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Counter-MANPADS Program Results

Fiscal Year 2008 Report to Congress

March 30, 2010

Homeland Security

Science and Technology Directorate

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Foreword

March 30, 2010

I am pleased to present the following report, "Counter-MANPADS Program Results," which the Department of Homeland Security's (DHS's) Science and Technology (S&T) Directorate prepared in response to requirements in Senate Report 110-84, which accompanies the Fiscal Year 2008 DHS Consolidated Appropriations Act (P.L. 110-161). The report provides the results of Phases I, II and III of S&T's Counter-MANPADS Program.

Pursuant to congressional requirements, this report is being provided to the following Members of Congress:

The Honorable David E. Price
Chairman, House Appropriations Subcommittee on Homeland Security

The Honorable Harold Rogers
Ranking Member, House Appropriations Subcommittee on Homeland Security

The Honorable Robert C. Byrd
Chairman, Senate Appropriations Subcommittee on Homeland Security

The Honorable George V. Voinovich
Ranking Member, Senate Appropriations Subcommittee on Homeland Security

This report contains proprietary information that is for U.S. Government use only and may not be disclosed outside the U.S. Government without written authorization from the specified owners of the data.

Inquiries relating to this report may be directed to me at (202) 254-5601 or the Department's Acting Chief Financial Officer, Peggy Sherry, at (202) 447-5751.

Sincerely,

Tara O'Toole

Dr. Tara O'Toole
Under Secretary for Science and Technology

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Executive Summary

The Science and Technology Directorate (S&T) of the U.S. Department of Homeland Security (DHS) has completed the Counter Man-Portable Air-Defense System (MANPADS) Program, a congressionally directed effort to develop and demonstrate the effectiveness of antimissile devices for commercial aircraft. DHS S&T successfully adapted existing directed infrared countermeasure (DIRCM) technologies, evaluated their ability to protect commercial platforms, assessed operational suitability and estimated total life-cycle costs. The production representative prototypes meet system effectiveness requirements and the design allows for a universal solution across large narrow-body and wide-body commercial aircraft. DHS S&T also evaluated other countermeasure technologies and determined that DIRCM is currently the most suitable for implementation in commercial aviation. This report summarizes program results, addresses remaining actions and defines a set of deployment alternatives and their projected costs.

The Counter-MANPADS Program Office accomplished its goals in three phases:

- Phase I: design and architecture analyses
- Phase II: system development; demonstration; test and evaluation; and Federal Aviation Administration (FAA) certification
- Phase III: suitability assessment of two DIRCM systems in the commercial airline operating environment

During Phase III, which began in March 2006, DHS S&T evaluated DIRCM systems on both cargo and passenger aircraft for more than 16,000 flight hours. Phase III also included live-fire missile tests to demonstrate each system's ability to counter single- and multi-threat attacks. Through these efforts, DHS S&T completed final performance and suitability assessments, further refined the DHS S&T Counter-MANPADS Life-Cycle Cost Model and developed a set of deployment alternatives and life-cycle cost estimates.

In accordance with the Wartime Supplemental Appropriations Act of 2003, DHS S&T developed a process for the certification of DIRCM counter-MANPADS systems. DHS S&T standardized the overall application process, the performance, data and test requirements and the evaluation criteria to establish that a counter-MANPADS system is effective and functional to protect commercial aircraft from MANPADS attacks. Should a decision to deploy counter-MANPADS systems be made, DHS would be able to apply this certification process to any counter-MANPADS acquisition.

Throughout all phases of the program, DHS S&T leveraged the expertise of government agencies and industry stakeholders to vet user requirements and concepts of operations and ensure applicable regulatory requirements were addressed. The Federal Aviation Administration

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(FAA) was a key partner in developing crew interface requirements, issuing the airworthiness approvals and facilitating DHS S&T flight tests to execute the program. The Department of Defense (DOD) provided extensive support in test and evaluation expertise and facilities, the evaluation of technical solutions and in the development of the certification standard. The Department of State and the Department of Commerce worked with DHS to determine the scope of the export control issues involved in using military technologies and are exploring potential resolutions to those issues.

DHS S&T established a Suitability Working Group to coordinate with the aviation community stakeholders and industry experts. This group met regularly to vet concepts of operation and maintenance, evaluate key cost assumptions and parameters and exchange views on deployment issues. The participation of [redacted] representatives enabled DHS S&T to further refine operations and logistics approaches and cost estimation assumptions.

Suitability Results and Analysis

DHS S&T completed field service evaluations to assess the suitability of the counter-MANPADS systems in the airline operating environment in terms of reliability, availability, effectiveness and overall interoperability. BAE Systems North America (BAE) installed its JETEYE® systems on three American Airlines 767-200s, accumulating [redacted] flight hours in passenger revenue service. Northrop Grumman Corporation (NGC) installed its Guardian™ systems on 10 FedEx MD-10s, accumulating [redacted] flight hours in cargo revenue service. DHS S&T analyzed data on installations, operations, system reliability, support logistics, maintenance and associated costs and evaluated the concepts of operations and logistical support.

The key DHS S&T findings are summarized as follows:

- Both systems meet Counter-MANPADS Program effectiveness requirements and can defeat multiple missiles under many attack scenarios. [redacted]

- Both systems currently fall short of Counter-MANPADS Program reliability requirements, which measure the system's ability to perform as designed in the operational environment without any failures. This shortfall results in increased spares and maintenance costs. Both vendors have identified product improvements that would further increase reliability but without a dedicated reliability improvement program, the improved systems still fall short of the program requirement. To mitigate the impact of lower reliability on airline operations and prevent delayed or canceled flights, counter-MANPADS deployment policy would have to allow airlines to defer the maintenance of inoperative counter-MANPADS system[redacted]

[redacted]

- The service evaluations demonstrated that the airlines can integrate these DIRCM systems without significant impacts to daily operations.
- However, any counter-MANPADS deployment must take into account two key conditions: (1) the need to grant export control relief for counter-MANPADS systems and (2) the need to allow limited continued flight operations until the system is repaired.

Deployment Costs

DHS S&T developed a life-cycle cost (LCC) model to estimate the research, development, test and evaluation (RDT&E), acquisition, installation, operations and support (O&S) and disposal costs for the deployment of these two DIRCM systems over a 20-year life cycle. During Phase III, DHS S&T collected acquisition, installation, operations, maintenance, repair and de-modification data to verify and refine cost assumptions in the cost model and vetted the model in detail with the Suitability Working Group. The deployment alternatives provide for a range of options to equip aircraft and respond in appropriate measure to a perceived level of risk. DHS S&T developed the following potential deployment alternatives using this risk-based approach:

- Deployment to targeted wide-body passenger aircraft in the U.S. commercial fleet that are evaluated to be at a higher risk;
- Deployment to all wide-body passenger aircraft, which carry larger passenger loads and have greater exposure to international destinations; and
- Deployment to all large passenger aircraft, wide-body and large narrow-body (Boeing 737/Airbus A318 or larger).

The following table summarizes the associated cost estimates and deployment timelines. The operations and support costs are the largest component of total life-cycle cost.

Deployment Alternative Costs for 20-Year Life Cycle

Deployment Alternative	**Aircraft Equipped**	**Passengers Protected Annually** (millions)	[redacted]	**Life-Cycle Cost** ($ billions)*
Targeted Wide-body Passenger Aircraft	98	20	[redacted]	2.2
All Wide-body Passenger Aircraft	526	107	[redacted]	6.8
All Large Passenger Aircraft	3,636	800	[redacted]	43.3

*Note: Assumptions and limitations of these cost estimates are defined in Section IV[redacted]

These cost estimates assume that counter-MANPADS deployment policy will support export control relief and allow for operation with temporarily inoperative systems. The current application of standard export licensing requirements under the International Traffic in Arms Regulation will cause serious operational, logistical and financial problems for U.S. air carriers [redacted]

[redacted]

and an unsustainable burden on the U.S. export licensing system. The reliability levels are such that, without the ability to continue limited operations with systems temporarily inoperative, the potential for flight delays and flight cancellations would substantially increase life-cycle costs.

Related Efforts

Congress directed DHS S&T to evaluate Emerging Counter-MANPADS Technologies (ECMT) under a separate program. The ECMT Program Office evaluated one airborne and two ground-based concepts using non-DIRCM countermeasures to protect commercial aircraft from MANPADS attacks. Through technology demonstration and analysis, DHS S&T determined that the concepts have technical and safety shortfalls that must be addressed before any commercial deployment of non-DIRCM technology can be considered.

DHS S&T completed Project CHLOE to assess the feasibility of persistent high-altitude standoff protection of commercial aircraft using unmanned aerial vehicles (UAVs). These tests demonstrated an ability to detect, track and lase a MANPADS; however, the countermeasure technology currently cannot meet performance requirements to defeat a MANPADS.

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Conclusions/Actions

If the proliferation of MANPADS is determined to be a threat to U.S. commercial aviation, DHS S&T has a potential solution. By developing two production-representative countermeasure prototypes and evaluating them in commercial operating environments, DHS S&T has demonstrated that it is possible to adapt existing missile countermeasure technologies to protect commercial aircraft from the threat of MANPADS, but at considerable cost and with an impact to airline operations. In addition, the commercialization of this technology generated technical and operational innovations that will directly benefit DOD and the warfighter. Key findings include:

- Both systems meet effectiveness requirements and can defeat multiple missiles under many attack scenarios. [redacted]

[redacted]

- Both systems currently fall short of Counter-MANPADS Program reliability requirements, increasing the costs for spares and maintenance. The system changes implemented during the service evaluations improved reliability by an aggregate [redacted] percent.
- The service evaluations demonstrated that airlines can integrate the systems into the commercial aviation environment without significant impacts to daily operations provided that counter-MANPADS deployment decision includes export control relief and allows airlines to defer maintenance and dispatch aircraft with temporarily inoperative systems. This would mitigate the potential for delayed or canceled flights.
- The 20-year life-cycle cost estimate for protecting all wide-body and large narrow-body passenger aircraft is $43.3 billion. Doubling reliability can reduce total life-cycle cost by approximately $10 billion, and reducing drag by 25 percent can reduce total life-cycle cost by approximately $4 billion.

If counter-MANPADS are deployed to protect commercial aircraft, the actions required to facilitate a deployment would include:

- Export control legislation to specifically address the use of military technologies employed to protect commercial aviation. Compliance with the current International Traffic in Arms Regulation/Export Administration Regulations requirements for counter-MANPADS systems would cause serious operational, logistical and financial problems for U.S. air carriers and an unsustainable burden on the U.S. export licensing system.
- [redacted]
- A reliability improvement program to reduce life-cycle cost and minimize the potential for disruptions to airline operations.

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Counter-MANPADS Program Results

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I. Legislative Language

This document responds to Senate Report 110-84, accompanying the Fiscal year (FY) 2008 Department of Homeland Security (DHS) Appropriations Act (P.L. 110-161), regarding comprehensive passenger aircraft suitability assessment, which states the specific reporting requirements set forth in:

> The Committee directs the Department to report on the first portion of Phase III testing by the end of fiscal year 2008 and provide a recommendation on whether these systems are suitable for deployment or not.

In response to this direction, DHS Science and Technology Directorate (S&T) transmitted an interim white paper in August 2008 reporting on the first portion of Phase III testing. In a December 21, 2006, DHS S&T letter to Senators Robert Byrd and Thad Cochran and Congressmen Jerry Lewis and David Obey, DHS S&T also outlined its intentions to provide a comprehensive Phase III report upon completion of the passenger service evaluation. This report contains those results.

DHS S&T began planning a commercial aircraft antimissile device in response to the conference report accompanying P.L. 108-76, Emergency Wartime Supplemental Appropriations for the Fiscal Year 2003. The report states:

> The conferees direct the Under Secretary for Science and Technology to prepare a program plan for the development of an antimissile device for commercial aircraft. The plan should identify the process for delivery and certification of a prototype and the proposed cost and schedule for such an activity. The report should be provided to the Committees on Appropriations within 30 days of enactment of this Act.

[redacted]

II. Introduction

In 2002, the Administration identified man-portable air defense systems (MANPADS) as a credible threat to commercial aviation. MANPADS have been used to attack 35 civilian aircraft, downing 25 and claiming over 600 lives.[1] Because aviation contributes more than $3.5 trillion to the global economy,[2] a successful MANPADS attack against a U.S. commercial passenger airplane would have significant economic impacts extending far beyond the tragic loss of life. The United States and other concerned countries have recognized the implications that the proliferation of such weapons represents to global economic and political stability and have taken steps to counter the threat.

In 2003, Congress directed DHS to develop and implement a plan for protecting commercial aircraft from MANPADS. DHS established a Counter-MANPADS Program Office within its Science & Technology Directorate to execute a two-phase program to adapt existing technology to large commercial aircraft. DHS S&T worked with government experts to develop a performance-based competitive solicitation for industry to provide solutions within 24 months. In 2005, DHS S&T received funding for a third phase of the program to evaluate the suitability of the systems in a commercial aviation environment, and in 2007, DHS S&T received funding for an additional commercial passenger service evaluation.

The Counter-MANPADS Program leveraged proven military technology and used a rigorous systems engineering approach to adapt the systems and evaluate their performance and suitability for commercial applications. DHS S&T worked closely with system developers and other stakeholders to develop and refine requirements, designs and concepts of operations and maintenance, mitigate technical and program risks and estimate total life-cycle costs.

DHS S&T used competitive and knowledge-based acquisition practices to ensure the solutions for implementation met user needs and provided the best value to the government.

A. Background

1. Commercial Aviation and the Economy

Commercial aviation represents a major portion of the domestic and international economies, as statistics compiled by the U.S. Department of Transportation, Airline Transport Association and the International Civil Aviation Organization show. The industry constitutes 7.5 percent of the

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[1]Sources for this information include *Homeland Security: Protecting Airliners from Terrorist Missiles*, CRS Report for Congress, updated February 15, 2005, pp. 3-6.
[2]*The Economic and Social Benefits of Air Transport 2008*, Air Transport Action Group, April 2008.

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global economy, translating to over $3.5 trillion and 32 million jobs worldwide.[3] In 2008, it constituted 5.2 percent of the U.S. gross domestic product, translating to $513.5 billion. At the end of 2008, 25 scheduled air carriers were flying large passenger aircraft and 67 regional carriers were operating smaller aircraft. On average, more than 20,000 flights with over two million seats occupied take off on a typical day in the United States.[4] Given the importance of the airline industry to the national and global economies, the United States is focused on the security of this industry.

2. The MANPADS Threat

MANPADS are short-range, shoulder-fired anti-aircraft missiles that are carried and fired by one or several individuals. They are easy to transport and conceal since they average the size and weight of a large duffle bag and easily fit in the trunk of an automobile. Figure 1 shows the Soviet SA-7 Strela MANPADS, a highly proliferated MANPADS and its launch canister. Figure 2 shows several models of MANPADS.

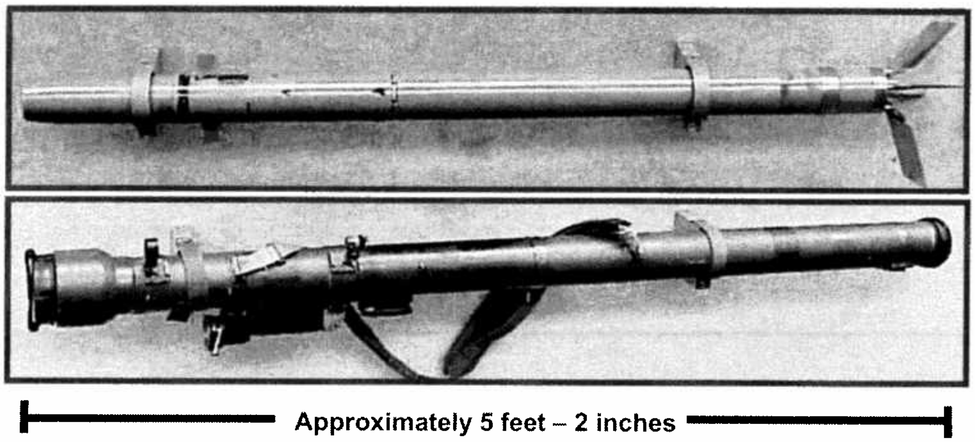

Figure 1: SA-7 Strela MANPADS, a Highly Proliferated Missile System

[3] Ibid.

