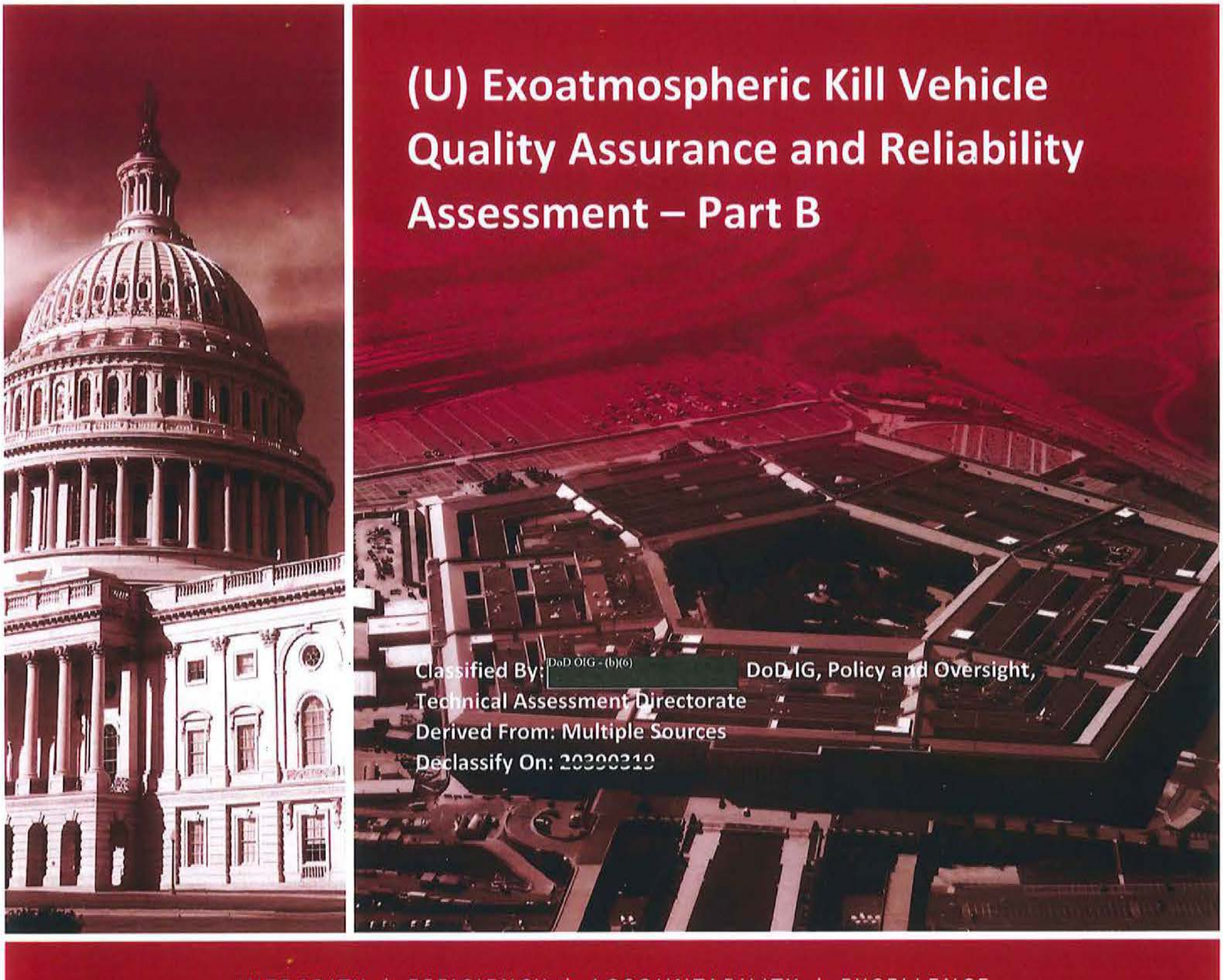
INSPECTOR GENERAL

U.S. Department of Defense

November 12, 2014



(U) Exoatmospheric Kill Vehicle Quality Assurance and Reliability Assessment – Part B

Classified By: DoD OIG - (b)(6) [redacted] DoD IG, Policy and Oversight, Technical Assessment Directorate
Derived From: Multiple Sources
Declassify On: ~~20390319~~

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(U) Results in Brief

Exoatmospheric Kill Vehicle
Quality Assurance and Reliability Assessment – Part B

November 12, 2014

(U) Objective

(U) Our objective was to perform a quality assurance and reliability assessment of the Missile Defense Agency's (MDA) Ground-Based Midcourse Defense (GMD), Exoatmospheric Kill Vehicle (EKV) procured from Raytheon Missile Systems. Our assessment resulted in two separate reports, Part A and Part B.

(U) Part A (Unclassified): Assess Raytheon's conformity to Aerospace Standard (AS)9100, "Quality Management Systems - Requirements for Aviation, Space and Defense Organizations," contractual quality assurance clauses, and internal quality assurance processes and procedures. The draft of this report was released on July 3, 2014.

(U) Part B (Classified): Assess the Exoatmospheric Kill Vehicle reliability of deployed assets.

(U) Findings

(U//~~FOUO~~) OSD/JS - (b)(5); DoD OIG (b)(1), 1.7(e) [redacted]

(U) Findings (cont'd)

(U) We identified two systemic findings:

- (U//~~FOUO~~) OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) [redacted]
- ~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) Recommendations

The Missile Defense Agency should:

- (U//~~FOUO~~) Perform an extensive assessment of EKV OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) [redacted] numbers, as appropriate.
- (U//~~FOUO~~) Use a fix effectiveness factor derived from a OSD/JS - (b)(5); DoD OIG - (b)(3) 10 USC 130 [redacted] accordance with military handbook MIL-HDBK-189C.

