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United States General Accounting Office
Washington, DC 20548

January 30, 2004

The Honorable Duncan Hunter
Chairman
The Honorable Ike Skelton
Ranking Minority Member
Committee on Armed Services
House of Representatives

The Honorable John L. Mica
Chairman
The Honorable Peter A. DeFazio
Ranking Minority Member
Subcommittee on Aviation
Committee on Transportation and Infrastructure
House of Representatives

Subject: *The Department of Homeland Security Needs to Fully Adopt a
Knowledge-based Approach to Its Counter-MANPADS Development
Program*

In late 2002, terrorists fired surface-to-air missiles at an Israeli airliner departing from Mombasa, Kenya—the first time man-portable air defense systems (MANPADS) had been used to attack commercial aircraft in a non-combat zone. Given concerns about the vulnerability of the commercial airline industry and the potential impact of an attack in the United States, you requested that we conduct an assessment of the federal government's efforts to address the MANPADS threat against commercial aircraft, including its nature and extent; the Department of Defense's monitoring of Stinger missiles exported to other countries; and U.S. bilateral and multilateral efforts to address international MANPADS proliferation. After we began work on this assessment, the Department of Homeland Security (DHS) took steps to initiate a 2-year system development and demonstration program for a counter-MANPADS system and awarded the initial contracts in January 2004. On December 4, 2003, we briefed your staff on our views about DHS's approach to developing the system. This report summarizes that information and transmits the portion of the briefing related to DHS's counter-MANPADS development effort (see encl. I). Our assessment of the other federal efforts to address the threat is ongoing, and we expect to complete our report in the spring of 2004.

Background

Due in part to the Mombasa attack, the White House convened a task force to develop a strategy to reduce the MANPADS threat against commercial aircraft. In reviewing available technical countermeasures, the task force identified an on-board jammer (directed infrared countermeasure, or DIRCM) as the most promising technology to meet current threats while potentially satisfying operational constraints imposed by the commercial aircraft industry such as minimizing the cost to operate and maintain these systems.

The Congress directed DHS to submit a plan to develop and demonstrate a counter-MANPADS device for commercial aircraft.¹ On October 3, 2003, DHS released a solicitation that outlines a 2-year, two-phased system development and demonstration program to produce prototype systems that would satisfy performance, operational, and cost constraints. In Phase I, which begins in January 2004, DHS intends to conduct preliminary design and analysis activities. In Phase II, which begins about 6 months later, they plan to develop and test the prototypes.

The objective of the DHS program is to (1) migrate existing military countermeasure technologies to the civil aviation environment and (2) minimize the total life-cycle cost of the system, which includes development, procurement, installation, operation and support costs. The solicitation focuses primarily on the DIRCM concept, which combines a missile warning system (MWS) to detect a missile launch and a laser to jam the guidance system of the missile. DOD currently uses DIRCM technology on some of its large transport aircraft, such as the C-17.

Results in Brief

DHS faces significant challenges in adapting a military counter-MANPADS system to commercial aircraft. These challenges include establishing system requirements, maturing technology and design, and setting reliable cost estimates. For instance, DHS has to account for a wide variety of aircraft types in designing and integrating the system. Our past work on the best practices of product developers in government and industry has found that the use of a knowledge-based approach is a key factor in successfully addressing such challenges. This approach includes the use of exit criteria or controls to ensure that sufficient knowledge has been attained at critical phases of the product development process. Based on input we provided during the course of our review, DHS updated its initial solicitation to incorporate these knowledge-based exit criteria. We think this a positive first step, and we are recommending that the Secretary of Homeland Security ensure that the knowledge-based approach is fully implemented throughout the course of its counter-MANPADS development program. DHS fully concurred.

¹ House Report 108-76, p. 84.