[4] Federal Aviation Administration, *FAA Aerospace Forecasts FY 2009-2025*, available online at: http://www.faa.gov/data_statistics/aviation/aerospace_forecasts/2009-2025/.

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Figure 2: Chechen Soldiers Armed with Several Models of MANPADS

As of 2006, approximately 20 countries have produced or licensed the production of 30 different types of MANPADS. To date, an estimated one million missiles have been manufactured and intelligence estimates indicate that at least 24 terrorist organizations possess MANPADS.[5] Most of the MANPADS the terrorist organizations possess use infrared seeking heat sensors, which guide the missile to the hot parts of an aircraft such as its engines. Figure 3 shows how infrared imagery highlights the hot parts of an aircraft. The most common MANPADS have a range of up to three miles and can strike an aircraft at altitudes in excess of 15,000 feet. Older MANPADS models can be purchased for less than $5,000.[6]

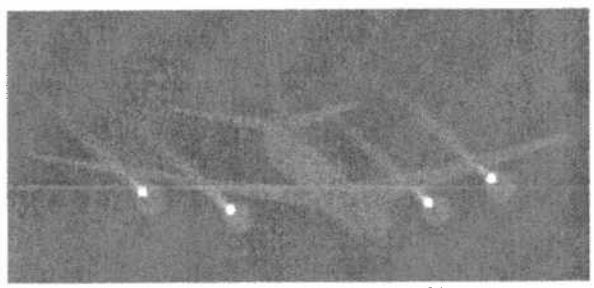

Figure 3: Typical Aircraft Heat Signature

Until recently, military aircraft were the primary targets of MANPADS. Notable exceptions have occurred in areas experiencing unrest and insurgency, such as in the Georgian cities of Sukhimi and Abkhazia where, in 1993, terrorists shot down two Transair Georgian Airline civilian aircraft, killing 108 people. On November 28, 2002, terrorists linked to Al-Qaida fired two MANPADS at an Israeli jetliner taking off from Mombasa, Kenya. Although the 2002 attack was not successful, it focused the world's attention on this potential threat. On November 23, 2003, a DHL International cargo aircraft departing Baghdad Airport in Iraq was struck by a

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[5]Sources for this information include *Homeland Security: Protecting Airliners from Terrorist Missiles*, CRS Report for Congress, updated February 15, 2005, pp. 3-6.
[6] Fact Sheet, Department of State, Bureau of Political-Military Affairs, Office of Weapons Removal Abatement, Washington, D.C., July 31, 2008.

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surface-to-air missile, resulting in the complete loss of hydraulics and ultimately the entire airframe upon landing. This incident confirmed that such missiles are a clear and present threat to commercial aviation. In August 2004, the U.S. Federal Bureau of Investigation (FBI) arrested two men in Albany, New York, while the men were trying to buy shoulder-fired missiles. As recently as June 2009, the Transportation Security Administration (TSA) canceled Delta Airlines' plans to start passenger service to Kenya and Liberia, citing security concerns and the possibility of MANPADS threats. The threat remains real and an international concern.[7]

3. The National Strategy

The 2002 Mombasa incident underscored Al-Qaida's continued interest in attacking the aviation industry and in the acquisition of MANPADS. The Administration assembled an interagency task force to address and develop ways to better manage vulnerabilities against a MANPADS attack. The Interagency MANPADS Working Group (IMWG) was established and currently serves as the lead interagency coordination mechanism for federal government aviation security stakeholders to cooperate on the development, implementation and exercise of strategies and specific measures to counter the threat of MANPADS to commercial aviation.

In 2002, a White House Task Force representing 20 agencies, under the auspices of the White House Office of Science and Technology Policy, developed a multi-layered strategy to counter the threat, specifically focusing on three areas as shown in Figure 4: (1) non-proliferation and threat reduction, (2) technical countermeasures and (3) tactical operations. To address this second area, Congress directed DHS "to prepare a program plan for the development of an antimissile device for commercial aircraft" in spring 2003. In September 2003, the DHS Undersecretary for S&T created the Counter-MANPADS Program Office to execute the program plan.

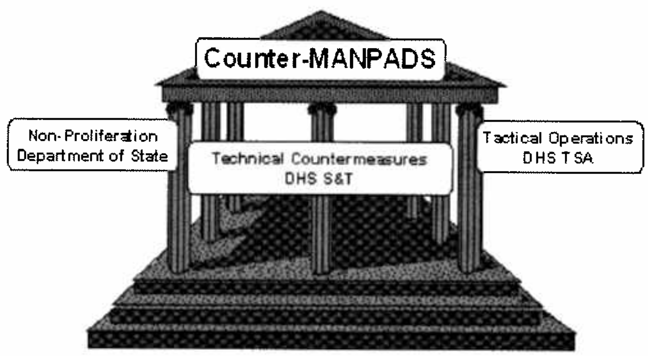

Figure 4: Counter-MANPADS Strategy Focuses On Three Primary Areas of Threat Reduction

[7] For a broad unclassified summary of the threat, see *Homeland Security: Protecting Airliners from Terrorist Missiles*, CRS Report to Congress RL31741, Congressional Research Service, Library of Congress, February 15, [redacted]

B. The DHS S&T Counter-MANPADS Program

The Counter-MANPADS Program mission was to develop, demonstrate and evaluate technologies to protect commercial aircraft from MANPADS. During fall 2003, the DHS S&T Counter-MANPADS Program Office released a performance-based solicitation for countermeasures protecting commercial wide-body and large narrow-body aircraft. DHS S&T conducted a competitive source selection process that encouraged and considered all approaches likely to meet performance, operational and cost constraints within the two-year allotted time frame. Of the original 24 white papers received, DHS S&T invited five companies whose solutions appeared most viable to submit full proposals and oral presentations. As a result of that source selection, BAE Systems North America (BAE), Northrop Grumman Corporation (NGC) and United Airlines (UAL) were each invited to negotiate Other Transaction Authority (OTA) agreements for Phase I of the program. BAE proposed a variant of the U.S. Army Advanced Threat Infrared Countermeasures (ATIRCM) system and NGC, a variant of the U.S. Air Force Large Aircraft Infrared Countermeasures (LAIRCM) system. UAL proposed a flare-based solution with a prior application on large aircraft.

During Phase I, a $13 million effort spanning the first six months of 2004, three vendors conducted trade studies regarding cost, maintenance, training, reliability, airframe and avionics integration. Phase I resulted in preliminary system designs and performance assessments. At the end of Phase I, DHS S&T considered the respective maturity of the technologies and their potential application to the commercial aviation in selecting BAE and NGC systems to proceed into Phase II of the DHS S&T program.

Phase II, a $111 million effort, began in August 2004 and continued through January 2006. During this 18-month phase, BAE and NGC (hereafter referred to as "the vendors") manufactured prototypes, integrated their solutions onto airframes, conducted ground and flight tests and obtained FAA airworthiness certification through Supplemental Type Certificates (STC). DHS S&T conducted independent analyses of the cost and maintenance data provided by the vendors and conducted independent testing and functional configuration audits to verify system conformance to performance requirements as defined in the Counter-MANPADS Program solicitation. Throughout these phases, DHS S&T worked closely with the vendors and other stakeholders to refine user requirements and concepts of operations and maintenance; mitigate technical and program risks; develop performance, reliability, maintainability and supportability metrics; and estimate total life-cycle costs. The Phase I and II findings are documented in a March 2006 report to Congress.[8]

In 2005, DHS S&T received funding for a third phase of the program to evaluate the suitability of the systems in a commercial aviation environment. DHS S&T began Phase III in March 2006

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[8] Department of Homeland Security Counter-MANPADS Program Summary: Report to Congress Detailing Phases I and II Findings of the Counter-MANPADS Program, March 2006.

with the primary objective of assessing overall suitability in the airline operating environment. The vendors manufactured additional prototypes, installed and operated the systems on both cargo and passenger revenue flights and accrued more than 12,000 operational hours. Phase III also included a live fire demonstration and additional test efforts to evaluate system improvements. Through these efforts, DHS S&T completed final performance and suitability assessments, further refined the DHS S&T Life-Cycle Cost Model and developed a set of deployment alternatives. The total funding for Phase III was $152 million, bringing the overall counter-MANPADS effort to $276 million. Figure 5 shows the distribution of the $276 million total program funding across the program participants, and Figure 6 shows how these funds were distributed across categories such as the DOD test facilities and subject matter expertise, systems engineering and technical support to the program, program management, engineering and hardware.

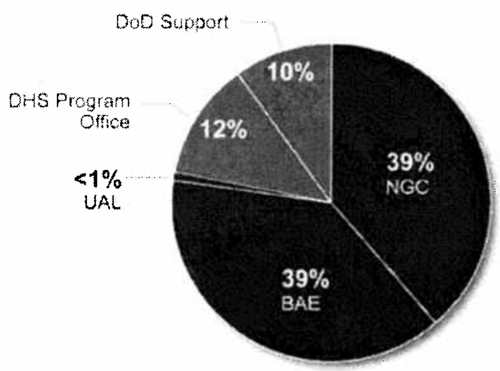

Figure 5: Program Funding by Participant

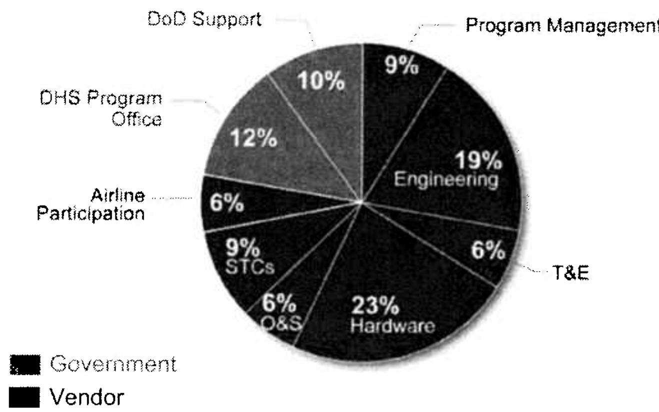

Figure 6: Program Funding by Category

C. Stakeholder Coordination

Interagency and stakeholder cooperation were essential to the Counter-MANPADS Program, as shown in Figure 7. DHS S&T leveraged the expertise of government agencies and industry stakeholders to vet user requirements and concepts of operations and ensure applicable regulatory requirements were addressed. The FAA was a key partner in developing crew interface requirements, issuing the airworthiness approvals and facilitating DHS S&T flight tests to execute the program. DOD provided extensive support in test and evaluation expertise and facilities, intelligence support, the evaluation of technical solutions and the development of the certification standard. The Departments of State, Defense and Commerce worked with DHS on export control issues associated with using military directed infrared countermeasure (DIRCM) technology. DHS also worked with TSA and FBI to assess security risks related to MANPADS at major U.S. airports.

Throughout the program, DHS S&T met with the commercial aviation community, including aircraft manufacturers, airlines and pilot organizations, to present concepts of operations, maintenance and user requirements, discuss deployment issues and understand the industry's concerns and perspectives. Stakeholder meetings facilitated industry involvement with participation from more than 50 different organizations. During Phase III of the Program, DHS S&T established a Suitability Working Group to strengthen communications and information exchange with stakeholders. This group met regularly to discuss details of operations and maintenance, evaluate key cost assumptions and parameters and exchange views on deployment issues. The participation of industry experts [redacted] enabled DHS S&T to further refine operational and logistic approaches and key cost assumptions. This group provided valuable data on delay and cancellation costs, airline personnel, displaced revenue costs and many other key cost parameters and sensitivities to improve the fidelity of the life-cycle cost model.

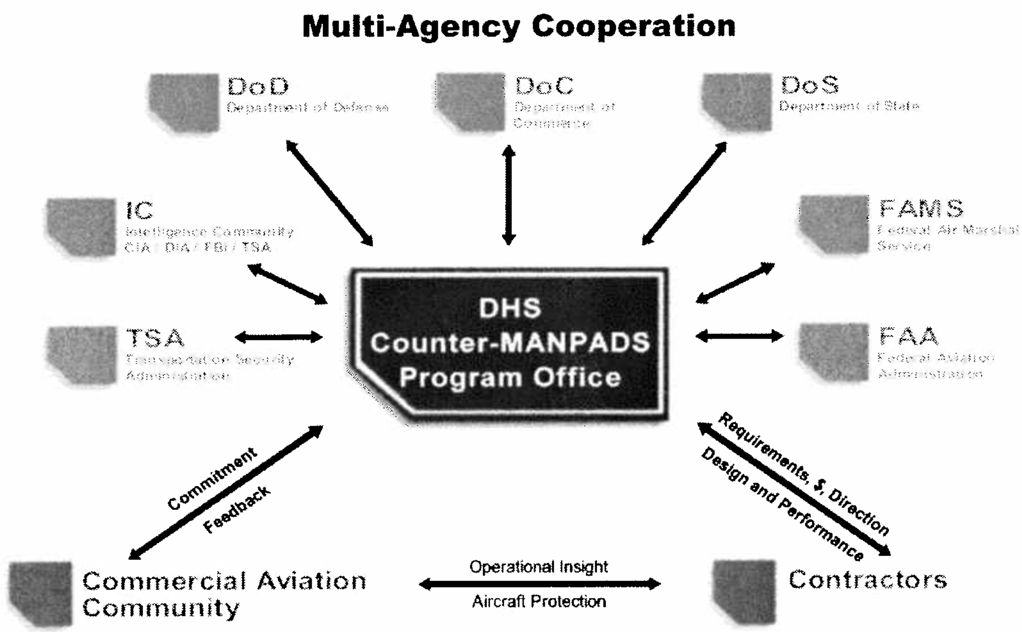

Figure 7: External Coordination is Key to Counter-MANPADS Program Success

D. System Description

Following DHS S&T guidance, the vendors designed systems following a rigorous systems engineering development process, in which DHS S&T communicated formal system requirements, assessed preliminary designs and conducted critical design reviews. DHS S&T additionally established specific entrance and exit criteria to transition vendors from one milestone to the next.

[redacted]

BAE and NGC developed their counter-MANPADS systems based upon the requirements and the legacy DIRCM military systems flown in combat situations by the United States and allied military forces. BAE and NGC, in coordination with DHS S&T, selected these proven technologies to reduce technical and schedule risks and provide the best value for end users. A DIRCM system performs the following major functions:

- Missile detection is performed by an ultraviolet (UV) missile warning system (MWS), which identifies potential threats. Each counter-MANPADS system uses four sensors to identify incoming missiles and identify the location of potential threats. Once the system identifies a possible threat, the MWS uses azimuth and elevation angles to move a point/track head to find the missile using an infrared camera.

- Tracking is accomplished by the point/track head identifying the missile in the infrared image and maintaining a lock on its position in the infrared field of view as the missile flies toward the aircraft.

- Jamming occurs after the counter-MANPADS infrared track camera acquires and centers a threat missile. A modulated laser countermeasure through the point/track head jams the missile seeker, causing it to veer off course and miss the targeted aircraft.

Each system also performs other functions such as data processing, crew interface and health monitoring. The primary difference between the two systems' architectures is in the aircraft installation approach. BAE's system is a distributed system where components are installed at different parts of the airframe, whereas the majority of NGC system components are installed in a single pod externally mounted to the airframe. The vendors relied upon trade studies to identify the architecture appropriate for their system installation and the number of line-replaceable units (LRUs). LRUs are system components enclosed within a single module to facilitate ease of removal and replacement.