1 (U) Fix effectiveness is the fraction reduction in failure rate due to implementation of corrective action.

(U) Results in Brief

Exoatmospheric Kill Vehicle
Quality Assurance and Reliability Assessment – Part B

(U) Recommendations (cont'd)

- (U//~~FOUO~~) Complete a clear and actionable plan OSD/JS - (b)(5), DoD OIG (b)(3) 10 USC 130 [redacted] The plan should include a Government-accepted approach for tracking and mitigation.

- (U//~~FOUO~~) OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5) [redacted]

- (U//~~FOUO~~) OSD/JS - (b)(5), DoD OIG - (b)(1), 1.7(e) [redacted] OSD/JS - (b)(5), DoD OIG (b)(3) 10 USC 130 [redacted]

(U) Management Comments and Our Response

(U) MDA fully agreed to three of the five recommendations of this report. OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5), DoD OIG - (b)(1), 1.7(e), (b)(3) 10 USC 130 [redacted] No further comments are required from MDA.

~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) Recommendations Table

(U) Management	Recommendations Requiring Comment	No Additional Comments Required
Missile Defense Agency		A1, A2, B1, and B2
United States Northern Command		B3

(U)

INSPECTOR GENERAL
DEPARTMENT OF DEFENSE
4800 MARK CENTER DRIVE
ALEXANDRIA, VIRGINIA 22350-1500

November 12, 2015

MEMORANDUM FOR DIRECTOR, MISSILE DEFENSE AGENCY
DIRECTOR OF OPERATIONS (J3), UNITED STATES NORTHERN COMMAND

SUBJECT: (U) Exoatmospheric Kill Vehicle Quality Assurance and Reliability Assessment – Part B (Report No. DODIG-2015-037)

(U) The DoD Office of Inspector General (OIG) conducted a quality assurance and reliability assessment of the Ground-Based Midcourse (GMD), Exoatmospheric Kill Vehicle (EKV), procured from Raytheon Missile Systems. Our assessment resulted in two reports, Part A and Part B. Part A, unclassified and released September 8, 2014, assessed the GMD EKV program's quality management system. Part B provides our assessment of the service life and reliability of fielded assets.

~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) We considered management comments on a draft of this report when preparing the final report. The comments received from the Missile Defense Agency and United States Northern Command conformed to the requirements of DoD Directive 7650.3; therefore, we do not require additional comments.

(U) Please direct questions to DoD OIG - (b)(6) [redacted] at DoD OIG - (b)(6) [redacted] (unclassified calls only) or DoD OIG - (b)(6) [redacted] If you desire, we will provide a formal briefing on the results.

Randolph R. Stone
Deputy Inspector General
Policy and Oversight

(U) Contents

(U) Introduction

(U) Objectives

(U) Our objective was to perform a quality assurance and reliability assessment of the Missile Defense Agency's (MDA) Ground-Based Midcourse Defense (GMD), Exoatmospheric Kill Vehicle (EKV) procured from Raytheon Missile Systems. We conducted the assessment onsite at the GMD Program Office, Huntsville, Alabama (GMD Program Office), and at Raytheon Missile Systems, Tucson, Arizona, during November 2014. Our assessment resulted in two parts.

- (U) Part A (Unclassified): Assess Raytheon EKV manufacturing conformity to Aerospace Standard (AS)9100, "Quality Management Systems – Requirements for Aviation, Space and Defense Organizations," contractual quality assurance clauses, and internal quality assurance processes and procedures. The draft of Part A was released on July 3, 2014.

- (U) Part B (Classified): Assess the reliability of EKV deployed assets by evaluating historical manufacturing and quality management system data. This report is Part B of our assessment.