DHS Faces Challenges in Adapting Military Counter-MANPADS System to Commercial Aircraft

In proceeding through Phases I and II of the counter-MANPADS development program, DHS intends to establish system requirements, mature technology and design, and set reliable cost estimates. Such issues are interrelated and their resolution will have a direct impact on DHS's ability to effectively implement its program. A brief discussion of these program issues follows:

- **Requirements** involving new technologies, system maintenance, system integration, and system security for the counter-MANPADS system are to be developed and this may involve trade-offs between competing objectives. For example, DHS intends to study the trade-off of system performance objectives with total cost to derive the most effective solution at a realistic life-cycle cost.
- **Technology and design** problems include a high false alarm rate affecting the current generation of Missile Warning Systems (MWS) used by the military; changes needed to adapt military countermeasures to commercial aircraft; and the use of classified jam codes by civilian aircrews. MWS's current high false alarm rate may increase system failures. Whenever the MWS detects a missile launch, the system cycles. If a false alarm has been received and the system is cycling unnecessarily, it will reach its mean-time-between-failure (MTBF) rate threshold much faster. A new MWS that would resolve this issue is being developed but is not yet mature. The solicitation also requires a "call back notification system" that would alert air traffic controllers once it detects a missile launch, but it has not been developed. A MWS with a high false alarm rate connected to a call back system could cause unnecessary airport closures.

The DHS solicitation also requires a system reliability MTBF rate of greater than 3,000 hours—10 times the current rate for DIRCM systems on military aircraft of 300 hours. A low reliability rate drives the operations and support costs and the ability of the airlines to maintain the system. DHS also intends to require a common system attached to the wide variety of commercial aircraft, even though the design, placement, and integration of this system are all unknowns that will affect each aircraft type differently. For example, a system container that causes a 1-percent excess drag on a Boeing 747 aircraft will cause greater drag on a smaller 737-model aircraft, which will affect the airlines' fuel consumption and increase costs.

Design issues surround the classified jam codes used in DIRCM. Military pilots are cleared to handle the classified material and military aircraft are safeguarded, but DHS has not yet developed a plan to handle the classified material and safeguard the hardware on a commercial aircraft. According to DHS officials, any system developed will need to have a tamper-proof design.

- **Operational test requirements** are not clearly specified by the solicitation. DHS compressed its development cycle to comply with congressional

direction. According to program officials, DHS has acted to reduce the time and cost required to conduct testing by having the contractor conduct required testing. However, DHS intends to approve both test concepts and the test plans. They stated that DHS will closely monitor all contractor conducted testing to ensure tests are correctly executed and accurately reported. Finally, operational testing will be conducted on DOD ranges using its test facilities. DOD uses independent live fire and operational test and evaluation that are not under the control of the developers to demonstrate that the developed system is suitable and effective before authorizing full-scale production.

- **Reliable cost estimates** regarding the procurement, integration, operation, and support of DIRCM system on commercial aircraft do not currently exist. DHS intends to conduct its own cost estimates and also require independent analysis, which will be difficult because (1) DHS does not know how many units will be required and, therefore, cannot determine a price based on economies of scale; (2) costs for integrating the system on different types of aircraft are not yet determined; and (3) the reliability rate is unknown and therefore operations and support costs are difficult to estimate.

In addition, the production of a large number of countermeasure systems quickly would probably require a significant capital investment to increase production capacity. An industry official placed their current production capability at roughly four DIRCM systems per month. According to a program official, DHS does not currently know how many or what combination of the estimated 6,800 aircraft in the U.S. fleet might be equipped. One option would be to initially equip the planes of the Civil Reserve Air Fleet (CRAF),² but doing even that could take years.

Knowledge-based Approach Has Been Adopted by Successful Product Developers

In the last several years, we have undertaken a body of work on how leading developers in industry and government use a knowledge-based approach to develop products that reduces risks and increases the likelihood of successful outcomes. This best practices model enables decision makers to be reasonably certain about their products at three critical junctures or knowledge points during development and helps them make informed investment decisions.

- *Knowledge Point 1:* Before product development is started, a match must be made between the customer's needs and the available resources—which include technical and engineering knowledge, time, and funding.

² The CRAF Program enlists the U.S. airline industry to help create an increased airlift capability for contingencies. Airlines sign contracts with the government entitling Air Mobility Command (AMC) to mobilize the aircraft and their aircrews when airlift needs exceed the capability of military aircraft.

- *Knowledge Point 2:* A product's design must be able to meet performance requirements and become stable about midway through development.
- *Knowledge Point 3:* The developer must show that the product can be manufactured within cost, schedule, and quality targets and is demonstrated to be reliable before production begins.