1. BAE Systems: The JETEYE® System

BAE's JETEYE® is a distributed system featuring [redacted] LRUs installed in equipment racks in the cargo bay, the engineering and electronic bay and the flight deck area, as shown in Figure 8. The JETEYE® system consists of a sensor and nullification segment, an infrastructure segment and an aircraft-specific installation kit (A-Kit) segment. The sensor and nullification segment is divided into a sensor subsystem, which detects and tracks missiles launched at the host aircraft, and a nullification subsystem, which aims and fires a laser jamming signal at the missile, causing it to lose track of the aircraft and turn away. Figure 8 illustrates the installation on an American Airlines 767-200.

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[redacted]

2. Northrop Grumman Corporation: The Guardian™ System

The NGC Guardian™ System solution uses a pod-based installation as shown in Figure 9. The Guardian™ system consists of [redacted] LRUs: [redacted] The Guardian™ System Pod LRU architecture consists of 1) a detection function performed by the missile warning system (MWS); 2) a tracking function performed by the DIRCM processor and the Guardian™ Pointer/Tracker; and 3) nullification function performed by the Viper™ Laser and the Guardian™ Pointer/Tracker. Figure 9 illustrates the installation on a FedEx Express MD-11.

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[redacted]

[redacted]

[redacted]

[redacted]

III. DIRCM Test and Evaluation Results

A. DHS S&T Performance Evaluations

Based on vendor and DHS-directed tests, modeling and simulations, DHS S&T determined that the DIRCM technology developed and demonstrated under this program can [redacted] meet program requirements for defeating MANPADS. [redacted]

1. System Engineering Test and Evaluation Program

DHS S&T and the vendors structured a traditional systems engineering verification approach (Figure 10) to evaluate system performance on commercial aircraft. Through computer modeling and simulation, the program was able to test millions of scenarios and, ultimately, launched 29 live-fire missiles to test system capabilities. In accordance with this process, as the program progressed through the performance verification, the fidelity of test points increased, but at a higher cost, so fewer test points could be gathered. This approach maximized the insight gained in a cost effective manner. After the Phase I studies and analysis DHS S&T directed test and evaluation activities in Phases II and III. The timeline is shown in Figure 11.

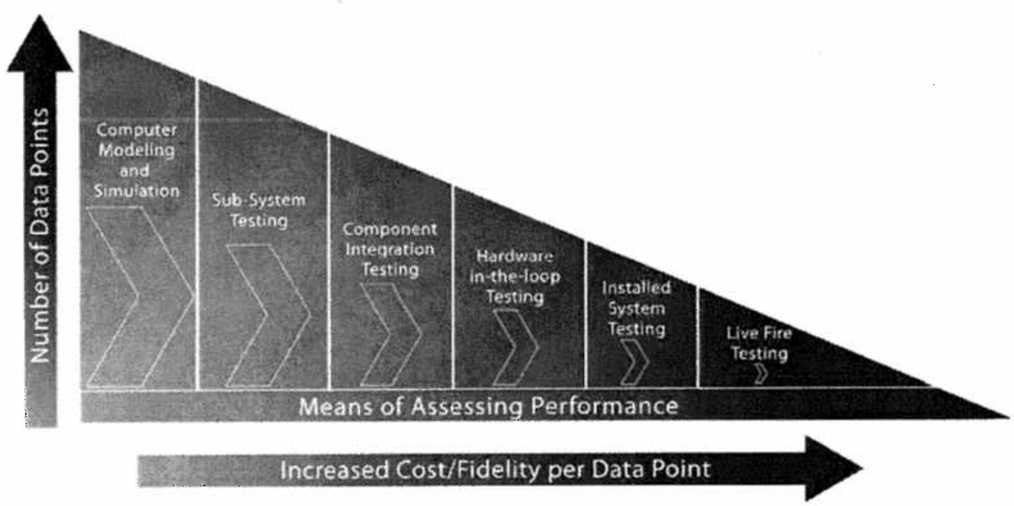

Figure 10: Systems Engineering Test Methodology

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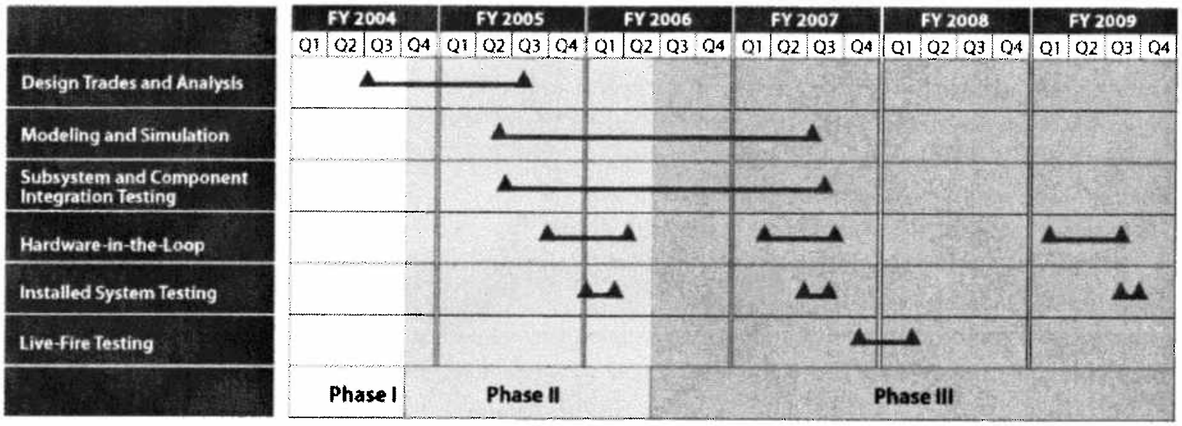

Figure 11: Test and Evaluation Timeline

a. Computer Modeling and Simulation

Computer-based modeling and simulation (M&S) allows comprehensive evaluation of performance under many different scenarios. Both vendors developed extensive M&S efforts in accordance with Counter-MANPADS Program requirements. DHS S&T reviewed the models, simulations, input data and assumptions. Both vendors provided a comprehensive evaluation of system performance over a broad range of conditions, selecting scenarios based on typical takeoff and landing profiles at select U.S. and international airports, over a variety of atmospheric conditions and aircraft types. The M&S process enabled both vendors to complete millions of engagement scenarios with the results forming the basis of the system performance estimates. Both vendors' M&S results, which include worst-case systems performance assumptions, predicted that the systems could meet system performance requirements.

b. Subsystem and Component Integration Testing

Integration testing allows component, subsystem and system-level evaluations in a methodical building-block approach. The vendors conducted this performance testing at integration labs, test ranges, environmental chambers and on the aircraft. To ensure each component or "building block" complied with system requirements, the testing generally proceeded in stages from component and software testing to system testing to installed-system ground testing to flight testing. Vendor quality assurance or government representatives witnessed many of the test events.

c. Hardware-in-the-Loop Countermeasure Testing

DHS S&T employed Hardware-in-the-loop (HITL) testing to verify the vendors' countermeasure subsystem effectiveness using real missile seekers at the Guided Weapons Evaluation Facility (GWEF) at Eglin Air Force Base, Florida. The GWEF provided realistic testing in a controlled [redacted] environment where many repetitions of missile engagements were performed to achieve statistically significant results. The GWEF simulated the aircraft infrared signature, MANPADS launch and flight maneuvers in real-time, employing the actual laser [redacted] of each vendor's counter-MANPADS system to evaluate the effectiveness of the DIRCM system against real threat missile seekers. The test scenarios used realistic high fidelity 747 and 737 infrared images which were funded and developed under this effort. These images compared favorably with radiometric air-to-air infrared measurements. The testing scenarios used these aircraft images to simulate typical commercial airport departures and tested more than 24,000 [redacted] missile engagements using [redacted] missiles at various launch ranges around the targeted aircraft. The resulting probabilities of success in defeating these missile shots were then averaged and compared to the system performance requirements and the vendor M&S results. Figure 12 shows the dynamic motion simulator and the high resolution 747 Infrared image used as the MANPADS target during the HITL simulations.

Figure 12: GWEF Hardware-in-the-Loop Simulator and High Fidelity IR Image

d. Installed System Testing

Installed system testing allows for the evaluation of system performance in the intended environment, accounting for performance impacts from factors such as blockage from aircraft structure and actual aircraft vibration. After completion of the vendor flight testing, government-directed flight tests were conducted at Eglin Air Force Base, using Mallina™ missile simulators, which provided the [redacted] signatures of various MANPADS to trigger the installed counter-MANPADS systems. With the NGC Guardian™ system installed on a MD-11 and the BAE JETEYE® system installed on a 767-200, DHS S&T was able to evaluate responses and installed system performance timelines under single and multiple simultaneous engagement scenarios. Both systems responded as expected and detailed analysis correlated well with the vendor performance predictions.

Over the course of the flight test programs, BAE flew the JETEYE® system approximately [redacted] hours on 767-200 aircraft and NGC flew the Guardian system [redacted] hours on 747 and MD-11

[redacted]

[redacted]

aircraft. These flight tests enabled the vendors to implement improvements to their Counter-MANPADS systems prior to the operational evaluations in Phase III.

Most DIRCM system performance evaluations conducted by DOD and DHS have been done on DOD test ranges which have minimal background energy and are not representative of commercial airport environments. To further assess system performance in the airport environment, DHS S&T conducted a performance demonstration of the BAE JETEYE® system at Memphis International airport during normal day-to-day operations. The 767-200 flew multiple low approaches while the DOD Joint Mobile Infrared Countermeasures Test System (JMITS), a high fidelity missile simulator, triggered the installed counter-MANPADS system. This demonstration showed the JETEYE® system could successfully detect a threat missile in a high clutter commercial airport environment. Figure 13 shows the JMITS tracking pedestal engaging the 767-200 test aircraft at Memphis. The Guardian™ system was not evaluated with the JMITS because this demonstration was outside the scope of the NGC contract. However, NGC conducted limited evaluations of Guardian™ system performance in clutter at several southwestern commercial airports during the Phase II vendor flight testing.

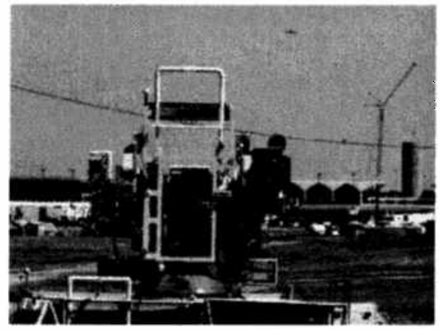

Figure 13: JMITS Engaging Test Aircraft

e. Live-Fire Testing

Live-fire tests are the most realistic test venue, but can only demonstrate a very limited number of scenarios because of costs and test range limitations. The DHS S&T-directed live fire tests occurred at White Sands Missile Range (WSMR) – Aerial Cable Range and concluded in December 2007. The BAE JETEYE® and NGC Guardian™ systems' demonstrated their ability to counter actual MANPADS launches during day and night conditions. A variety of threat missiles fired upon the counter-MANPADS systems attached to an elevated gondola, which emulated a 747 infrared signature.

Live-fire testing is very expensive and because of the high cost of launching missiles, only a few scenarios can be demonstrated. Candidate scenarios were constructed to evaluate the boundaries of the systems' performance, but designed to be within each system's predicted capabilities. Launch range geometry and safety considerations also bounded the possible scenarios. The candidate scenarios were evaluated using HITL testing to determine the probability of success of each engagement. The final matrix was a tradeoff between favorable probability of successful outcome and performance challenging multiple-launch scenarios.

A total of 29 MANPADS missiles were fired at the DIRCM systems to demonstrate system effectiveness in countering [redacted] attacks. Overall, the systems worked well and [redacted] defeated the missiles [redacted] Live-fire timeline and effectiveness performance analysis were in line with the flight test and HITL results. Figure 14 shows the test setup at WSMR where the counter-MANPADS systems were mounted on the 747 IR representative target, suspended and live missiles launched.

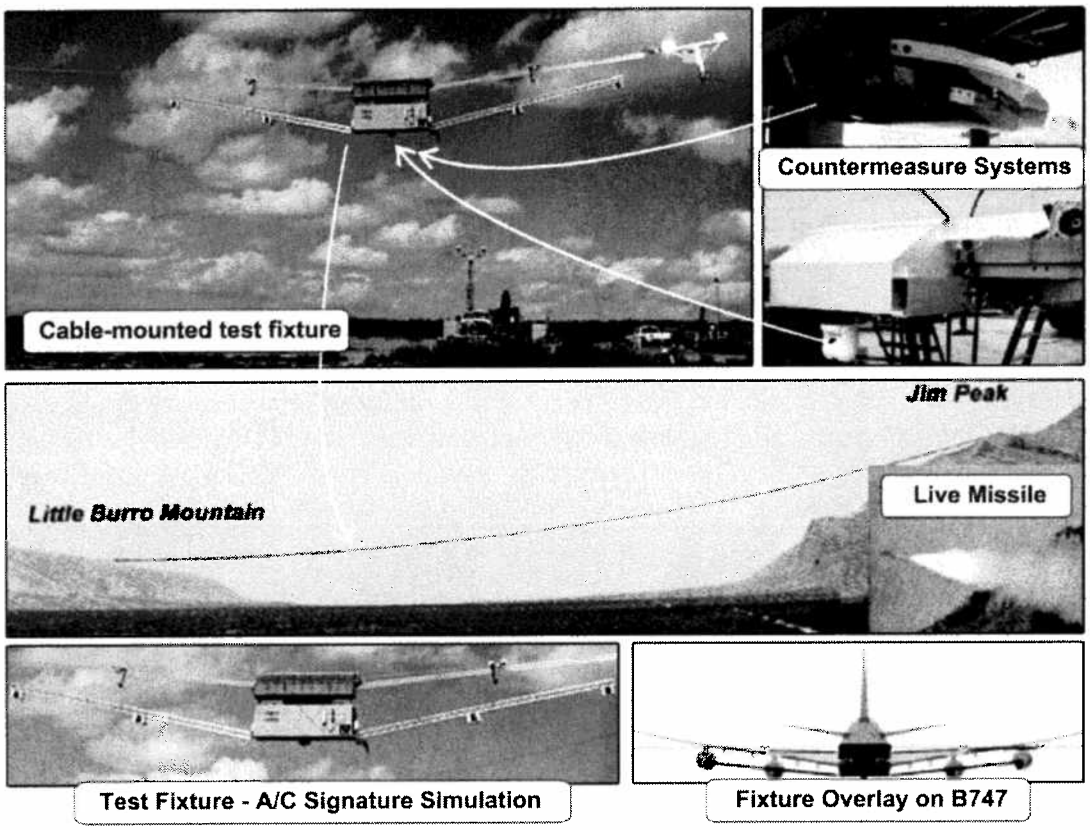

Figure 14: Live-Fire Test at White Sands Missile Range

B. DHS S&T Operational Evaluations

DHS S&T conducted extensive operational service evaluations to obtain data and insight into the suitability of the counter-MANPADS systems in a real-world airline operating environment. The key objectives of the service evaluations were to:

- Accumulate system operational flight hours on commercial aircraft

[redacted]

- Collect and assess installation, operations, performance, reliability, availability and maintainability data
- Update the DHS S&T Life-Cycle Cost Estimates

Figure 15 shows the service evaluation flight routes. The service evaluations provided data and insight into concepts of operations, logistics and support concepts, and allowed DHS S&T to identify areas of improvement for increased availability, lower costs and greater passenger protection.