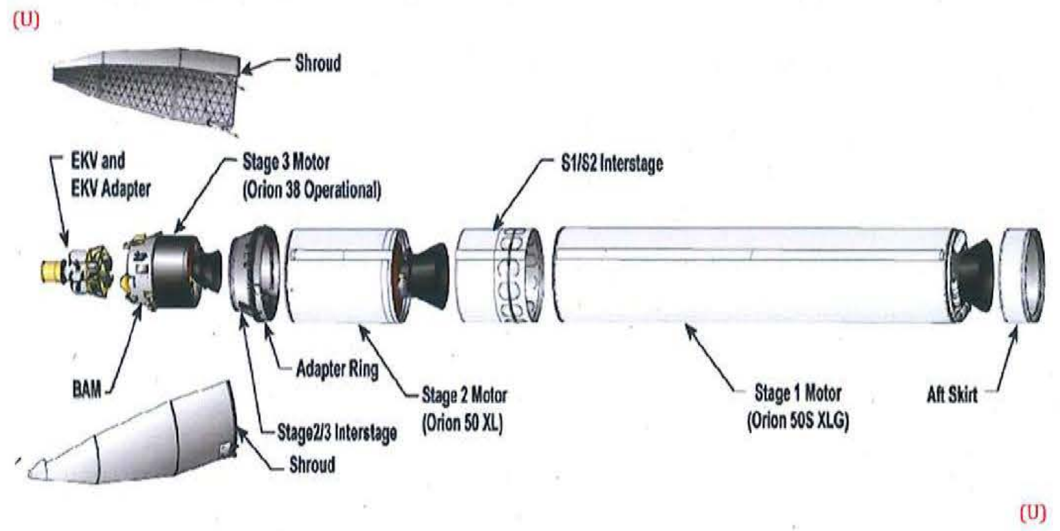
(U) Background

(U) Ground-Based Midcourse Defense System

(U) The GMD program, which is part of the Ballistic Missile Defense System, was initiated in the 1990s to develop a homeland missile defense system against rogue nations. Using space, ground, and shipboard sensors, the GMD battle management system assesses the threat, determines if the threat exists in its battle management space, and launches an interceptor to intercept and destroy the warhead in flight. Today, the GMD system is composed of 30 Ground-Based Interceptors (GBIs) located in missile fields in Fort Greely, Alaska, and Vandenberg Air Force Base, California, with fire control nodes in Colorado and Alaska. A memorandum released in March 2013 by the Secretary of Defense sought to increase the number of GBIs by 14 for a total of 44.

(U) Figure 1 shows a three-stage GBI with the EKV as the Payload. The booster portion of the GBI carries the EKV toward the target's predicted location in space. Once released from the booster, the EKV uses guidance data transmitted from the Ground Support and Fire Control System components and onboard sensors to identify and destroy the target warhead.

Figure 1 – (U) Ground-Based Interceptor



Source: MDA GMD Program Overview, November 4, 2013

(U) EKV impact with the target warhead is outside the Earth's atmosphere using the direct collision to destroy the target warhead. Boeing is the prime contractor for the GBI and procures the EKV from Raytheon Missile Systems. There are two primary variants of the EKV system, capability enhancement I (CE-I) and capability enhancement II (CE-II). The CE-I configuration includes connector upgrades from the first prototype to address obsolescence issues. The CE-II version is an upgrade of CE-I to resolve processor obsolescence issues and enable the EKV to track a greater number of objects. There are other subconfigurations within CE-I and CE-I variants that resulted from resolving design and manufacturing risks.

(U) Ground-Based Interceptor and Exoatmospheric Kill Vehicle Reliability

(U) Origin of Reliability Assessment – Flight Test Failures

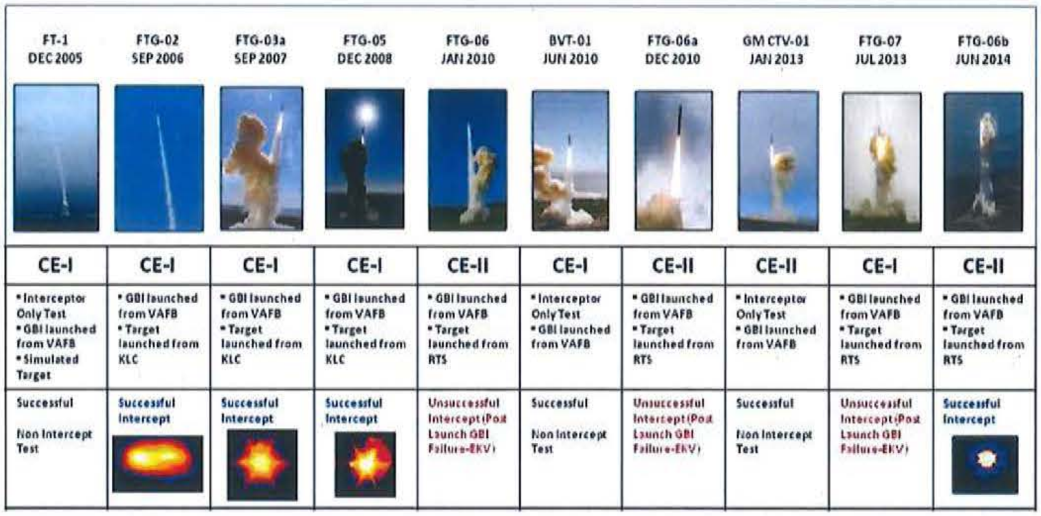
(U//~~FOUO~~) Prior to Flight Test Ground-Based Interceptor (FTG) 06b in June 2014, the GMD Program had not been able to demonstrate a successful CE-II Interceptor test in two CE-II flight attempts. FTG-06 in January 2010 failed due to a missing lockwire on a CE-II EKV wire harness connector. Work instructions were updated as part of the corrective action to ensure verification of all lockwires. The GMD Program Office added a retest designated as FTG-06a. However, this retest also failed in December 2010 due to the effects of vibration on the EKV guidance system. [redacted]

USNORTHCOM - (b)(1), 1.7(e)

[redacted] The Ground-Based Interceptor Flight Test History (Figure 2) provides a summary of flight test events and failures noted in FTG-06, FTG-06a, and FTG-07.

Figure 2. (U) EKV Flight Test Events and Failures CE-I and CE-II

(U)



(U)

Source: GMD Program Office, August 4, 2014

(U) Legend

(U)

CTV	Controlled Test Vehicle	KLC	Kodiak Launch Complex, Alaska
FT	Flight Test	RTS	Reagan Test Site
FTG	Flight Test Ground-Based Interceptor	VAFB	Vandenberg Air Force Base, California
GBI	Ground-Based Interceptor		

(U)

(U) DoD IG Reliability Assessment Approach

(U) The GBI-EKV reliability assessment was based on a review of program documentation and data provided by the GMD Program Office. Critical documentation for this assessment included program documentation, current fielded asset reliability data, and demonstration of reliability analysis tools used to predict reliability values for fielded assets. We assessed CE-I and CE-II manufacturing and testing documentation for factors such as process variation and design maturity that affect the reliability of EKV.