A knowledge-based approach also involves the use of controls or exit criteria to ensure that the required knowledge has been attained at each critical juncture. It ensures that managers will (1) conduct activities to capture relevant product development knowledge, (2) provide evidence that knowledge was captured, and (3) hold decision reviews to determine that appropriate knowledge was captured to allow a move to the next phase. If the knowledge attained at each juncture does not confirm the business case on which the effort was originally justified, the program does not go forward.

Use of a knowledge-based approach has enabled leading organizations to deliver high quality products on time and within budget. Product development efforts that have not followed a knowledge-based approach can be frequently characterized by poor cost, schedule, and performance outcomes.

DHS Has Begun to Use Knowledge-based Approach

DHS included a number of knowledge-based elements in its original solicitation released on October 3, 2003. Among other things, it plans to conduct design reviews, require periodic performance assessments from the contractor, utilize an integrated product team to identify and resolve issues, conduct systems engineering work in both phases, and require the development of a prototype to help identify and resolve specific design and manufacturing risks. In terms of systems engineering, for example, DHS intends to use a comprehensive, iterative technical management process that includes translating operational requirements into configured systems, integrating technical inputs, managing interfaces, and characterizing and managing risks.

During our review, we asked DHS to identify its controls or exit criteria for use in determining whether needed knowledge had been attained by the end of Phases I and II of its program. In its solicitation of October 3, 2003, DHS had required the contractor to satisfy certain criteria in order to receive payment for each milestone. However, the Phase I exit criteria were not knowledge-based. Rather, they were based on the contractor providing information, such as the Long Lead Items List, at key payment milestones. They did not require the contractor to demonstrate that key product knowledge has been obtained. Also, the Phase II exit criteria were not identified and were to be proposed by the contractor and subject to negotiation.

We presented DHS officials with recommended exit criteria from our past reports (see examples in encl. I, p. 20), and they agreed to integrate them into an updated solicitation and use them in monitoring the contractors' progress. For example, at Knowledge Point 1, exit criteria include the demonstration that critical technologies

are mature and system requirements are finalized. At Knowledge Point 2, criteria include the completion of 90 percent of engineering drawings at design review and the demonstration that a prototype's design meets requirements. At Knowledge Point 3, criteria include the demonstration that manufacturing processes are under statistical control.

Conclusion

To address the significant challenges involved in adapting a military counter-MANPADS system to commercial aircraft, DHS would benefit from fully adopting the knowledge-based approach used by leading developers in government and industry. This approach is predicated on the use of exit criteria at each phase of the development process to ensure that needed knowledge is attained before proceeding to the next phase. To their credit, DHS officials responsible for this effort have agreed to this approach, successfully incorporated exit criteria into their updated solicitation, and agreed to use them to monitor progress.³ This is a positive first step, but DHS needs to ensure that the knowledge-based approach is fully utilized throughout this development effort.

Recommendation for Executive Action

We recommend that the Secretary of Homeland Security fully adopt the knowledge-based approach, including the use of exit criteria, to help ensure that key decisions in DHS's effort to develop and demonstrate a counter-MANPADS system are based on sufficient information.

Agency Comments and Our Evaluation

In written comments to a draft of this report (see encl. II), DHS fully concurred with our findings and recommendation. DHS also provided separate technical comments, which we have incorporated as appropriate.

Scope and Methodology

In conducting our review, we compared DHS's plan for its counter-MANPADS system development and demonstration program plan against the best practices of commercial and military acquisitions identified in our past reports and focused whether DHS will have sufficient information to make knowledge-based decisions at each milestone. To determine what military countermeasures are available for adaptation to commercial aircraft and what their performance capabilities, cost, and schedule ramifications might be, we met with DOD, Air Force, Army, and Navy officials and analyzed relevant documentation, including studies and test reports. We interviewed representatives from Northrop Grumman, Boeing, BAE Systems, Raytheon Corporation, and Sanders Design International regarding countermeasure systems currently in production or development. We also met with representatives

³ Examples are included on page 20 of the enclosed briefing.

from the airline industry, air transportation association, and RAND. We conducted our work from April 2003 through January 2004 in accordance with generally accepted government auditing standards.

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We are sending copies of this report to the Secretary, Department of Homeland Security; the Director, Office of Management and Budget; and other interested congressional committees. Copies are available to others upon request. In addition, the report will be available at no charge on the GAO Web site at <http://www.gao.gov>.