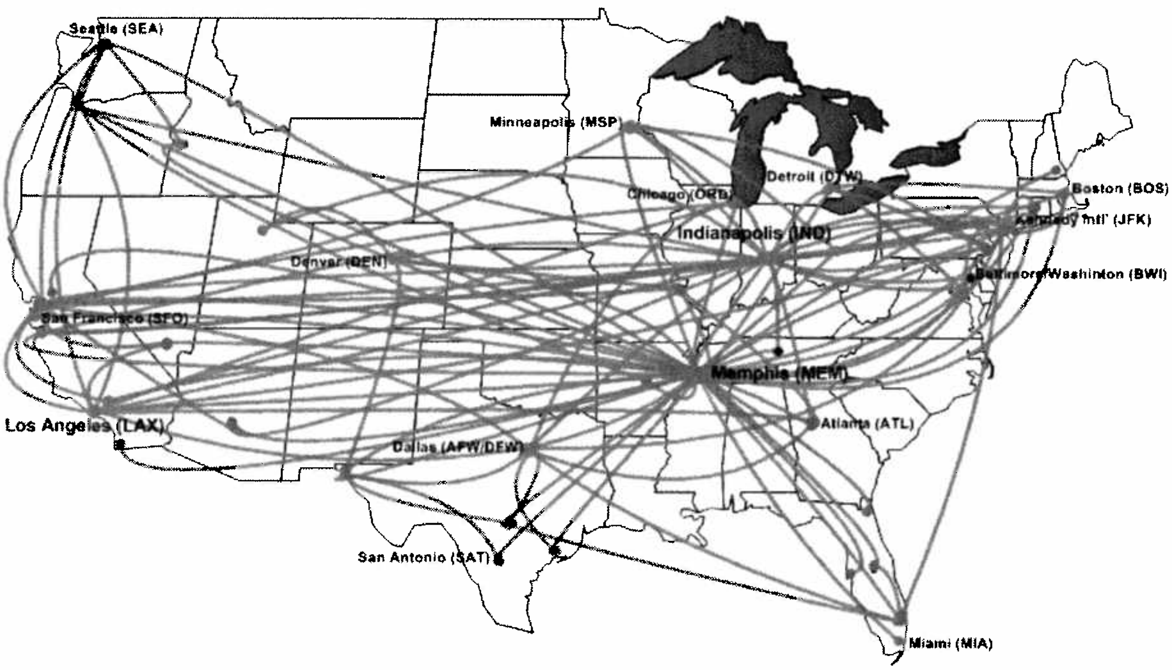

Figure 15: Service Evaluation Routes

1. JETEYE® Passenger Aircraft Service Evaluation

BAE Systems, in partnership with American Airlines, installed JETEYE® systems on three American Airlines 767-200s. Over 10 months, the JETEYE® systems accumulated ove[redacted] flight hours in revenue service. JETEYE® systems flew on regularly scheduled flights from John F. Kennedy International Airport (JFK), Los Angeles International Airport (LAX), San Francisco International Airport (SFO) and Miami International Airport (MIA). DHS S&T gathered reliability, availability and maintainability metrics along with system performance data in a commercial passenger-airline environment.

[redacted]

2. Guardian™ Cargo Aircraft Service Evaluation

Northrop Grumman, in partnership with FedEx, installed Guardian™ system pods on 10 FedEx MD-10s. Over 12 months, the Guardian™ systems accumulated ove[redacted]flight hours in revenue service. Guardian™ pods flew between more than 80 city pairs on regularly scheduled flights cycling through maintenance hubs at LAX, Memphis International Airport (MEM) and Indianapolis International Airport (IND). DHS S&T gathered reliability, availability and maintainability metrics along with system performance data in a commercial cargo-airline environment.

[redacted]

IV. Analysis

A. Performance Assessment

The Counter-MANPADS Phase III solicitation defines the program requirements for the two systems. Except as noted in Table 1, which follows, both counter-MANPADS systems meet or exceed the performance requirements. The sections that follow detail key analyses and assessments.

Table 1: Requirements Summary

[redacted]

Coverage: The system shall be capable of effective operation against a MANPADS attack within the threat envelope, with 360-degree coverage in azimuth and elevation angles commensurate with typical commercial flight profiles and MANPADS profiles.	Met
[redacted]	
Emergency Notification: The system shall transmit an Emergency Ground Notification (EGN) signal to Air Traffic Control (ATC) through the aircraft transponder, based on the highest confidence of a detected missile launch event.	Met See IV.A.3 for further discussion

[redacted]

[redacted]

1. Threat, Coverage & Probability of Success

Based on a comprehensive test and evaluation effort, DHS S&T determined that the DIRCM technology developed and demonstrated under this program meets program requirements for defeating MANPADS. [redacted]

[redacted]

[redacted]

3. Emergency Ground Notification

DHS S&T established the requirement for emergency ground notification to automatically notify authorities of a MANPADS attack. Both vendors demonstrated the ability to issue an EGN using the aircraft transponder system. [redacted]

[redacted] Because a false notification can potentially disrupt the national air space and because potential EGN users have not established any requirements for EGN data, DHS S&T does not recommend implementing this functionality at this time. FAA representatives have concurred with this recommendation. Existing FAA procedures[9] are in place should a MANPADS situation arise.

B. Aircraft Integration Assessment

DHS S&T findings with regard to aircraft integration requirements are shown in Table 2. Key analyses and assessments are discussed in greater detail in the following sections.

Table 2: Aircraft Integration Requirements Summary

Requirement	Result/Finding
Aircraft: The system shall be capable of being installed on commercial aircraft the size of a Boeing 737 or larger. This includes the following aircraft: • A300 • A310 • A318 • A319 • A320 • A340 • A321 • A330 • A380 • 717 • 727 • 737 • 747 • 757 • 767 • 777 • DC-9 • DC-10 • MD-10 • MD-11 • MD-80 • MD-90 • L1011	Met
Common Aircraft Interface: The system shall provide a common means of attaching countermeasures equipment to the aircraft to facilitate interchangeability. The method and equipment used for aircraft modification and complete system installation shall be capable of accomplishment by third parties under appropriate commercial licensing agreement.	Met

[9] Order JO 7110.65S Air Traffic Control, 2-9-3

[redacted]

Requirement	Result/Finding
[redacted]	
Drag: Additional aircraft drag for the counter-MANPADS system shall not exceed one percent.	Met See IV.B.2 for further discussion
Weight: The total system shall have an installed weight of no more than 600 pounds (550 pounds objective).	Met
Prime power: The system shall be capable of drawing normal aircraft power from existing aircraft power sources.	Met
Flight Deck Interface: The system shall provide the following capability at the flight deck for aircrew action/interface: Circuit Breaker Protection System Status EGN Inhibit EGN Termination Missile Event Notification System Power Control	Met See IV.B.3 for further discussion

1. Aircraft Installation

The Counter-MANPADS Program established a threshold requirement of 1,200 man hours to fully equip (i.e., install all A- and B-Kit components) and check the system. [redacted]

[redacted]

[redacted]

[redacted] Nonetheless, both vendors completed the installations within the scheduled heavy-maintenance visits (HMV) without the need to extend the maintenance visit. An extended maintenance visit results in reduced aircraft utilization with potentially significant cost implications, so this aspect of the installation is essential to minimize deployment costs. Through feedback from airline partners, both vendors identified improvements to reduce installation and check-out periods. With the implementation of lessons learned and the learning curve advantages multiple installations provide, the installation and check-out time is expected to be within the 1,200 man-hour requirement in a full system-deployment.

While DHS S&T limited its evaluation to four aircraft types, both vendors conducted fleet assessments and worked closely with their airline partners to ensure system compatibility with other aircraft types.

2. Drag & Weight

DHS S&T established a counter-MANPADS system drag increase limit of one percent. Both vendors performed Computational Fluid Dynamics (CFD) analyses on installed system configurations to assess the additional drag caused by the system. CFD is an analytical tool commonly used by the industry to predict drag changes on aircraft. Through this analysis both vendors determined that the additional drag due to the counter-MANPADS systems was below the requirement of one percent for wide-body aircraft. However, the drag increase is higher than one percent for narrow-body aircraft. [redacted]

Both installed systems (A-Kits and B-Kits) weigh less than the 600-pound threshold requirement. The Suitability Working Group expressed concern that the additional weight and fuel associated with a counter-MANPADS system may cause revenue-generating passengers or freight to be left behind on flights that are either range or weight limited. These flights may include take-offs from high altitude airports or flights on which aircraft are already operating near the range limit prior to counter-MANPADS system installation. After receiving input from industry sources, DHS S&T has assumed two percent of narrow-body and five percent of wide-body flights will be affected and included the cost of this lost revenue in the LCC model. Opportunities to reduce weight on either system are limited primarily to combining the functionality of electronics boxes.

DHS S&T drag estimates used in the LCC model are based on CFD analyses of the installed systems. In addition to CFD analyses, data were gathered throughout the service evaluations on pre- and post-installation aircraft in an attempt to gain more insight into system weight and draft effects on fuel burn. Given the small magnitude of the drag increases, the service evaluation data showed no measurable impact. This finding is consistent with CFD analysis and the degree to which standard aircraft fuel flow meters can detect small increases in fuel flow. Nonetheless,

[redacted]

[redacted]

very small fuel flow increases can add up substantially over the life of a deployment considering the size of the U.S. commercial fleet and the number of flights executed over a 20-year life cycle.

3. Flight Deck Interface

DHS S&T established flight deck interface requirements in partnership with the FAA. Both systems comply with these requirements. [redacted]

DHS S&T recommends three areas of standardization:

- Fault warning color and terminology, which dictate pilot protocols
- Fault suppression during periods of high pilot workload
- Required actions to address a fault warning.

Integrating the Counter -MANPADS systems with the existing aircraft caution and alerting systems should also be explored to simplify the system interface and ensure consistency with current flight crew protocols and training. DHS S&T concluded that this effort was not a cost-effective use of program funds for a service evaluation.

4. FAA Certification

Under the FAA's Code of Federal Regulations (CFR), the FAA issues a supplemental type certificate (STC) to certify the airworthiness of aircraft design modifications, such as the counter-MANPADS installation. The STC defines the certification basis and the impact of the design change on the existing type design and lists any limitations associated with the modification. The two vendor teams conducted extensive tests and analyses to demonstrate that the systems meet FAA airworthiness requirements, and as a result, the FAA issued STC approvals for the MD-10/-11, 747 and 767 airframes. However, the CFR does not have performance requirements for counter-MANPADS systems. In accordance with Section 4026(b)(2) of the Intelligence Reform and Terrorism Prevention Act of 2004 (P.L. 108-458), the FAA accepted DHS S&T's preliminary certification that the counter-MANPADS systems are effective and functional for defending commercial aircraft from MANPADS. As a result, the STCs contain limitations that preclude their use beyond the DHS S&T service evaluations. The STCs also do not authorize the use of the Emergency Ground Notification function on the

[redacted]

[redacted]

systems. To eliminate these limitations on the STCs, DHS would need to provide a DHS performance certification. Given lessons learned from the service evaluations, DHS, in partnership with the FAA, would also need to finalize fault warning and annunciation requirements, as well as flight crew procedures and training for the counter-MANPADS systems.

Prior to any counter-MANPADS deployment, all aircraft in the equipped fleet would require separate STCs for both the JETEYE® and Guardian™ systems. The current U.S. large passenger aircraft fleet consists of 22 different aircraft types (e.g., 737, A320, each of which would require an STC).[10] In addition, each aircraft type includes varying configurations designated by series numbers (e.g. 777-100, 777-200 ER that would also need to be covered by STC). The existing STCs obtained during the DHS S&T Counter-MANPADS Program cover less than 10 percent of the current fleet types; however, both vendors could leverage a substantial amount of the data approved under these STCs in the completion of the remaining STCs. Both vendors conducted extensive fleet surveys to understand the efforts and costs for both new and amended STCs.

C. Reliability, Availability & Maintainability Assessment

To gain insight into the operational environment of the systems, tailor-made data acquisition, processing and reporting tools were developed. Hundreds of parameters were collected in support of the service evaluation data collection objectives, including:

- System Hours: The operating hours in flight and on the ground. System statuses during these conditions were recorded to understand system behavior as a function of operation mode and operating environment. DHS S&T calculated times between system failures using these data in combination with System Failure Data.

- Aircraft Data: Aircraft specific data including flight hours and aircraft cycles were gathered to better understand the operational environment in which the systems were operating. In addition, aircraft speed, altitude, ambient temperature and other conditions were recorded to understand the operational environment of the system and document conditions at time of any system failure.

- System Failure Data: Fault codes were recorded to provide insight into the system failure modes and the systems' ability to detect and isolate faults

- LRU Installation/Repair Data: Installation, Removal and Replacement times at the flight line, LRU repair times at the vendor depot and LRU repair materials data were captured to provide understanding of the maintenance burden required to support deployed systems

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[10] OAG BACK, Back *Aviation* 2009 Fleet Database, accessed 4-23-09.

[redacted]

- Installation and Maintenance Costs: Labor hours and materials costs were used in combination with LRU Installation/Repair Data to gain insight into the maintenance support costs associated with system deployment

The data acquisition, processing and reporting tools provided detailed insight into system performance previously unavailable in similar DOD programs. Data analysis made it possible to characterize the hours that the counter-MANPADS systems flew during the service evaluations. Flight hours of the counter-MANPADS systems fell into three general categories:

- Operational Flight Hours – Cumulative flight hours during which the systems were powered-on, operating normally and available to protect the aircraft from MANPADS attack
- Flight Hours with Critical Fault – Cumulative flight hours during which the systems were operating with fault indication and therefore unavailable to protect the aircraft. Critical faults are defined as any condition that can affect the systems' ability to detect, declare, track, jam and report threats.
- Flight Hours with System Off – Cumulative flight hours during which the systems did not have power applied and therefore unavailable to protect the aircraft. A portion of these hours were due to the pilots not operating the systems according to CONOPS.

[redacted]

[redacted]

Figure 17 and Figure 18 show the distribution of flight hours for BAE JETEYE® and NGC Guardian™ during the service evaluations.

These flight-hour distributions were used as the basis for the reliability, availability and maintainability analyses performed by DHS S&T.

Table 3 summarizes compliance with the reliability, availability and maintainability requirements. In addition to the minimum performance threshold requirements, DHS also established objectives as desired performance targets for mean flight hours between failure (MFHBF) and mean time to repair (MTTR). The sections that follow detail key analyses and assessments.

Table 3: Reliability, Availability & Maintainability Requirements Summary

Requirement	Result/Finding
MFHBF: The MFHBF shall be greater than 3,000 (threshold) or 4,500 (objective) system operating hours in the commercial aircraft environment over a fleet wide average of all aircraft types, as specified in the Counter-MANPADS Program Office Cost Ground Rules and Assumptions Document.	Threshold: Not Met Objective: Not Met
MTTR: System components shall be removable and replaceable by existing air carrier maintenance personnel using standard tools and support equipment. The system should not require special test equipment at the flight line level for alignment, removal, replacement or maintenance. Unscheduled flight-line maintenance time to repair (MTTR) shall be 60 minutes or less (threshold) or 30 minutes or less (objective).	Threshold: Met Objective: Not Met
Availability: The system shall be operationally available without imposing any delays to takeoff or landing preparations.	Met

1. System Reliability

Reliability is the ability of the counter MANPADS system to perform as designed in its operating environment over time without any failures. Reliability is often measured in commercial aviation in terms of MFHBF. The Counter-MANPADS Program established a threshold MFHBF of 3,000 hours, with an objective of 4,500 hours. Airlines additionally focus on the measure mean flight hours between unscheduled removals (MFHBUR), which, although not a program requirement, includes any false failure indications that result in LRU removals.