(U//~~FOUO~~) GBI/EKV Reliability Modeling and Prediction

(U) Expert Panel Recommendation for Reliability Prediction Approach

(U) In September 2010, MDA assembled a team of experts from industry, DoD, and academia to determine the best method to quantify GBI reliability. The expert panel established criteria for GBI failure data evaluation and "scoring" to use in the GBI reliability model. Based on the input from the GMD program office and available data, the panel determined that the Bayesian method was the best approach to quantify the reliability of the GBI fleet. The expert panel recommended a two-phase reliability model approach. A relatively simple Bayesian[2] model was recommended by the expert panel to implement as an initial phase (Phase 1). For Phase 2, the panel recommended using lessons learned from the Phase 1 to improve the model by using ground test data to construct prior distribution for the model. The panel also recommended for Phase 2 to include the following factors in the model: the effect of flight environments (for example, vibration, shock, etc.), unit-level test data, assembly and subassembly functional test data, and environmental test data at all available levels.

(U//~~FOUO~~) Current GBI Reliability Prediction Approach

(U//~~FOUO~~) The current reliability model determines the reliability of the hardware assemblies on the GBI using Bayesian uniform system priors and a fixed-aged degradation factor $R_t = R_0 (1\text{-}DF)^{\Delta t}$. In Bayesian Analysis, a uniform system prior, used when parameters of a system are unknown, is a distribution of parameters for which all reliabilities between 0 and 1 are assumed equally likely. R_t is the reliability at the desired time, R_o is the initial reliability, DF is the degradation factor, and Δt is the time in years from emplacement to the date desired. OSD/JS - (b)(5); DoD OIG (b)(3), 10 USC 130 [redacted]. The data for each block consists of success and failure data from flight, acceptance test procedures (ATP), qualification, and one shot tests. OSD/JS - (b)(5); DoD OIG (b)(3), 10 USC 130 [redacted]. The industry standard (MIL-HDBK-189C) typically assumes the fix effectiveness factor (FEF) is 70 percent. Paragraph 6.3.3.4 of MIL-HDBK-189C states that FEF value should be derived from a thorough root cause analysis and credible mitigation solution to enhance the accuracy of the reliability calculation. It further (U//~~FOUO~~) states that the use of

[2] (U) Refer to Appendix B for a description of the Bayesian Analysis.

(U//~~FOUO~~) FEFs not based on such analysis can significantly degrade assessment accuracy. OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U//~~FOUO~~) The GBI system is considered OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]. The prior distribution for each component and failure mode is computed as an equal allocation from the uniform prior of GBI fleet reliability. Monte Carlo simulations[3] were run to get the reliability numbers. The numbers were sorted from highest to lowest. The 75 percent lowest value was selected and then multiplied by the age degradation factor to determine the final 75 percent lower confidence value outputted by the model. OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) & (b)(3), 10 USC 130 [redacted]

(U) GBI Reliability Goal

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

[3] (U) Monte Carlo simulation is a probability distribution generated from uniform random variables over several iterations.

Figure 3 – ~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

OSD/JS - (b)(1), 1.4(a), USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) Existing EKV Reliability Predictions

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

Figure 4 – (U) FY 2013 Fleet Reliability Pixie Chart

OSD/JS - (b)(1), 1.4(a), USNORTHCOM - (b)(1), 1.4(a) & (g)

[redacted]

Figure 5 – ~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

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(U) Risk-Based Upgrades

(U) Risk Management Process

(U) The GMD Program implements a risk management process and uses tools to enhance product reliability. The GMD Risk Management Plan (RMP) is the document used to manage risks to the EKV and the GMD Program. The RMP is used to document, categorize, track, and report EKV issues that affect cost, schedule, or performance. When a risk is identified, a risk mitigation plan containing several actionable items is tracked until the issue poses an acceptable program risk or is completely eliminated. GMD Program maintains a risk database that contains all risks including those closed so that a program history and lessons learned are readily available.

(U) GMD Program Office also prepares an annual Integrated Fleet Assessment Report. This report provides an assessment of the health of fielded assets. The report is a summary of risk data from the Boeing Opportunities and Risk Information System (BORIS) database and the Integrated Fleet Assessment Spreadsheet Tool (iFAST). iFAST calculates an overall GBI risk assessment based upon reliability data and weighting criteria for technical, cost, and schedule characteristics.

(U) Planned Upgrades

(U) GMD Program Office conducts analysis on GBIs to rank refurbishment candidates to reduce program risk. The analysis uses additional evaluation criteria to include Risk Review Board Rating based on the probability and consequence, Collateral Damage Risk, upgrade location, disassembly level, task duration, and hardware cost. The list of approved risks for individual upgrades of Flight Test Rotation (FTR) is defined as part of the Pre-Upgrade/Pre-Repair Review (PURR) process. The PURR process documents the current configuration variations baseline to determine which interceptor should be upgraded and identifies the risks to be mitigated.