Should you or your staff have any questions on matters discussed in this report, please contact me on (202) 512-4841 or Jim Morrison at (202) 512-7078. Principal contributors to this report were Mike Aiken, Natalie Britton, Terry Parker, and Richard Strittmatter.

Handwritten signature of Robert E. Levin in black ink.

Robert E. Levin
Director, Acquisition and Sourcing Management

Enclosures



DHS's Exit Criteria Are Not Linked to Knowledge

Briefing to the House Committee on
Armed Services and House Committee
on Transportation and Infrastructure
Subcommittee on Aviation
December 4, 2003



MANPADS Threat: Commercial Aircraft Are at Risk

- Easily transportable and concealable, and relatively inexpensive (less than \$1,000 to \$100,000)
- Some training required to use system effectively
- 35 MANPADS attacks on commercial aircraft since 1978
 - All but one (November 2002) occurred in combat zones



U.S. Stinger missile system
Source: CRS / U.S. Army



MANPADS Threat: Systems Are Widely Available

- 20 countries manufacture MANPADS; nearly all countries possess them
- Estimated 500,000 – 750,000 worldwide, both in national arsenals and on the black market
- Many different missile types and capabilities; new versions under development
- MANPADS from Iraq present new security challenges



MANPADS Threat: Systems Are Widely Available

- Determining actual threat is difficult
 - Numbers on black and gray markets difficult to estimate
 - Effective lifetime of systems uncertain
- U.S. has not performed assessment of where MANPADS threat falls relative to other terrorist threats
 - Officials acknowledge that consequences of a MANPADS attack on a U.S. commercial aircraft would be severe
- Difficult, therefore, to prioritize and allocate resources to the many potential terrorist threats facing the U.S.



White House Task Force Recommendation and DHS Response

Task Force Recommendation

- Identified on-board jammer (directed infrared countermeasure—DIRCM) as most promising existing technical countermeasure because of limitations with other systems
 - Ground-based systems provided limited coverage
 - Expendables posed environmental hazard
 - Lamps offered limited capability

DHS Actions

- Submitted congressionally mandated plan to Congress (May 22, 2003) outlining development and demonstration of an anti-missile device for commercial aircraft
- Released counter-MANPADS development and demonstration solicitation (Oct. 3, 2003)



DHS Program Plan

Primary Objectives

- Migrate current countermeasure technologies from the military to the civil aviation environment
 - Focus is on DIRCM, but other alternatives will be considered for the first phase of the program
 - DIRCM is effective against current threats
- Minimize total life-cycle cost of system
 - Willing to trade requirements to minimize life-cycle cost

Ambitious 24-Month Program Schedule

- Two-phase Systems Development & Demonstration (SD&D) beginning Jan. 2004
 - Phase I—Preliminary Design & Analysis for two or more systems (6 months)
 - Phase II—Prototype Development & Testing for up to two systems (18 months)



Knowledge-Based Approach Can Lead to Better Acquisition Outcomes

- GAO's past reviews of commercial and defense practices in product development have identified best practices
- Successful programs reduce risk by ensuring that high levels of knowledge are achieved at key points in development
- Using exit criteria linked to knowledge will ensure that program has sufficient information to proceed

Knowledge Point 1

Achieve match between a customer's needs and the developer's available resources—technology, time, engineering knowledge, and funding—before program start

Knowledge Point 2

Stabilize design midway through development and meet performance requirements before initial manufacturing begins

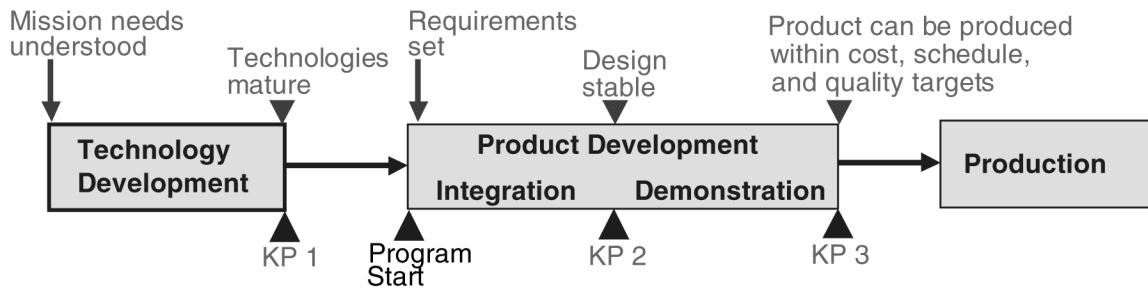
Knowledge Point 3

Determine that product meets cost, schedule, and quality targets and demonstrate reliability before production begins