[redacted]

[redacted]

Table 4 and Table 5 provide the service evaluation results and show that the system configurations flown do not meet program threshold reliability requirements. However, throughout the program, both vendors used Failure Reporting and Corrective Action Systems (FRACAS) to evaluate failures and improve reliability. Both vendors also have product improvements in work under parallel DOD programs that will further increase reliability. Therefore, DHS S&T predicts that reliability for a future deployment is much higher than what was demonstrated, however, without a dedicated counter-MANPADS reliability improvement program, the improved systems still fall short of the program requirement. The operating procedures dictate turning certain system components off during cruise when they are not needed to extend system operating time across more flight hours, thus increasing reliability. Variations between wide-body and narrow-body cruise durations yield differences in reliability predictions, [redacted]

[redacted] During the service evaluation, problems were uncovered, isolated through the FRACAS process and fixes devised. Improvements led to an increase in system reliability of seven percent. The JETEYE® 2012 baseline also incorporates upgrades currently under development for the Army's ATIRCM program, [redacted]

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[11] Demonstrated MFHBUR is calculated as Operational Flight Hours/Number of LRU removals due to failure indication. Demonstrated MFHBF is calculated as Operational Flight Hours/Number of confirmed LRU failures.

[redacted]

[redacted]

[redacted] The Guardian™ 2012 baseline system also incorporates a series of block upgrades [redacted]

2. System Operational Availability

Operational Availability (A_o) is defined as the percentage of flight hours that the counter-MANPADS systems were available to counter threats and is obtained using a relationship between up-time and total time with total time being the sum of up time and down time. DHS S&T computed the demonstrated operational availability using data gathered in the service evaluations using Equation 1.

Equation 1. Operational Availability

$$A_{o\ Demonstrated} = \frac{Up\_time}{Up\_time + Down\_time} * A_s$$

In Equation 1, up-time is operational flight hours. Down time is defined as all aircraft flight hours during which a counter-MANPADS system is not operating to specifications. Down time is composed of flight hours with critical fault(s) and flight hours with the system off. Because of the limited scope of the service evaluations DHS S&T removed hours associated with not having spares available for the purpose of the demonstrated availability calculations (i.e., A_s = 100 percent in the previous equation).

During the service evaluations, the counter-MANPADS availability requirement was to be operationally available without imposing any delays to takeoff or landing preparations. Both vendors met this requirement through the use of the Minimum Equipment List (MEL) process, which identifies the minimum equipment necessary to conduct safe flight operations. The MEL

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[12] See previous note.

[redacted]

process provides dispatch relief for airlines to defer maintenance and continue operations until the failed LRU can be removed and replaced. As a result, the counter-MANPADS systems caused no flight delays or cancellations during the service evaluations. The ability to dispatch with the system inoperative prevents flight delays at the expense of system availability; the longer maintenance is deferred, the lower the availability. Figure 19 shows the relationship between deferred maintenance duration, reliability (MFHBUR) and operational availability.

System availability increases with system reliability and decreases the longer maintenance is deferred. In other words, system availability is sacrificed for aircraft dispatch availability.

As the vendors exercise FRACAS and implement planned product improvements, system MFHBF and MFHBUR will increase. Availability will increase with reliability, so the reliability increases discussed in the Reliability Results Section IV.C.1 will result in a higher availability for a 2012 deployment. In calculating predicted 2012 operational availability, up-time is defined as MFHBUR and down-time is defined as the average deferred maintenance (DM) duration. An average deferred maintenance duration of six days is assumed, and spares availability, A_s is assumed to be 99 percent. Equation 2 shows the calculation used to obtain predicted operational availability.

Equation 2. Predicted Operational Availability

$$A_{o\,\mathrm{Pr}edicted} = \frac{MFHBUR}{MFHBUR + DM\_Duration} * A_s$$

[redacted]

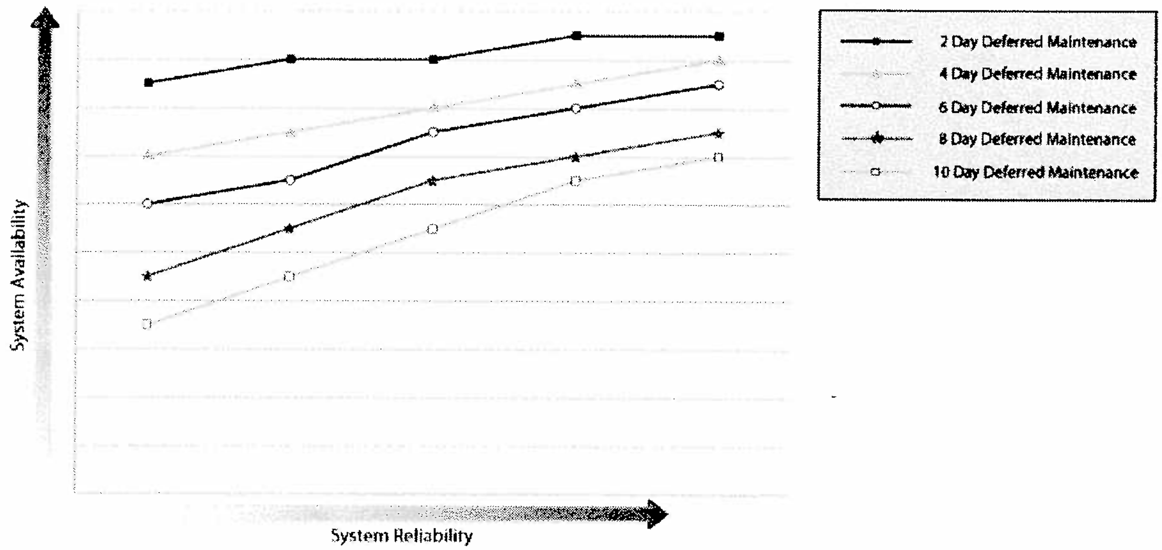

Figure 19: Deferred Maintenance Duration, Reliability and System Availability Trade Space

[redacted]

3. System Maintainability

The Counter-MANPADS Program evaluated the ability of each system to integrate into the current airline maintenance environment. FedEx and American Airlines incorporated each

[redacted]

[redacted]

system's maintenance data into their airline documentation. The airline maintenance technicians (AMTs) demonstrated that their standard skill set allows them to perform scheduled maintenance and removal and replacement (R&R) of system components. Both systems demonstrated the ability to meet the 60-minute requirement for isolation, R&R and re-testing a failed LRU. As a part of the maintenance CONOPS, each system was equipped with Built-in-Test (BIT) capability. BIT allowed AMTs and flight crews to monitor system health and LRU fault status. [redacted]

D. Cost Assessment

DHS S&T program cost requirements are shown in Table 8 along with the DHS findings of compliance. The following sections discuss vendor compliance with these requirements further detail.

Table 8: Program Cost Benchmarks

Requirement	Result/Finding
[redacted]	
Operations & Support (O&S) Cost: The systems shall have an O&S cost of less than \$300 (\$FY03) per flight segment for 1,000th unit delivered and installed (\$354 per flight segment in \$FY10)	Met

1. Unit Acquisition Cost

DHS S&T established a unit acquisition cost of \$1 million for the 1,000th unit delivered and installed, which includes the cost of the B-kit and A-kit components, as well as the installation labor. DHS determined this cost for each system using vendor estimates. The JETEYE® system at [redacted] The Guardian™ system at [redacted]

[redacted]

[redacted]

2. Cost Per Available Seat Mile

While DHS did not have a cost per available seat mile (CASM) benchmark requirement, it is a standard metric utilized by the U.S. commercial airlines to measure cost and revenue impact on passenger aircraft. DHS S&T used the latest FAA projections for both the number of seats and miles per flight to determine the O&S CASM values. The value for the 1,000 aircraft implementation scenario is about 0.1 cents, which includes all O&S costs, not just those directly incurred by airlines. This value is reduced by approximately one half when considering only those costs directly incurred by the airlines (e.g. fuel burn, airline mechanic labor hours, etc.). For reference purposes, the U.S. passenger airlines flew over one trillion available seat miles in 2008. [redacted] Any increase in CASM directly impacts airline profitability.

E. Life-Cycle Cost Estimate

DHS S&T developed a life-cycle cost (LCC) model following rigorous standards of review and benchmarking to estimate the cost of three counter-MANPADS commercial deployment alternatives. All costs shown are in constant government FY 2010 dollars and span the life of the deployment. The estimate is not a cost-benefit analysis, as DHS S&T did not conduct a formal evaluation of the benefits of implementation. Table 9 shows the life-cycle cost estimates for the three deployment alternatives.

Table 9: Costs of Deployment Alternatives

Deployment Alternative	Aircraft Equipped	Passengers Protected Annually (millions)	[redacted]	Life-Cycle Cost ($ billions)
Targeted Wide-body Passenger Aircraft	98	20	[redacted]	2.2
All Wide-body Passenger Aircraft	526	107	[redacted]	6.8
All Large Passenger Aircraft	3636	800	[redacted]	43.3

The DHS S&T counter-MANPADS deployment estimate includes RDT&E, acquisition and installation, O&S and disposal activities throughout the 20-year lifetime of the equipment. Throughout the program, DHS S&T refined and matured the underlying cost elements and estimates to an engineering-level of estimation. During Phase III service evaluations, DHS S&T collected acquisition, installation, operations, maintenance, repair and de-modification data to verify and refine cost assumptions. Where available, DHS S&T used experience-based data

[redacted]

from the systems under study to estimate cost. Also during Phase III, the Suitability Working Group vetted key airline cost assumptions and provided airline-specific costs and figures associated with delays, cancellations, personnel quantities, salaries and attrition rates and maintenance intervals and durations. Boeing and Airbus also provided fuel burn estimates for drag and weight increases. DHS S&T then benchmarked line-items, top-level estimates and relative phase cost percentages against analogous historical programs to assess cost reasonableness.

The DHS Counter-MANPADS Phase II Report provided preliminary LCC estimates for a notional 1,000 aircraft deployment scenario. Since the release of that report, the cost estimate has increased as a result of evolution of the cost model. Updates to the DHS S&T LCC model since Phase II include lowering the projected starting reliability of the systems, constraining reliability growth during the program, updating the cost of aviation fuel, re-baselining from FY 2003 dollars to FY 2010 dollars, incorporating vendor-based acquisition costs of the systems and adding omitted support costs, including tech refresh, spiral upgrades and transport and insurance on LRUs for repair. Table 10 shows the incremental adjustments to the life-cycle cost model that yield the current All Large Passenger Aircraft deployment estimate.

Table 10: Life-Cycle Cost Refinements

Phase II to Phase III Life-Cycle Cost Refinement	**Revised Total Cost** ($ billions)
End of Phase II Estimate for 1,000 Aircraft in $FY03	5.8
Include new RDT&E and O&S Cost Elements (system improvements, logistics transportation, insurance, etc.)	7.2
Replace composite system cost with vendor-specific system cost	7.8
Replace composite system reliability with vendor-specific reliability	8.9
Update fuel price	10.4
Add Technology Refresh and Spiral Upgrade	10.9
End of Phase III for 1,000 Aircraft in $FY03	10.9
Increase from 1,000 to 3636 aircraft	36.8
Inflate from $FY03 to $FY10	43.3
End of Phase III for all Large Passenger Aircraft in $FY10	43.3

The following sections provide additional detail on the deployment alternatives, key cost assumptions, LCC model cost elements and risk and uncertainty.

1. Deployment Alternatives

DHS S&T developed three deployment alternatives to provide a range of equipage options that respond in appropriate measure to a perceived level of risk. [redacted]

[redacted]

[redacted] The deployment alternatives include:

(1) **Targeted Wide-body Passenger Aircraft Alternative**: This alternative covers a limited number of U.S. commercial wide-body passenger aircraft and protects approximately 20 million passengers annually. This alternative equips 98 aircraft that are designated as higher risk [redacted] Because this deployment alternative is based on an evolving threat, the actual number of aircraft appropriate for this deployment alternative could change on the basis of updated risk analysis.

(2) **All Wide-body Passenger Aircraft Alternative**: This alternative covers all 526 wide-body aircraft in the current U.S. passenger commercial fleet and protects approximately 107 million passengers annually.[13] [redacted]

(3) **All Large Passenger Aircraft Alternative**: This alternative covers all 3,636 U.S. passenger wide-body and narrow-body aircraft (Boeing 737/Airbus A318 or larger) in the U.S. commercial fleet and protects approximately 800 million passengers annually. This alternative equips all large U.S. passenger aircraft traveling both internationally and domestically.

2. Key Cost Assumptions

a. Export Relief

Current International Traffic in Arms Regulation (ITAR) and Export Administration Regulations (EAR) prohibit commercial aircraft equipped with counter-MANPADS systems from international operations without the appropriate licenses. [redacted]

- [redacted]

[13] OAG BACK, Back *Aviation* 2009 Fleet Database, accessed 4-23-09.

[redacted]

[redacted]

b. Deferred Maintenance

The MEL identifies the minimum equipment necessary to conduct safe flight operations and the conditions and limitations for operations with inoperative equipment. The MEL process provides dispatch relief for airlines to defer maintenance and continue operations until a failed LRU can be removed and replaced. The cost estimate assumes airlines have up to [redacted] days of dispatch relief when a counter-MANPADS system fails and that no flight delays or cancellations will result from system maintenance. A cost sensitivity analysis that considers no dispatch relief and the potential for flight delays and cancellations is contained in Section IV.3.D.

c. Analysis Assumptions

In addition to the policy and implementation assumptions discussed previously, the cost model adheres to the following scope, accounting and cost-limiting assumptions:

Scope:

- Only wide-body and large narrow-body passenger aircraft operated by U.S. air carriers under Part 121 service are considered. Cargo aircraft, regional jets and turboprops are excluded from the life-cycle cost analysis.
- Deployment will begin in 2012, following production contract award in January 2011. Long lead item procurement dictates that the first dedicated B-kit would not be available for installation on an aircraft until June of 2012. A-kit installation begins in January of 2012.
- The number of aircraft in the analysis is based on the number of applicable aircraft operating as of December 31, 2008, according to data extracted from the BACK Aviation™ database for the commercial airline fleet as of December 31, 2008, including 3,110 narrow-body passenger aircraft and 526 wide-body passenger aircraft[14]

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[14] Ibid.

[redacted]

- The LCC estimates are based on two vendors with a 50/50 production and installation split between BAE and NGC counter-MANPADS systems
- Counter-MANPADS systems produced for each alternative are in addition to, not supplanting, any system production planned for military aircraft

[redacted]

Accounting:

- Costs are reported in constant FY 2010 dollars. DHS S&T utilized deflation factors from the FY 2010 President's Budget, in accordance with guidance from OMB's Circular A-94.
- Jet fuel costs are estimated at $3.81 per gallon in FY 2010 dollars, corresponding to the FY 2010-inflated July 2008 peak jet fuel price

Limiting:

- The service life of the counter-MANPADS system is 20 years. At the end of system service life, the system is removed and disposed of.
- A-Kit modifications are assumed to take place during regularly scheduled heavy maintenance, with the exception of the Targeted Wide-body Passenger Aircraft deployment where 50 percent of the installations are assumed to be completed with special visits
- Other nations will not impose entry or operating restrictions on U.S. counter-MANPADS-equipped aircraft
- All counter-MANPADS systems are added to commercial aircraft on a retrofit basis

[redacted]

[redacted]

3. Cost Analysis

a. Total Cost Breakout

Figure 20 shows the RDT&E, acquisition, O&S and disposal cost distributions for an All Large Passenger Aircraft deployment. Key operations and support cost components, which account for 81 percent of total life-cycle costs, are also shown. [redacted]

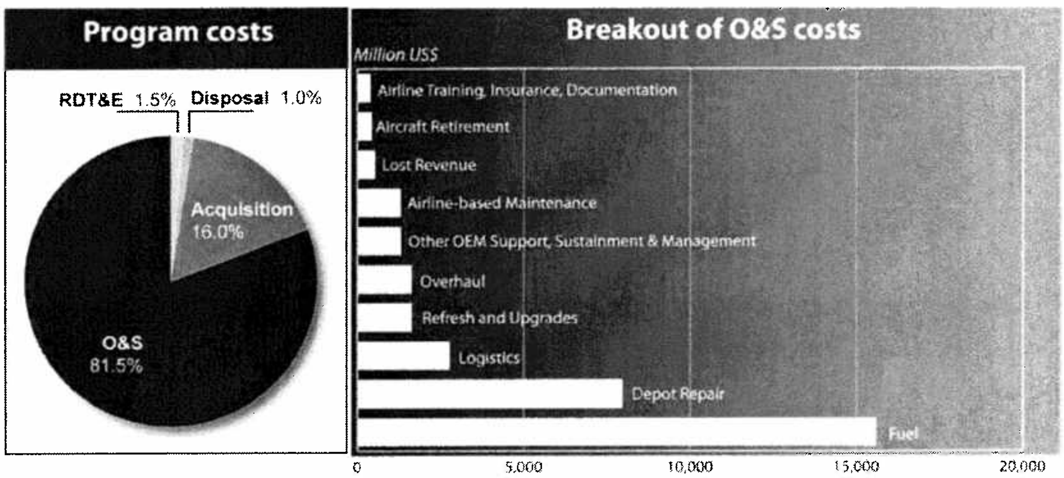

Figure 20: Major Program Cost Components for the All Large Passenger Aircraft Deployment

[redacted]

[redacted]

[redacted]

The following sections detail the assumptions and calculations underlying the key cost elements in the LCC model.

b. Research, Development, Test and Evaluation Costs

Research, development, test and evaluation (RDT&E) covers all non-recurring costs associated with system improvements, certification and related costs. This includes costs of performance and suitability improvements identified in the service evaluations. The RDT&E effort starts at the same time as deployment contract award and is commensurate with the number of aircraft equipped. Table 12 shows the chief cost components of the RDT&E cost estimate. The following sections provide additional details on each cost component.