(U) Future Reliability

(U/~~FOUO~~) The current GBI reliability model predicts the reliability growth using the Bayesian-based reliability prediction approach. OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) and (b)(3), 10 USC 130 [redacted]

(U/~~FOUO~~) OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

Figure 6 – (U) FY 2014 Fleet Reliability Pixie Chart

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OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) Assessment of EKV Manufacturing Maturity

(U) Our assessment of EKV manufacturing maturity included an evaluation of the manufacturing process documentation used from initial CE-I production to CE-II production. The four primary areas of the assessment were quality management systems, work instructions, configuration management, and acceptance testing. [redacted] DoD OIG - (b)(1), 1.7(e) and (b)(3), 10 USC 130 [redacted]

(U) Raytheon Quality Management System Requirements

(U) The requirements for Raytheon's quality management system for the EKV program changed between CE-I and CE-II, creating reliability variants. In 2005, Raytheon conformed to the ISO 9001 standard, but was not certified. In 2008, a no-cost requirement applicability matrix was established from GMD Program Office to Boeing to Raytheon flowing down Mission Assurance Provision (MAP) requirements. However, Raytheon did not flow MAP requirements to its subtier suppliers. In 2010, Raytheon became AS9100 Certified. Then in 2012, the Development and Sustainment Contract invoked a tailored set of the MDA Assurance Provisions Requirement Applicability Matrix (RAM) along with the MDA Parts, Material, and Process (PMAP); both added extensive design, manufacturing, test, and quality requirements to the contract. In 2012, the Development and Sustainment Contract required the MAP flowed down to the critical suppliers and additional requirements were added based on CE-I lessons learned, resulting in continual improvements in areas such as tin whiskers, red plague, and counterfeit parts. Through the evolution of the EKV program, there have been continuous improvements to mission assurance requirements due to lessons learned.

(U) Comparison of CE-I to CE-II Work Instructions for Production

(U//~~FOUO~~) We performed a comparison of CE-I variant work instructions to CE-II work instructions to identify changes that would affect the quality and reliability of the fully assembled EKV. This involved reviewing the work instructions used for [redacted] of the CE-I configuration, and then assessing the current CE-II, [redacted] work instructions. The focus was on integration operations related to the installation of the IMU and EU, the Payload mate process and a cable routing process. Comparisons of [redacted] to most current CE-II work instruction were performed to identify differences between serial numbers and to make an overall judgment of the effectiveness of the instructions. [redacted]

(U) Work Instruction Variations

(U/~~FOUO~~) There were few differences between the content identified in work instructions for [redacted]. The main difference between the two instructions was the change from paper work instructions to an electronic work instructions and records system (PRISM). However, there were several differences [redacted] instructions. Of note, the work instruction for [redacted] shows clarification for cable routing operations and provided precise torques operation requirements. Also, tool characteristics and tool identification numbers along with critical lift, critical handling, and critical operation notations for the EU were added to the work instructions.

(U//~~FOUO~~) The greatest difference was between [redacted] and the current CE-II [redacted] work instructions. The CE-II work instructions added lists for parts, tools, and other items needed for the operation before each major operation section. Detailed pictures and 3-D models were added in the electronic work instructions to provide colored lines for cabling to better depict cable routing for the specific types of cables and to allow the technician to zoom in on specific views. For clarity, Raytheon also improved quality shop floor operations by moving operations to a clean room environment with foreign object debris controls, contamination controls, and inspections. This also required personnel working on the EKV to wear hairnets, booties, smocks, and gloves while handling parts during the installation. These practices are typical for high-reliability systems, such as satellites. Work instructions also included details for unpacking and steps for operation preparation.

(U//~~FOUO~~) Overall there were noted improvements from the [redacted] work instructions to the current CE-II work instructions in identification of processes and addition of quality inspection points. The CE-II quality inspection procedure includes a checklist that ensures the inspector inspects all critical operations. Furthermore, inspections were added to capture lessons learned from previous nonconformances or process problems. This appears to reduce the number of issues and improve the quality of the final shipped item.

(U) Summary of Work Instruction Variations

(U) In the evolution of CE-I to CE-II EKV production, substantial process changes were implemented to ensure product reliability, such as clean room operations, control of cable routing, fastener torque specifications, and checklists for inspections which are necessary for product repeatability. OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) and, (b)(3) 10 USC 130 [redacted]

(U) Configuration Management

(U/~~/FOUO~~) Configuration management was evaluated as part of our assessment. We OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) [redacted] OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) [redacted] However, Boeing responded with a letter dated May 22, 2009, directing Raytheon to use a modified document baseline not approved by the Government, which effectively removed certain requirements from Raytheon's contract. Consequently, a total of 40 requirements had been excluded through a contract letter. For example Boeing excluded the following from Raytheon's contract without Government approval:

- (U) 15 requirements from the Payload Prime Item Development Specification,
- (U) 2 requirements from the Command Launch Equipment to Payload Interface Design Description Revision F,
- (U) 1 requirement from the GMD Fire Control and Communications Ground-Based Interceptor Interface Control Specification Revision G, and
- (U) 3 requirements from the Command and Launch Equipment to Knowledge Database Interface Design Description Revision.

~~(S)~~ OSD/JS - (b)(1), 1.4(a), USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U//~~FOUO~~) OSD/JS - (b)(5), DoD OIG - (b)(3) 10 USC 130 [redacted] Continual changes to design and contract requirements were difficult to manage. The Development and Sustainment Contract has improved design stability, although there are several contractors implementing design efforts including OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130, and (b)(4) [redacted] OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130, and (b)(4) [redacted] OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted].

(U) Testing

(U) We performed a comparative analysis of acceptance testing between [redacted] to determine if there are any changes in testing requirements, specifically in the areas of vibration, shock, and thermal cycle testing. The comparative analysis was done by assessing the acceptance test specification differences for the EKV Guidance Unit/Kill Vehicle and the acceptance test specifications differences for the EKV Payload for the [redacted] Payloads.