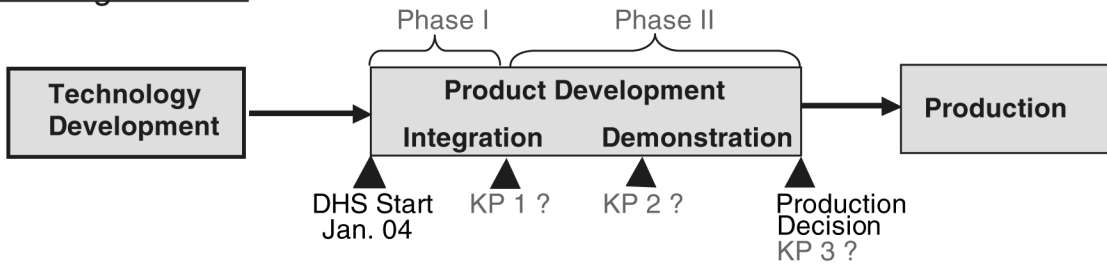


Ambitious Program Schedule Presents Challenges for DHS

Knowledge-Based Approach



DHS Program Plan





DHS Program Plan Incorporates Many Aspects of a Knowledge-Based Acquisition Process...

- **Preliminary Design Review (PDR)**—evaluates progress, technical adequacy, proposed software architectures and risk resolution of selected design approach
- **Critical Design Review (CDR)**—determines that design satisfies performance and engineering requirements
- **Program Management Reviews**—requires periodic performance assessments from contractor
- **Integrated Product Team**—includes representatives from appropriate disciplines working together to build successful programs, identify and resolve issues, and make recommendations
- **Systems Engineering**—uses comprehensive, iterative technical management process that includes translating operational requirements into configured systems, integrating technical inputs, managing interfaces, and characterizing and managing risk
- **Prototype Development**—assists in identification and resolution of specific design or manufacturing risks



...But Areas of Concern Remain

- **Mission Need**

- United States intelligence community has not completed a comprehensive assessment of the MANPADS threat in the context of other terrorist threats
 - U.S. faces a variety of threats within its borders
 - Likelihood and impact of MANPADS attack compared to other terrorist threats is unknown
- Mission needs will not be fully articulated at program start

- **Alternatives**

- DHS has not fully analyzed alternatives to an on-board jammer
- The level of effort that non-DIRCM options will receive is unclear

- **Requirements**

- Will not be clearly or completely defined at program start



...But Areas of Concern Remain (cont.)

- **Technology & Design**

- Some critical technologies are immature and require development
 - Laser—unclear if miniaturization of the laser turret will meet required reliability rate (Mean Time between Failure – MTBF)
- Some design specifications require new technology
 - Missile warning system (MWS)
 - Call-back notification
- Design, placement, and integration of system container are unknowns
- Plan for handling and safeguarding classified hardware and software unknown
 - Requires tamper-proof design



...But Areas of Concern Remain (cont.)

- **Production**
 - Production capacity is currently unknown
 - Prototype may not be production representative
- **Testing**
 - Heavy reliance on contractor testing
 - Testing required during Phase I limited to modeling and simulation
 - Reliability will not be adequately demonstrated in Phase II
- **Cost assessments**
 - Cost analysis scheduled during Phase I will be assumption-based
 - Unit costs unclear; number of units required unknown
 - Integration costs unknown
 - O&S costs unclear; i.e., MTBF unknown
 - Potential unit and O&S costs of equipping and maintaining countermeasures systems on aircraft are high
 - Cost and scope of potential contract is unknown



Linking Best Practice Exit Criteria to Knowledge Will Help Reduce Risk

KP 1 Exit Criteria

- Demonstrate maturity of critical technologies
- Complete trade-offs and finalize requirements
- Complete initial cost and schedule estimates using results from preliminary design review