[redacted]

Table 12: RDT&E Phase Estimated Costs as a Percent of Total LCC

WBS Elements	Deployment size			Basis of Estimate
	98	526	3636	
RDT&E				
Performance Upgrades	3%	1%	<1%	Program Experience
Suitability Upgrades	1%	<1%	<1%	Program Experience
Security Upgrades	1%	<1%	<1%	Engineering Estimate
STC Certification	3%	2%	1%	SWG
DHS System Performance Certification	1%	<1%	<1%	Engineering Estimate
System Test & Evaluation	1%	<1%	<1%	Service Evaluation
Systems Engineering & Program Mgmt	2%	1%	<1%	Other program
Production Support & Reliability	<1%	<1%	<1%	Vendor Price
Government Program Office	<1%	<1%	<1%	Program Experience

1) STC and DHS Certification

The largest component of RDT&E by cost is obtaining Supplemental Type Certificates (STCs) from FAA. A separate STC will be required for each system for each of the aircraft types in the deployment alternative, as well as an amendment for each series within the type. The All Large Passenger Aircraft alternative, this includes 22 STCs and 37 STC amendments. DHS S&T assumes a new STC for an aircraft type costs approximately $6 million in FY 2010 dollars; an amended STC for a different series of that aircraft type costs approximately $4 million FY 2010 dollars. STCs exist for the JETEYE® installation on the 767-200 and for the Guardian™ installation on the MD-10/-11 and 747-100/-200/-300, covering seven percent of current aircraft types. The LCC model front loads the STC expense in the first years of a deployment. Figure 22 shows existing STCs and the required STCs for the remaining wide-body and narrow-body aircraft types in the current fleet.

DHS certification of effectiveness and functionality will be specific to a particular vendor system, assuming that each applicant provides the appropriate data to certify all aircraft in the commercial fleet. DHS S&T assumes it will cost each vendor $45 million to complete this certification. This cost would occur in 2011, based on the LCC scenario used for this report.

[redacted]

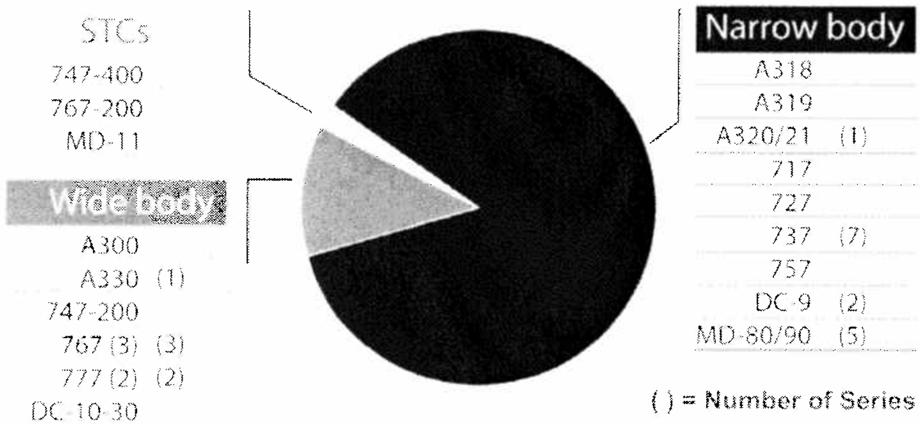

Figure 22: New STC Requirements for All Large Passenger Aircraft Deployment Alternatives

[redacted]

3) Other Costs in RDT&E

The remainder of the RDT&E costs are vendor program management and systems engineering, estimated as a percent of total RDT&E funds, and the government program office, staffed with 10 full time equivalents through the duration of RDT&E.

c. Acquisition Cost

Total acquisition cost includes all costs associated with procurement and installation of the countermeasure systems, production start-up including non-recurring investments in production facilities at vendors and suppliers, initial spares, test equipment and facilities and system engineering and program management for both vendors. The key acquisition cost elements are shown in Table 13. The following sections provide additional detail on each of these cost components.

[redacted]

Table 13: Acquisition Phase Estimated Costs as a Percent of Total LCC

WBS Elements	Deployment size			Basis of Estimate
	98	526	3636	
Acquisition				
Prime Mission Equipment (A- & B-kit)	8%	11%	10%	Vendor Price
Shipping and Install	1%	1%	1%	Service Evaluation
Speedlines (Alternative)	1%	0%	0%	SWG
OEM SE/PM	3%	2%	1%	Other Program
Logistics and Support Mgmt Planning	<1%	<1%	<1%	Engineering Estimate
Shipping Containers	<1%	<1%	<1%	Service Evaluation
Special Tooling, Test Equipment	14%	4%	1%	Vendor Price
Initial Training	<1%	<1%	<1%	Service Evaluation
Field Service Personnel	<1%	<1%	<1%	Engineering Estimate
Spares	2%	2%	2%	Engineering Estimate
Initial Documentation & Manuals	<1%	<1%	<1%	Other Program
Government Program Office	1%	<1%	<1%	Program Experience

1) Prime Mission Equipment, Shipping, Installation and Speed Lines

In the major cost categories given in the previous section, installed systems consist of all hardware, installation, system check out, shipping and special visits. The estimate uses vendors' cost estimates for hardware. DHS S&T based manufacturing cost improvement curves (CIC) on vendor pricing models. Lower costs per unit are realized with the procurement of greater quantities or fewer vendors, but not in the absence of competition.

Although both vendors estimated a CIC on A-kit installation, DHS S&T did not incorporate one into the LCC model. Installation costs are based on the threshold value of 1,000 hours for A-kit install and 15 hours for B-kit install, multiplied by an airline maintenance technician's hourly value of time. Under the distributed approach DHS doubled the estimate for first year installation labor.

A key LCC model assumption is that A-kit installation occurs during a regularly scheduled heavy maintenance visit (HMV) for the aircraft. DHS modified this assumption by a 50-percent special visit rate for only the Targeted Wide-body Passenger Aircraft alternative because of the reduced likelihood that the aircraft designated to be equipped will be scheduled for an HMV. Special visit installations deprive the airline of aircraft revenue service for seven days and require 300 more labor hours to gain access to the necessary locations on the aircraft.

[redacted]

2) Systems Engineering and Program Management

Vendor systems engineering and program management (SE/PM) and government program office (PO) are the costs of program management from the contractor (during production) and government (during acquisition.) DHS S&T modeled vendor SE/PM as a percentage of the acquisition phase and estimates government PO as a fixed number of full time equivalents, based on actual cost.

3) Spares

DHS S&T derived the quantities for initial spares through detailed, stochastic sparing cost-benefit analyses using projected reliability and the time required to repair a unit and return it to the spares pool. The LCC model assumed sparing quantities that yield 99-percent sparing availability.

4) Non-Recurring Engineering Production Start-up

This category includes all the non-recurring costs to initiate production, such as infrastructure, special tooling and special test equipment needed to meet production and repair rates based on vendors' production rate studies.

5) Logistics, Training, Data and Support Planning

This category includes costs such as logistics and maintenance planning, initial training for pilots and aircraft maintenance technicians, updating airline documentation and installation field service assistance to airlines.

d. Operations and Support Costs

The O&S estimate includes the costs associated with operating, maintaining and repairing the systems throughout their productive life. O&S costs also include line items directly incurred by the airlines, such as the removal and replacement of failed system LRUs, scheduled maintenance and additional fuel costs. The key O&S cost elements are shown in Table 14 and are discussed in further detail in the following sections.

1) Fuel

The largest cost in the estimate is fuel. The estimate considers three contributing sources: additional fuel burn due to the additional drag of externally-mounted components, fuel burn due to the added weight and the fuel consumption associated with powering the system. The fuel burn increase also considers the additional weight of the additional fuel. DHS S&T estimated the additional fuel burn due to each influence by aircraft types and vetted the estimate with airline industry representatives. Because the impact of fuel burn due to the system drag is difficult to measure operationally, the cost model estimates the increased drag through each vendor's CFD.

[redacted]

The cost of aviation fuel was estimated at \$3.81 per gallon (\$FY10), based on the peak fuel cost of \$3.75 per gallon in 2008. Although fuel prices have since dropped substantially, the higher cost per gallon is warranted because: (1) fuel prices are very volatile and can double without warning, thus a higher price is more likely to capture rather than omit relevant costs; (2) cap and trade legislation, if enacted for emissions control, will likely raise fuel prices. Cost sensitivities to the fuel cost, drag and counter-MANPADS system weight assumptions are presented later in this section.

[redacted]

Table 14: Estimated O&S Costs as a Percent of Total LCC

WBS Elements	Deployment size			Basis of Estimate
	98	526	3636	
Operations & Support				
Fuel				
Fuel	23%	33%	42%	Engineering estimate
Depot Repair				
Depot Unscheduled LRU repair	8%	13%	17%	Service Evaluation
Depot Operational Communications	<1%	<1%	<1%	Airline Actual
Logistics				
3PL: Transport & Insur.	3%	5%	6%	Service Eval
Airline Logistics Support	1%	<1%	<1%	SWG
3PL: Warehouse & Tracking	<1%	<1%	<1%	Warehouse Actual
Vendor Field Support	<1%	<1%	<1%	Engineering estimate
Packing container replacement	<1%	<1%	<1%	Vendor price
Refresh & Upgrades				
Technology Refresh	3%	4%	4%	Vendor price
Technology Upgrades	5%	2%	<1%	Other program
Overhaul				
Depot Overhaul	2%	4%	4%	Vendor price
Other Vendor Support, Sustainment & Management				
Depot Sustaining Engineering Support	1%	2%	1%	Engineering estimate
Depot Support Equipmt Maint	4%	1%	<1%	Vendor price
Depot Software Maintenance Support	1%	1%	1%	Parametric
Depot Technical Documentation Updates	<1%	<1%	<1%	Engineering estimate
Airline Technical Documentation Updates	<1%	<1%	<1%	Engineering estimate
Program Management (PM)	7%	2%	<1%	Other program
Airline-Based Maintenance				
Scheduled Maintenance	1%	1%	1%	Service Evaluation
Unscheduled Maintenance	<1%	<1%	<1%	Service Evaluation
Consumables	<1%	<1%	<1%	Service Evaluation
Security Measures during Maintenance	<1%	<1%	1%	Engineering estimate
Lost Revenue				
Lost Revenue	1%	3%	1%	SWG
Aircraft Retirement				
Aircraft Retirement (Aging Fleet)	2%	1%	1%	Engineering estimate
Airline Training, Insurance,				
Recurring Airline Personnel Training	<1%	1%	1%	Service Evaluation
Insurance	<1%	<1%	<1%	Subject matter expert

2) Depot LRU Repair and Overhaul

The second highest cost item in the LCC model is depot repair. Unscheduled depot repair is a function of predicted LRU failure rates (i.e., reliability) and average annual fleet block hours (i.e., aircraft operating hours between the gate departure and gate arrival) plus a no fault found removal factor. DHS S&T used projected reliability applied against cumulative flight hours to

[redacted]

compute the rate of remove and replace events. The cost of each depot repair was estimated as a factor of its acquisition cost, capped by a limit based on worst case actuals. Cost sensitivities to system reliability are presented later in this section.

DHS S&T assumes three overhauls to occur on each system to accomplish maintenance on parts that experience wear and tear over the 20-year life of the unit. The cost of each overhaul was estimated as a factor of acquisition cost.

3) Logistics

The DHS S&T concept of repair and support operations assumes a third-party logistics provider (3PL) to facilitate system integration into commercial operations. The 3PL manages support functions and acts as a conduit between the airlines and the vendor for parts. The 3PL stores good spares and provides them to the airline when and where the spare is needed. Costs incurred in the performance of spares provision include storage facilities, transportation of a good part from the warehouse to the airport, transport of a failed part from the airport to the vendor depot, transport of repaired parts from the vendor to a storage, inventory management and insurance of parts in transit.

4) Technology Refresh and Spiral Upgrade

Technology refresh consists of hardware and software development and implementation costs to maintain functionality, address parts obsolescence and facilitate maintenance. It is not a reliability upgrade. This cost is assessed on all electronics processors and communication equipment. The cost is estimated based on the acquisition value of the refreshable equipment for each system.

The estimate also includes a spiral upgrade to integrate DOD improvements into the counter-MANPADS systems. This cost does not include the RDT&E of such spiral upgrades but only the costs to incorporate them into the commercial baseline. DHS S&T assumes the cost to integrate such upgrades are less than the costs to maintain differing baselines on DOD common equipment.

5) Airline-based Maintenance

Costs in this area include airline personnel labor to conduct scheduled and unscheduled maintenance. This includes the labor and material required to remove and replace faulting LRUs, provide supply/logistics support, perform scheduled maintenance tasks such as cleaning and inspections, as well as the security costs associated with international operations and maintenance.

6) Other Vendor-Based Costs

Other vendor-based costs include support of fielded units. This category includes depot sustaining engineering support, FRACAS, depot software maintenance, technical documentation

[redacted]

updates, management of vendor activities during O&S for each vendor, field support to airline maintenance technicians, test stand maintenance, equipment used in repair and the replacement of LRU shipping containers that are damaged or destroyed.

7) Lost Revenue

Lost revenue is the cost of lost passenger or freight carriage due to the additional weight of an installed counter-MANPADS system. Based on feedback from the Suitability Working Group, DHS S&T estimates that two percent of all narrow-body flights and five percent of all wide-body flights operate at maximum weight limits, which means that either passengers or cargo must be off-loaded because of the weight of the counter-MANPADS system. The revenue rate is based on the Department of Transportation, Bureau of Transportation Statistics T2 Report data.

8) Aircraft Retirement

Aircraft of varying ages populate the U.S. commercial fleet. On average, a passenger aircraft is retired or sold to another fleet after 20 years of service. DHS S&T estimates that roughly three percent of aircraft are retired annually. This cost element captures the cost of removing the counter-MANPADS A-kits and B-kits from a retiring aircraft, installing a new A-kit on the replacement aircraft and placing the existing B-kit on the replacement aircraft.

9) Airline Training, Insurance and Documentation

The remaining O&S costs include insurance, documentation updates and recurring training. DHS S&T assumes that airlines, or some other entity, will carry insurance on the counter-MANPADS systems to cover loss or damage during operations, consistent with other high-value assets that the airline possesses. Documentation includes updates to airline-specific maintenance manuals and databases. The estimate also covers recurrent counter-MANPADS training for pilots and mechanics.

e. Disposal Costs

The disposal estimate covers the de-modification and repair of all equipped aircraft and the disposal costs of the system and are shown in Table 15.