(U) We found that [redacted] was tested to a later Payload Acceptance Test Specification revision (ATS60854-462 Revision G) than [redacted] (ATS60854-462 Rev B). However, there were no significant difference between Revision B and Revision G of the Payload Acceptance Test Specification; therefore, there is no concern regarding Payload testing.

(U) With regards to EKV Guidance Unit/Kill Vehicle acceptance testing, [redacted] was subject to a later revision (ATS60854-451 Revision G) of the EKV Guidance Unit/Kill Vehicle Acceptance Test Specification than [redacted] (ATS60854-451 Revision A). We found that a change in the area of divert lateral vibration had been made in Revision G. The new profile was developed based on the data collected during previous flight tests and analysis that Raytheon performed (ENB 01-09-5.0-200 Revision -). It is our understanding that the acceptance test specification was updated to ensure full testing of the divert lateral vibration and shock spectrum. [redacted].

(U) Service Life

~~(S)~~ [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) DoD OIG - (b)(3), 10 USC 130 [redacted]. OSD/JS (b)(5), DoD OIG -(b)(3), 10 USC 130 [redacted] Additionally, as part of the Development and Sustainment Contract, MDA stated that it has established and will continue to conduct a Stockpile Reliability Program (SRP) to build additional confidence in the assemblies and extend usable component service life based on test data. MDA asserts that items that are identified, based on test data, as not meeting required service life will be replaced with new and/or redesigned assemblies during EKV upgrades.

(U/~~/FOUO)~~ OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted] OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U/~~/FOUO)~~ OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]
OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) Section 2 Summary

(U/~~/FOUO)~~ MDA is on a path to improve its method of predicting reliability, which is the Bayesian Analysis approach. However, the current predictions for field asset
OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) Overall Findings and Recommendations

(U) Finding A

(U) Reliability of Interceptors

(U) The GMD Program GBI reliability predictions stated in the Integrated Fleet Assessment Report (November 2013), which include EKV reliability, [redacted]

- **(U) Fleet Reliability Predictions –** The Integrated Fleet Assessment Report uses the Bayesian Analysis to statistically predict individual GBI reliability. The Bayesian approach assumes each component has the same prior distribution. Each component is made by different manufacturers and contains unique processes.

- **(U) Fix Effectiveness Factor –** The Fix Effectiveness Factor takes into account human error in determining and resolving hardware and software nonconformances. The GMD Program's [redacted].

- **(U) Raytheon Missile Systems Quality Management System Maturity –** Our assessment of the quality management system used by Raytheon in the manufacturing of EKVs found very significant changes that should be considered in the fleet assessment report, such as the following.

  - (U) Prior to the Development and Sustainment Contract, stringent [redacted]

  - ~~(S)~~ [redacted]

- ~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]
- ~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) Recommendations, Management Comments and Our Response.

(U) Recommendation A1

(U/~~/FOUO)~~ We recommend that the Director, Missile Defense Agency perform an extensive assessment of manufacturing process maturity OSD/JS (b)(5) [redacted]

(U) Director, Missile Defense Agency

(U/~~/FOUO)~~ Director, Missile Defense Agency, agreed and stated that earlier in FY 2014, MDA started a comprehensive review of the GBI manufacturing process maturity; the results will be reflected OSD/JS (b)(5) [redacted] where appropriate.

(U) Our Response

(U) The Director's comments are responsive. We request that MDA notify the OIG when the actions are complete. No further comments are required.

(U) Recommendation A2

(U/~~/FOUO)~~ OSD/JS - (b)(5) [redacted]

OSD/JS - (b)(5); DoD OIG - (b)(3) 10 USC 130 [redacted]

(U) Director, Missile Defense Agency

(U/~~/FOUO)~~ Director, Missile Defense Agency, partially agreed. The Director stated the current GBI reliability assessment methodology was established based on a Government/Academia/Industry Expert Panel in 2010. However, as part of the

OSD/JS - (b)(5) [redacted]

(U/~~/FOUO)~~ OSD/JS - (b)(5) [redacted]
OSD/JS - (b)(5) [redacted]

(U) Our Response

(U/~~/FOUO)~~ The Director's comments are responsive. We agree that further refinement of the Probabilistic Risk Assessment methodology is required, and we stress that it should use factors such as those identified in DoD Handbook Reliability Growth Management (MIL-STD-189C) OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]"[4] Based on the reliability growth concepts and methodologies presented in the MIL-HDBK-189C handbook; which have evolved over the last few decades by actual applications to Army, Navy, and Air Force systems; on average, a corrective action that is developed and implemented will rarely totally eliminate the mode's failure rate. Although MDA is OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

[4] (U) MDA Technical Comments, DoD IG EKV Quality Assurance and Reliability Report – Discussion Draft Section 2, Item No. 17, June 2014.

(U) Finding B

(U) Service Life

(U) OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) and (b)(3), 10 USC 130; [redacted]

(U) OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) and (b)(3), 10 USC 130; [redacted]

- (U) OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) and (b)(3), 10 USC 130; [redacted]
- (U) OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) and (b)(3), 10 USC 130 [redacted]
- (U) OSD/JS - (b)(5); DoD OIG - (b)(1), 1.7(e) and (b)(3), 10 USC 130 [redacted]

(U) Recommendations, Management Comments and Our Response

(U) Recommendation B1

(U//~~FOUO~~) We recommend that the Director, Missile Defense Agency, complete a clear and actionable plan to mitigate OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]**. The plan should include a Government-accepted approach for tracking and mitigation.**

(U) Director, Missile Defense Agency

(U//~~FOUO~~) OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) Our Response

(U//~~FOUO~~) OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) Recommendation B2

(U//~~FOUO~~) OSD/JS - (b)(5), DoD OIG (b)(3) 10 USC 130 [redacted]

(U) Director, Missile Defense Agency

(U//~~FOUO~~) OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]; [redacted] OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) Our Response

(U//~~FOUO~~) The Director's comments are responsive. No further comments are required.