Decision review for program launch

KP 2 Exit Criteria

- Complete 90% of engineering drawings by CDR
- Demonstrate with prototype that design meets requirements
- Complete failure modes and effects analysis
- Identify critical manufacturing processes
- Identify reliability rate targets and growth plan

Decision review to enter system demonstration

KP 3 Exit Criteria

- Demonstrate manufacturing processes
- Build and test production representative prototypes
- Demonstrate in operational environment
- Demonstrate critical processes are capable and in statistical control

Decision review to begin production



DHS's Exit Criteria Are Not Linked to Knowledge

- DHS will use exit criteria linked to progress payments at selected milestones to monitor and reward contractor performance
 - Phase I exit criteria are not knowledge-driven
 - Phase II exit criteria have not been identified. These criteria will be proposed by the contractor and are subject to negotiation



Conclusions

- DHS's plan includes many elements of a knowledge-based approach to product development, including
 - PDR and CDR
 - Systems engineering
 - Prototype development
 - Program management reviews
 - Integrated product team
- Despite this, they will lack sufficient information to:
 - Develop accurate cost estimates
 - Know if product will work as intended
 - Understand if product can be manufactured as designed
- Until comprehensive threat assessment is completed, mission need will not be fully understood
- Current exit criteria are event-based, not knowledge-based



Recommendations

- DHS needs to fully adopt a knowledge-based approach in its acquisition process and implement the type of exit criteria outlined in this briefing to ensure that each decision is based on sufficient information.

Comments from the Department of Homeland Security

U.S. Department of Homeland Security
Washington, DC 20528



**Homeland
Security**

January 22, 2004

R.E. Levin
Director, Acquisition and Sourcing Management
United States General Accounting Office

Dear Mr. Levin:

Thank you for the opportunity to comment on your GAO Draft Report, dated January 12, 2004, titled: *The Department of Homeland Security Needs to Fully Adopt a Knowledge-based Approach to Its Counter-MANPADS Development Program*. As you know, the Department of Homeland Security considers the Counter-MANPADS program one of its vital initiatives in air transportation security for the American people. We appreciate the GAO's participation effort, and your insights and suggestions in the execution of the program. As we launch into the validation phase of transitioning existing military technologies to civilian aircraft, there are many technical, schedule, and cost unknowns.

We fully concur with your assessment that knowledge-based evaluations of technical requirements, schedules, total system cost estimates, etc. are essential to the success of this program. In fact, each of the contractors selected to perform phase one of this effort have been told the Government evaluators are employing knowledge-based evaluations throughout the program. Based on the GAO's preliminary recommendations, we had developed preliminary milestone exit criteria for the solicitation.

For your consideration we have included two enclosures: the first is a formal response to your recommendation that C-MANPADS Program Office use a knowledge-based management approach. The second attachment contains comments or suggests word or phrase changes that we hope would prove useful in clarifying the C-MANPADS SPO's direction.

Again, thank you for the opportunity to comment.

Respectfully,

A handwritten signature in cursive script that reads "Charles E. McQueary".

Dr. Charles E. McQueary
Under Secretary for Science and Technology

Enclosures:
As stated

GAO DRAFT REPORT – DATED JANUARY 12, 2004
(GAO-04-341R)

“DHS NEEDS TO FULLY ADOPT A KNOWLEDGE-BASED APPROACH TO ITS COUNTER-MANPADS DEVELOPMENT PROGRAM”

DHS COMMENTS ON THE GAO RECOMMENATION

RECOMMENDATION: GAO recommends that the Secretary of Homeland Security fully adopt the knowledge-based approach, including the use of exit criteria, to help ensure that key decisions in DHS’ effort to develop and demonstrate a counter-MANPADS system are based on sufficient information. (p. 8/GAO draft report)

DHS RESPONSE: Concur. As indicated in subject report, the DHS Counter-MANPADS Special Program Office (SPO) began to incorporate knowledge-based exit criteria into Counter-MANPADS solicitation based on input received from GAO during the course of their review. DHS remains committed to the adoption of a knowledge-based approach throughout the program and has established knowledge-based entrance and exit criteria as an integral part of each milestone.

Now on p. 6.

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