[redacted]

[redacted]

Table 15: Estimated Disposal Costs

WBS Elements	Deployment size			Basis of Estimate
	98	526	3636	
Disposal				
Demodification	<1%	<1%	<1%	Engineering Estimate
Disposal	<1%	<1%	<1%	Other Program

f. Risk Analysis

DHS S&T identified the areas of greatest risk in the cost estimate through sensitivity analyses. DHS altered key cost parameters in the LCC model by increments of 25 percent and 50 percent and assessed the impact on overall costs for the All Large Passenger Aircraft deployment alternative. The cost increases associated with reduced CIC, reduced reliability, increased drag, increased fuel cost, increased labor rates, increased installation labor, increased A-kit structural modifications, special visit installations and RDT&E schedule overruns are shown in Figure 23. This chart shows that the highest sensitivity is with respect to no CIC, which affects both acquisition and maintenance costs. Removing the CIC, which can occur with changing baselines, drives up total LCC by more than 40 percent. Reducing the reliability by 50 percent has the second largest impact on cost, driving up total LCC by approximately 33 percent. This chart also shows that the LCC is not as sensitive to A-kit weight, labor cost and installation labor increases.

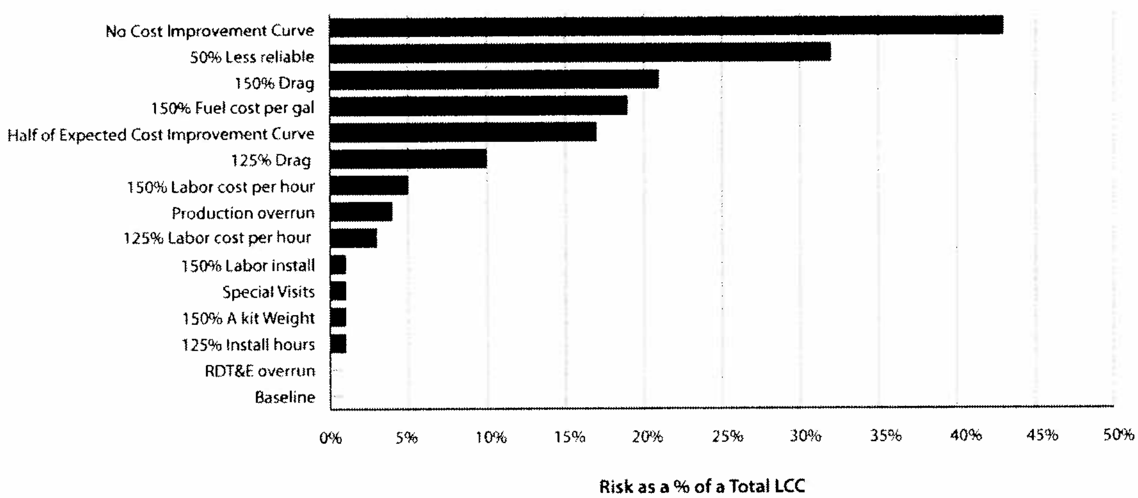

Figure 23: Sensitivity Analysis on Cost Parameters for the All Large Passenger Aircraft Deployment

[redacted]

[redacted]

DHS S&T also evaluated cost sensitivity to the following key assumptions in the model:

- No Flight Cancellations: The cost estimate assumes that deferred maintenance and export relief measures will mitigate the risk any potential flight cancellations. However, if these assumptions are not fulfilled, flight cancellations could result if equipment is not available for immediate removal and replacement, or if export licenses are not in place prior to flights. To assess the risk associated with potential flight cancellations, DHS assumed cancellations to 0.5 percent of flights annually and five percent of flights annually. The cost sensitivities to these revised assumptions are shown in Figure 24.

- No Flight Delays: The current cost estimate assumes that airlines will have the flexibility to defer maintenance on inoperative counter-MANPADS systems and, as a result of this flexibility, system maintenance will not cause any flight delays. However, if airlines are not granted this flexibility and are required to replace inoperative systems before a flight, a flight delay could result. In addition, if a counter-MANPADS system is damaged during ground operations, it could require immediate removal. To assess the risk associated with potential flight delays, DHS assumed a two-hour delay to 0.5 percent of flights annually and five percent of flights annually. The cost sensitivities to these revised assumptions are shown in Figure 24.

- Static U.S. passenger fleet: The current cost estimate assumes the U.S. passenger aircraft fleet is static because it is very difficult to predict fleet growth. To assess the risk associated with potential growth, DHS S&T assumed an average fleet growth rate of three percent considering projections from the 2008 FAA Aviation Forecast and Boeing and Airbus forecasts. The cost sensitivity to this revised assumption is shown in Figure 24.

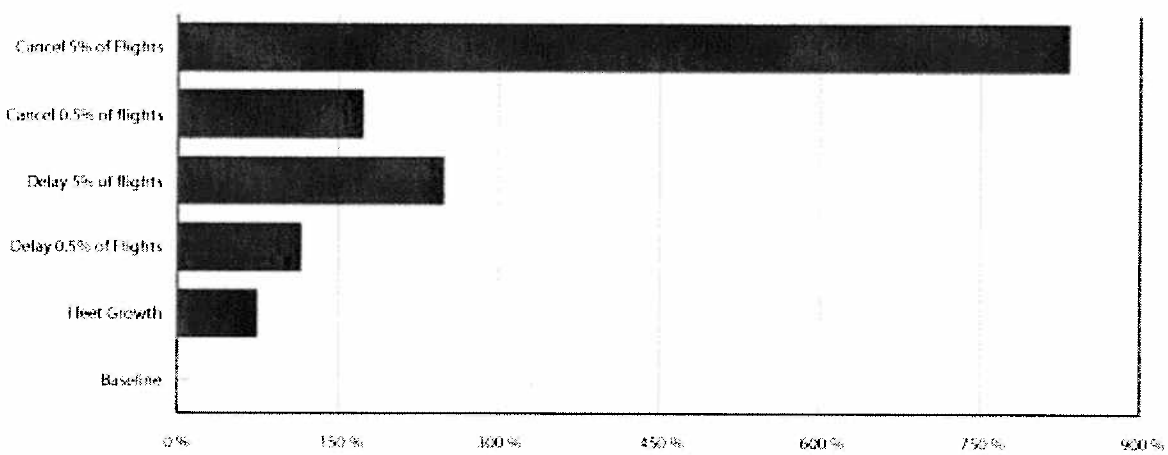

Figure 24: Sensitivity Analysis on No Dispatch Relief, as a Percent of Life-Cycle Cost

[redacted]

[redacted]

g. Uncertainty Analysis

In accordance with good cost estimating practices as outlined in the recent GAO guidelines, DHS S&T assessed uncertainty on the life-cycle cost. Sensitivity analyses in the previous section capture known risks to the analysis, by varying sensitive parameters than have an assumed static value but in reality fluctuate.[15] Uncertainty analysis attempts to model the impact of unknown risks by stochastically varying the estimate. DHS S&T accomplished this by applying a normal distribution on the overall estimate and using analogous program standard deviations.[16] An 80-percent confidence yields a cost estimate of $74.4 billion at the one-sigma point in Figure 25.

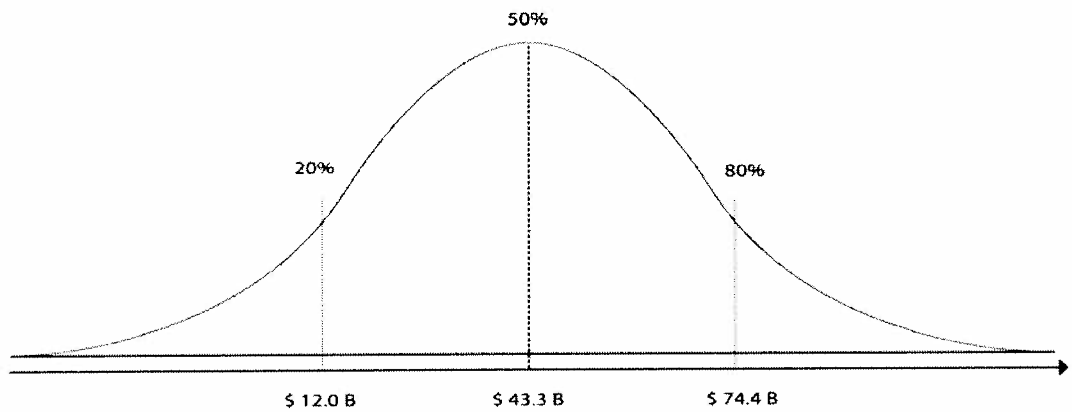

Figure 25: LCC Estimate with Confidence Intervals for an All Large Passenger Aircraft Deployment

h. Ten-Year Life-cycle

Substantial technological improvements are expected under a full deployment, as a result of learning during production and operation and considering current DOD efforts to advance counter-MANPADS technologies. That likelihood, and the desire to compare DIRCM technologies to ground-based systems with a 10-year life-cycle, drove an alternatives cost analysis for a 10-year life-cycle. The estimated costs of fielding the counter-MANPADS system for a life-cycle of 10 years are shown in Table 16.

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[15] An example is using a distribution of repair costs instead of a mean cost of repair.

[16] Richard L. Coleman, Eric R. Druker, Peter J.Braxton, Bethia L. Cullis, and Christina M.Kanick, "What Percentile Are We At Now? And Where Are We Going? Are We Really at the 50th Percentile?" SCEA/ISPA Conference, St Louis, 2 June 2009.

[redacted]

Table 16: Costs for 10-Year Life-cycle ($FY10 Millions)

LCC Phase	Targeted Wide-body Passenger Aircraft	All Wide-body Passenger Aircraft	All Large Passenger Aircraft
RDT&E Phase	248	384	648
Acquisition Phase	573	1,349	6,961
O&S Phase	789	2,848	17,702
Disposal	13	66	440
Total	1,623	4,647	25,751

i. Cost Summary

The projected life-cycle cost for an All Large Passenger Aircraft deployment is $43.3 billion. As with most acquisitions, the O&S is the most expensive portion of the LCC estimate. The additional fuel cost associated with the system, due primarily to drag, is the largest cost element within O&S. A 25-percent reduction in drag would produce a life time savings of approximately $4 billion. The second largest cost element of O&S is depot repair, driven primarily by reliability. Doubling reliability would produce a lifetime savings of approximately $10 billion.

DHS S&T also identified cost sensitivity to the CIC and recognizes that there is greater potential for an improved learning curve with a single vendor. However, DHS S&T has not explored the cost-benefit trade between maximizing CIC with a single vendor, versus the benefits associated with multiple vendors. There are also substantial cost risks associated with a deployment policy that does not allow airlines to defer maintenance or does not provide export relief, resulting in potential flight delays and cancellations that can dramatically increase cost.

F. Deployment Considerations

1. Export Control Relief

The Department of State's ITAR and the Department of Commerce's EAR are regulatory barriers for a commercial deployment of counter-MANPADS systems. The ITAR and EAR regulate the export of U.S. critical military technologies on the United States Munitions List (USML) and establish the security needed for protecting those technologies. These laws are applicable to the counter-MANPADS systems, which are military technologies re-engineered for commercial aviation.

Current regulations consider a counter-MANPADS-equipped flight an export of the technology when it leaves the country, creating the requirement for an export license. U.S. airlines also rely heavily on foreign maintenance centers and employ an internationally diverse workforce; however, providing system installation and maintenance data to foreign persons also requires export licenses, as does the installation of this equipment on a foreign-owned airplane operated

[redacted]

by a U.S. airline. In short, compliance with the ITAR requirements for counter-MANPADS systems will cause serious operational, logistical and financial problems for U.S. air carriers and an unsustainable burden on the U.S. export licensing system. Export control legislation is needed to specifically address the use of military technologies employed to protect commercial aviation.

DHS S&T undertook an extensive coordination effort with the Departments of State, Commerce and Defense to explore potential solutions to export impediments. These efforts include national offices with technology protection responsibilities examining a wide variety of technology protection measures. As noted in the cost section, DHS S&T has explored alternative security measures and incorporated them into the life-cycle cost estimate. The decision to remove the A-Kit from the USML is currently awaiting a final decision from appropriate government reviewers. However, legislation would need to provide export relief for the B-Kit.

2. Airline Profitability

Representatives from the Suitability Working Group, as well as other industry stakeholders, emphasized that airlines currently operate on very thin, or frequently negative, profit margins. A counter-MANPADS system deployment has the potential to affect airline profitability and create a competitive disadvantage. The life-cycle cost estimates are sensitive to a number of key assumptions and conditions that, if violated, have the potential to substantially increase airline costs. These include:

- Export control relief, as discussed in the previous section;
- Equipage timeline: A deployment that minimizes impacts to airline operations must be based on heavy maintenance schedules. Efforts to compress deployment timeline will substantially increase deployment costs and potentially cause disruptions in airline service and profitability. Installation outside the regular HMV pulls an aircraft out of service for a full seven days, equating to a loss of up to $300,000 per aircraft; and
- Deferred maintenance: The cost estimate assumes airlines have up to [redacted] days to defer maintenance when a counter-MANPADS system fails. Without this flexibility, airline dispatch reliability would drop significantly and airline costs could rise dramatically.

In addition to these factors, the additional drag and weight of the counter-MANPADS installation could cause some of the longest international routes currently served by U.S. airlines to become unprofitable or unachievable.

3. System Improvements

The suitability assessment identified areas for improvement, discussion of which follows.

[redacted]

a. System Reliability Improvements

System reliability remains a major concern. System failure rates, which are significantly higher than those typically found in commercial aviation, would increase airline maintenance and depot repair costs. For more seamless airline integration, dedicated improvement efforts prior to deployment can improve reliability and reduce operating costs. The DHS S&T cost analysis indicates that doubling system reliability reduces operating costs by approximately $10 billion.

b. Spiral Upgrades to Address New Threats and Technology Improvements

The MANPADS threat will evolve over time in both the technical sophistication of embedded counter-measures and increases in intercept altitude and range. Since vendors of counter-MANPADS systems for commercial aircraft are also suppliers of analogous defensive systems for U.S. military aircraft, they must continually upgrade the technical capabilities of their military systems to keep pace with advances in the MANPADS threat. The counter-MANPADS systems available for deployment on commercial aircraft would benefit from military system upgrades. If systems are deployed on commercial aircraft, a parallel RDT&E program to provide spiral upgrades based on military system improvements will ensure that the commercial systems keep pace with emerging threats and improve system performance.

4. Deployment Timeline

DHS S&T estimates that a streamlined acquisition approach will require a minimum of [redacted] years before the first aircraft can be equipped and protected. Figure 26 shows the likely deployment schedule, and Figure 27 shows the A-Kit and B-kit manufacturing timeline. Manufacturing capabilities and aircraft maintenance schedules limit the equipage rate; factors such as the hiring of needed skilled labor, infrastructure development and long production lead items limit initial B-Kit production rate in the first three years. Developing second and third sources for long lead items may reduce schedule risk. After the fourth year (applicable only to the all passenger aircraft deployment), aircraft heavy maintenance schedules limit installation schedules. By removing the aircraft from service for the sole purpose of installing the counter-MANPADS system, airlines can compress A-Kit installation schedules. These "special visits," however, incur additional costs and disrupt airline operations.