(U) Recommendation B3

(U) Redirected Recommendation

(U) We redirected Recommendation B3 to the Commander, United States Northern Command.

(U/~~FOUO~~) We recommend that the Commander, United States Northern Command, OSD/JS - (b)(5), DoD OIG - (b)(1) 1.7e and (b)(3), 10 USC 130 [redacted]

(U) Director of Operations (J3), United States Northern Command

~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted] OSD/JS - (b)(5), USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

(U) Our Response

(U/~~FOUO~~) The United States Northern Command, Director of Operations, comments are responsive. No further comments are required.

(U) Appendix A

(U) Scope and Methodology

(U) We conducted this assessment from September 2013 through September 2014 in accordance with the Council of the Inspectors General on Integrity and Efficiency, "Quality Standards for Inspection and Evaluation." Those standards require that we plan and perform the assessment to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our assessment objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our assessment objectives.

(U) To perform the reliability assessment, we reviewed program documentation and data provided by the GMD Program Office in Huntsville, Alabama, and Raytheon Missile Systems in Tucson, Arizona. The assessment focused on the following:

- (U) GBI fleet reliability data,
- (U) Applicable statutory and regulatory requirements, and
- (U) Missile pedigrees and manufacturing data packages.

(U) We reviewed program office documentation, including EKV configuration differences, field asset reliability data, reliability analysis tools used to predict reliability values for fielded assets, and program office risk management information. At Raytheon, we reviewed contractual requirements, manufacturing and quality management system documentation, failure reporting data, and waivers and deviations. Because both CE-I and CE-II configurations are in use, we compared select builds to note changes in the quality management system process and procedures and assess process variations and design maturity affecting reliability.

(U) DoD OIG Assessment Criteria

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

- ~~(S)~~ OSD/JS - (b)(1), 1.4(a); USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]
- (U) OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]
- (U) EKV Development and Sustainment Contract,
- (U) MIL-HDBK-189C, Department of Defense Handbook, Reliability Growth Management,
- (U) MIL-HDBK-781A, Department of Defense, Handbook for reliability Test Methods, Plans, and Environment for Engineering Development Qualification, and Production, and
- (U) MIL-STD-883J, Department of Defense Test Methods Standard Microcircuits.

(U) Use of Technical Assistance

(U) Quality assurance engineers and quality assurance specialists with a background in defense assisted in the assessment. We established teams of subject matter experts who assessed to the AS9100C Quality Management System standard. The subject matter expert teams consisted of 17 quality assurance engineers who have received AS9100C certification training, and have an average of 17 years of quality assurance audit experience.

(U) Appendix B

(U) Bayesian Analysis

(U) Some analysts argue that Bayesian Analysis is subjective because the conclusion depends on the assumptions made on prior distributions. In Bayesian modeling, current knowledge of the model parameters is expressed by placing a probability distribution on the parameters, called the "prior distribution." When new data become available, the data are then combined with the prior distribution to produce an updated probability distribution called the "posterior distribution," on which all Bayesian inference is based. When prior knowledge of the system and data are limited, a uniform prior distribution is typically used for the model. The uniform distribution for the reliability model assumes all values between 0 and 1 are equally likely for each component. Due to OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) OSD/JS - (b)(5); DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) Appendix C

(U) Prior Coverage

(U) During the last 5 years, the Government Accountability Office (GA) issued eight reports discussing the Ground-Based Midcourse Defense, Exoatmospheric Kill Vehicle. Unrestricted GAO reports can be accessed over the Internet at http::/[/www.gao.gov](http://www.gao.gov).

(U) GAO

(U) Report No. GAO-13-294SP, "Defense Acquisitions: Assessments of Selected Weapon Programs," March 28, 2013

(U) Report No. GAO-12-486, "Missile Defense: Opportunity Exists to Strengthen Acquisitions by Reducing Concurrency," April 20, 2012

(U) Report No. GAO-12-400SP, "Defense Acquisitions: Assessments of Selected Weapon Programs," March 29, 2012

(U) Report No. GAO-11-555T, "Missile Defense: Actions Needed to Improve Transparency and Accountability," April 13, 2011

(U) Report No. GAO-11-233SP, "Defense Acquisitions: Assessments of Selected Weapons Programs," March 29, 2011

(U) Report No. GAO-11-372, "Missile Defense: Actions Needed to Improve Transparency and Accountability," March 24, 2011

(U) Report No. GAO-10-311, "Defense Acquisitions: Missile Defense Transition Provides Opportunity to Strengthen Acquisition Approach," February 25, 2010

(U) Report No. GAO-09-403T, "Defense Acquisitions: Charting a Course for Improved Missile Defense Testing," February 25, 2009

(U) Appendix D

(U) Derivative Sources

- (U) GMD Integrated Fleet Assessment Report (D743-25770-1)

  Declassify On: 20381106
  Date of Source: 06 November 2013

- (U) GBI Reliability MDA Briefing

  Declassify On: 20361019
  Date of Sources: March 2013

- (U) DoD IG P&O-TAD 5RMS02 Annex (Secret level annex to Finding No 5RMS02)