[redacted]

[redacted]

5. DHS Certification

The Emergency Wartime Supplemental Act of 2003 (P.L. 108-11) directed the DHS "to prepare a program plan for the development of an antimissile device for commercial aircraft. The plan should identify the process for delivery and certification of a prototype...." To address this congressional requirement, DHS S&T drafted documentation to define the certification process

[redacted]

(Volume I) and to standardize the performance requirements (Volume II) specific to DIRCM systems. These documents leverage the test, evaluation, verification and validation lessons learned from Phases II and III of the DHS S&T Counter-MANPADS Program, and reflect best practices within the countermeasure and aviation industries. Certification Volume II defines minimum performance levels, documentation requirements to support the claimed levels of system performance and assessment criteria to establish that a DIRCM system is effective and functional for defeating MANPADS. The certification documents are in the DHS S&T review and approval process.

Although DHS S&T developed the process and the requirements for certification, the actual certification of the two prototypes was not within the scope of the BAE and NGC OTAs. DHS S&T has no plans at this time to certify the BAE and NGC systems. However, much of the data obtained during Phases II and III can be leveraged for this purpose. DHS S&T believes that both systems can be partially or fully certified per the standard [redacted]

V. Conclusions and Actions

DHS S&T completed a comprehensive evaluation to assess the suitability of the counter-MANPADS systems in the airline operating environment that included over 16,000 flight hours in the commercial aviation environment. DHS S&T analyzed data on installations, operations, system reliability, support logistics, maintenance and associated costs and also evaluated each vendor's concepts of operation and logistical support. DHS S&T's evaluation of other technologies determined that DIRCM is currently the most suitable technology to move forward; [redacted] A full operational test and evaluation phase would first evaluate and revise the design through deployment of the system under a more complete range of realistic operating conditions to ensure performance metrics are met. Key findings include:

- Both systems meet effectiveness requirements and can defeat multiple missiles under many attack scenarios.
- [redacted] The service evaluations improved reliability by an aggregate [redacted] percent and both vendors are pursuing reliability improvements under DOD programs, but reliability remains significantly below the levels expected in commercial aviation environments. To mitigate the impact of low reliability on airline operations and prevent delayed or canceled flights, counter-MANPADS deployment policy would need to allow airlines to continue flight operations and defer the maintenance of inoperative systems for up to [redacted] days.
- The service evaluations demonstrated that airlines can integrate the systems into the commercial aviation environment without significant impacts to daily operations provided that export control relief is granted and airlines may continue flight operations with temporarily inoperative systems.
- The 20-year life-cycle cost estimate for protecting all wide-body and large narrow-body passenger aircraft is $43.3 billion. Doubling reliability can reduce total life-cycle cost by approximately $10 billion. Reducing drag by 25 percent can reduce total life-cycle cost by approximately $4 billion.
- The earliest a counter-MANPADS system could be deployed would be within [redacted] years from a decision to deploy using a standard acquisition timeline.

If counter-MANPADS are deployed to protect commercial aircraft, the actions required include:

- Export control legislation to specifically address the use of military technologies employed to protect commercial aviation. Compliance with the current International

[redacted]

[redacted]

Traffic in Arms Regulation/Export Administration Regulations requirements for counter-MANPADS systems would cause serious operational, logistical and financial problems for U.S. air carriers and an unsustainable burden on the U.S. export licensing system.

- [redacted]
- A reliability improvement program to reduce life-cycle cost and minimize disruptions to airline operations.

[redacted]

[redacted]

Appendix A. Acronyms

A-Kit	Aircraft-specific Installation Kit
ATC	Air Traffic Control
ATIRCM	Advanced Threat Infrared Countermeasures
BAE	BAE Systems North America
B-Kit	Countermeasure-specific Components
CAPS2	Civil Aviation Protection System, 2nd Generation
CASM	Cost per Available Seat Mile
CHLOE	Counter-MANPADS High-altitude Laser-based Off-bore sight Experiment
CONOPS	Concept of Operations
DHS	Department of Homeland Security
DIRCM	Directed Infrared Countermeasure
DOD	Department of Defense
EAR	Export Administration Regulations
ECMT	Emerging Counter-MANPADS Technology
EGN	Emergency Ground Notification
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FedEx	Federal Express
HITL	Hardware-in-the-Loop
ITAR	International Traffic in Arms Regulations
LAIRCM	Large Aircraft Infrared Countermeasures
LCC	Life-Cycle Cost
LRU	Line Replaceable Unit
M&S	Modeling and Simulation
MANPADS	Man-Portable Air Defense System(s)
MEL	Minimum Equipment List
MFHBF	Mean Flight Hours Between Failure
MFHBUR	Mean Flight Hours Between Unscheduled Removal
MTTR	Mean Time To Repair
MWS	Missile Warning System
NASA	National Aeronautics and Space Administration
NGC	Northrop Grumman Corporation
NGST	Northrop Grumman Space Technology
O&S	Operations and Support
OTA	Other Transaction Authority
PCA	Propulsion Control Aircraft
PCAR	Propulsion Control Aircraft Recovery
PM	Program Management
RDT&E	Research, Development, Test and Evaluation

[redacted]

S&T	Science and Technology
SE	Systems Engineering
SRD	System Requirements Document
STC	Supplemental Type Certificate
TOC	Throttle Only Control
TRL	Technology Readiness Level
TSA	Transportation Security Administration
UAL	United Airlines
USML	United States Munitions List

[redacted]

[redacted]

Appendix B. Related Technologies and Efforts

1. Emerging Counter-MANPADS Technologies Project

The Emerging Counter-MANPADS Technologies (ECMT) Program began in 2006 to evaluate ground-based and airborne MANPADS detection and countermeasure solutions to protect commercial aircraft from shoulder-fired missiles. The ECMT Project evaluated three commercial aviation defense technologies as alternatives to on-board DIRCM systems: [redacted] The U.S. Department of Homeland Security Science and Technology Directorate (DHS S&T) determined that the technologies are immature and rated at the Technology Readiness Level (TRL) of 3 (on a scale of 1 through 9) as defined by the Defense Acquisition Guide Book.

The TRL o[redacted]ystem remains very low (TRL 3) because of the considerable amount of development still needed to give confidence to an integrated system performing the prescribed function. [redacted]stimated the cost and time to achieve a higher rating of TRL 6-7 is approximatel[redacted] However, this estimate is based on contractor supplied data and the government assesses that this estimate could potentially double because of the uncertainties in the contractor supplied cost data and the maturity of the system concept at this point of development. Information and technology gaps for this system include: public safety; Federal Aviation Administration- (FAA-) critical infrastructure and aircraft safety; missile detection and tracking; airport air picture tracking; and system effectiveness. Government agencies, such as the Food and Drug Administration and the FAA, have expressed serious concerns about the suitability and interoperability of using a[redacted] in the civilian environment. The 10-year life-cycle cost to protect the 35 Operational Evolution Plan airports, which is approximately [redacted] percent of passenger flights, as estimated by an independent DHS assessor and adjusted for risk is [redacted] ($FY08).

DHS assessed the [redacted] system to also be a TRL 3. The [redacted] cost and time estimate to achieve TRL 6-7 is [redacted] This estimate is also based on contractor supplied data and DHS S&T concurs with this cost estimate. The 10-year life-cycle cost to protect the same 35 airports mentioned previously, as estimated by an independent DHS assessor and adjusted for risk, is [redacted] ($FY08). It should be noted that this [redacted] at almost any range far exceeds the maximum permissible exposure levels if it is focused on human tissue. Also, the missile warning algorithm[redacted] have not yet been developed, therefore estimated time to detect and declare would need to be re-evaluated once algorithm changes are made. Given the severe consequences of the [redacted] on a non-target, the entire process of identifying non-targets (i.e., a Federal Aviation Regulations investigation) needs considerable additional analysis and a subsequent demonstration.

[redacted]

[redacted]

Th[redacted]system evaluated by the ECMT Program was a variation of the[redacted] The proposed the system consists of an onboard counter-MANPADS system that uses missile warning information[redacted]The system proved to have a low false alarm rate and was able to successfully detect and decoy incoming missiles[redacted] However, two key suitability concerns exist: [redacted]component of the MWS and the use of[redacted] in the civilian environment. The[redacted] The ECMT Program did not assess the TRL for th[redacted]to focus primarily on the feasibility of[redacted]

None of the systems evaluated under the ECMT Program fully comply with FAA operational and safety requirements. DHS S&T concluded that the ground-based technologies are too immature to be considered for deployment. Furthermore a ground-based approach is limited to localized protection of aircraft. Many domestic and international flights will remain unprotected unless the technology is exported and installed at all airports worldwide. DHS S&T has no plans to conduct a follow-on program to further investigate the maturation of any of the system concepts evaluated in the ECMT Program. The results are documented in a separate DHS S&T report titled, "Detailing the Findings of the ECMT Program."

2. Project CHLOE

The objective of Project CHLOE (Figure 28) was to assess the feasibility of persistent high-altitude standoff Counter-MANPADS protection of commercial aircraft, evaluate the concept of operations and estimate life-cycle costs. The system was required to protect aircraft within the air space bounded by the threat envelope (defined as a three-mile radius around each aircraft operating at or below 18,000 feet above ground level) applied to standard approach and take off corridors of commercial aircraft (nominally extending up to 65 miles from airports along all flight paths). Secondary objectives were to investigate and demonstrate other DHS S&T missions and payloads compatible with the CHLOE platform and operating environment and interface to Air Traffic Control and law enforcement for Situational Awareness. These objectives were addressed via studies and analysis, M&S and three field demonstrations.

Leveraging the 2007 Counter-MANPADS Phase III live-fire test at White Sands Missile Range, the Naval Research Laboratory modified a prototype two-color Infrared (IR) MWS, integrated it [redacted]

[redacted]

into a UAS surrogate (NASA ER-2) and passively monitored the MANPADS launches from high altitude (> 50,000 feet). This demonstration confirmed the concept of high-altitude off-axis MANPADS detection and tracking, identified performance gaps and helped refine CHLOE sensor/system requirements.

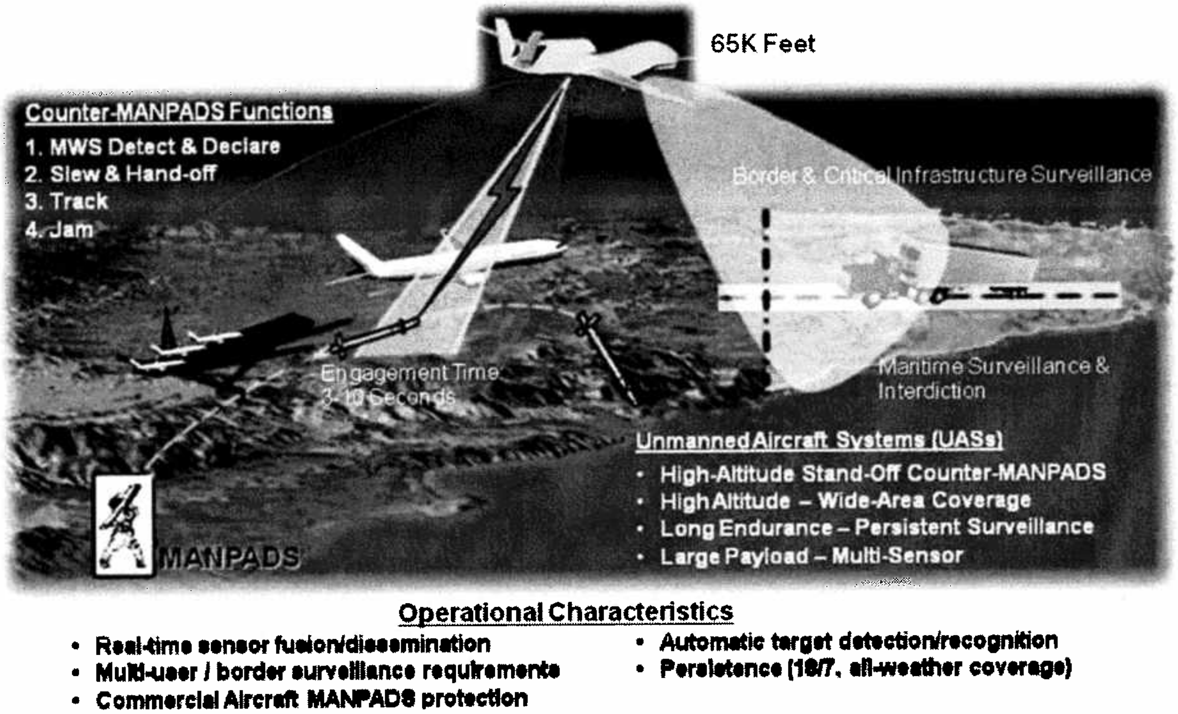


Figure 28: Project CHLOE Overview

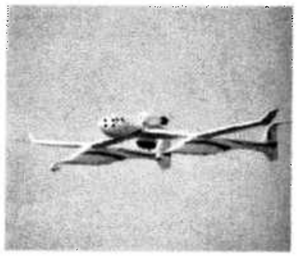
The second demonstration consisted of overflights of the Holloman High Speed Test Track by the Scaled Composites Inc. White Knight aircraft (surrogate UAS) outfitted with a modified NGC Guardian™ pod in 2008 (Figure 29). Instrumented MANPADS were attached to a sled and were fired down the track. The system flew at altitudes over 45,000 feet and detected, tracked and lased the MANPADS. Data collected were used to refine the CONOPS; evaluate CHLOE MWS/counter-measure handoff timing and network requirements; and assess energy-on-missile-dome levels. The demonstration was completed in September 2008.

The third demonstration consisted of laboratory testing of an NGC Viper™ laser against various MANPADS seekers to support CHLOE laser power requirements development. The experimentation was conducted by Naval Surface Weapons Center during May through September 2009, and the results and analysis documented in the Off-Axis Effectiveness Study Report. These data will be used to quantify technology gaps and support requirements development.

[redacted]

[redacted]

These CHLOE project successfully demonstrated an ability to detect, track and lase a MANPADS from a high altitude; however, the countermeasure technology cannot meet performance requirements to defeat a MANPADS. The results are documented in a separate DHS S&T report and DHS S&T has no current plans or funding to conduct follow-on development of any of the system concepts evaluated in the CHLOE Program.



Scaled Composites White Knight (surrogate UAS) with DIRCM pod

Energy-on-Dome scenario at Holloman High Speed Test Track (HHSTT)

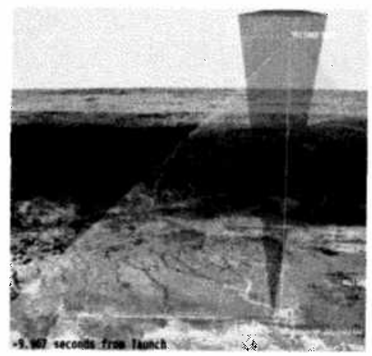


Figure 29: CHLOE Sled Test

3. Propulsion Control for Aircraft Recovery Project

The DHS S&T Propulsion Control for Aircraft Recovery (PCAR) Project developed flight control products based on propulsion that can be used to recover a damaged commercial aircraft. A MANPADS hit is one of many scenarios that can result in the loss of flight controls. The PCAR Project leveraged the Throttles-only Control (TOC) and Propulsion Control Aircraft (PCA) technologies developed by NASA in the late 1990s. TOC and PCA are survivability techniques that can protect commercial airline systems after any scenario, such as a MANPADS attack, that results in the partial or complete loss of normal flight controls. This flight control augmentation technology allows the pilot to safely land a damaged aircraft using the aircraft engine thrust and remaining aircraft control authority. PCA is a semi-automated version of TOC, which allows the pilot to control the aircraft using the autopilot.

The PCAR Program demonstrated TOC on a United Airlines Boeing 757 with NASA, United Air Lines, flight test and commercial line pilots and verified the simulator results. In addition, NASA Dryden, the Department of Homeland Security and Boeing Phantom Works conducted a joint PCA feasibility study. This study resulted in a 747 preliminary PCA system architecture, a set of system requirements for the 747, a concept of operations and an FAA certification plan a life-cycle cost estimate. A separate DHS S&T report documents the results.

[redacted]

[redacted]

[redacted]

[redacted]