  Declassify On: 20381114
  Date of Source: 14 November 2013

- (U) DoD IG P&O-TAD Service Life Assessment Engineering Work Paper

  Declassify On: 20390319
  Date of Source: 19 March 2014

- (U) Ground-Based Midcourse Defense (GMD) Security Classification Guide (SCG), Change 1 August 25, 2008 to include administrative changes July 11, 2011

(U) Management Comments

DoD Project No. DTOTAD-0005: Exoatmospheric Kill Vehicle Quality Assurance Assessment
DRAFT REPORT (Part B)
September 19, 2014

Missile Defense Agency Response to DoD IG Recommendations

Instructions:
For Each recommendation, MDA should either "Concur", "Partially concur", or "Non-Concur" and explain the basis for any disagreement. (Alternate labels, such as "Concur with Comment" are not acceptable). The comments should also describe how each agreed-to action will be accomplished and include an estimated completion date.

RECOMMENDATIONS

Recommendation A1: (U//~~FOUO~~) OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5) [redacted]

MDA Response to Recommendation A1: (U) Concur

(U//~~FOUO~~) Earlier this fiscal year, MDA started a comprehensive review of the GBI manufacturing process maturity. The Government and Industry technical and quality teams have reviewed the EKV manufacturing processes and test thoroughness / OSD/JS - (b)(5) [redacted]

Recommendation A2: (U//~~FOUO~~) OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted] OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

MDA Response to Recommendation A2: (U) Partially-concur

(U//~~FOUO~~) The current GBI reliability assessment methodology was established based upon a Government/Academia/Industry Expert panel in 2010. As part of the on-going OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

Recommendation B1: (U//~~FOUO~~) OSD/JS - (b)(5) [redacted] OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

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MDA Response to Recommendation B1: **(U) Concur**

(U//~~FOUO~~) OSD/JS - (b)(5) OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

Recommendation B2: (U//~~FOUO~~) OSD/JS - (b)(5) OSD/JS - (b)(5) [redacted]

MDA Response to Recommendation B2: **(U) Concur**

(U//~~FOUO~~) OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

Recommendation B3: (//~~FOUO~~) OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

(U) Final Report Reference

(U) Redirected Recommendation B3

MDA Response to Recommendation B3:

(U//~~FOUO~~) OSD/JS - (b)(5) OSD/JS - (b)(5), DoD OIG - (b)(3), 10 USC 130 [redacted]

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UNITED STATES NORTHERN COMMAND

OCT 1 6 2014

MEMORANDUM FOR INSPECTOR GENERAL DEPARTMENT OF DEFENSE

FROM: Director of Operations (J3)
United States Northern Command
250 Vandenberg St
Peterson AFB CO 80914

SUBJECT: (U) Response to Exoatmospheric Kill Vehicle Quality Assurance and Reliability Assessment – Part B dtd 29 September 2014

1. ~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]
USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

2. ~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]
USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

3. ~~(S)~~ USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]
USNORTHCOM - (b)(1), 1.4(a) & (g) [redacted]

4. (U) USNORTHCOM appreciates the Inspector General's quality assurance and assessment of the Exoatmospheric Kill Vehicle program and the opportunity to comment. Point of contact is Brigadier General Matt Molloy, USAF, NC/J3D, DoD OIG - (b)(6) [redacted]

JACK L. BRIGGS II
Major General, USAF

Classified by: DoD OIG - (b)(6) [redacted] DAFC
Derived From: NORTHCOM BMD SCG dtd 11 March 2011
Declassify On: ~~08OCT2039~~

DETER PREVENT DEFEAT

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(U) Acronyms and Abbreviations

(U) AS	(U) Aerospace Standard
(U) ATP	(U) Acceptance Test Procedure
(U) BORIS	(U) Boeing Opportunities and Risk Information System
(U) CE	(U) Capability Enhancement
(U) EKV	(U) Exoatmospheric Kill Vehicle
(U) EU	(U) Electronics Unit
(U) FEF	(U) Fix Effectiveness Factor
(U) FTG	(U) Flight Test Ground-Based Interceptor
(U) FTR	(U) Flight Test Rotation
(U) GBI	(U) Ground-Based Interceptor
(U) GMD	(U) Ground-Based Midcourse Defense
(U) iFAST	(U) Integrated Fleet Assessment Spreadsheet Tool
(U) IMU	(U) Inertial Measurement Unit
(U) MAP	(U) Mission Assurance Provisions
(U) MBIT	(U) Maintenance Built-In-Test
(U) MDA	(U) Missile Defense Agency
(U) MLA	(U) Manufacturing Lien Authorization
(U) NCMR	(U) Nonconforming Material Report
(U) NORTHCOM	(U) United States Northern Command
(U) OBV	(U) Orbital Boost Vehicle
(U) PES	(U) Probability of Engagement Success
(U) PMAP	(U) Parts, Material, and Processes
(U) PURR	(U) Pre-Upgrade/Pre-Repair Review
(U) QN	(U) Quality Notice
(U) RAM	(U) Requirement Applicability Matrix
(U) RDW	(U) Request for Deviation/Waiver
(U) RIS	(U) Requirement Issue Sheet
(U) RMP	(U)Risk Management Plan
(U) SN	(U) Serial Number

(U) SOW	(U) Statement of Work
(U) SRP	(U) Stockpile Reliability Program

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