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Homeland Security: Protecting Airliners from Terrorist Missiles

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Homeland Security: Protecting Airliners from Terrorist Missiles

Summary

Recent events have focused attention on the threat that terrorists with shoulder fired surface-to-air missiles (SAMs) pose to commercial airliners. Most believe that no single solution exists to effectively mitigate this threat. Instead, a menu of options may be considered, including installing infrared (IR) countermeasures on aircraft; modifying flight operations and air traffic control procedures; improving airport and regional security; and strengthening missile non-proliferation efforts. Equipping aircraft with missile countermeasure systems can protect the aircraft even when operating in areas where ground-based security measures are unavailable or infeasible to implement. However, this option has a relatively high cost, between \$1 million and \$3 million per aircraft, and the time needed for implementation does not allow for immediate response to the existing terrorist threat. Procedural improvements such as specific flight crew training, altering air traffic procedures to minimize exposure to the threat, and improved security near airports may be less costly than countermeasures and could more immediately help deter domestic terrorist attacks. However, these techniques by themselves cannot completely mitigate the risk of domestic attacks and would not protect U.S. airliners flying to and from foreign airports. Legislation introduced in the 108th Congress (H.R. 580, S. 311) calls for the installation of missile defense systems in all turbojet aircraft used in scheduled air carrier service. The Department of Homeland Security (DHS) appropriations for Fiscal Year 2004 (P.L. 108-90) designated \$60 million dollars for development and testing of a prototype missile countermeasure system for commercial aircraft. DHS anticipates a two year program totaling about \$100 million to develop, test, and certify a suitable system.

This report will be updated as needed.

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Introduction

Shoulder-fired surface-to-air missiles (SAMs), also known as MANPADs (man-portable air defense systems), developed in the late 1950s to provide military ground forces protection from enemy aircraft, are receiving a great deal of attention as potential terrorist weapons. These missiles, affordable and widely available through a variety of sources, have been used successfully over the past three decades both in military conflicts¹ as well as by terrorist organizations. The missiles are about 5 to 6 feet in length, weigh about 35 to 40 pounds, and, depending on the model, can be purchased on the black market anywhere from a few hundred dollars for older models to upwards of almost a quarter million dollars for newer, more capable models. Seventeen countries, including the United States, produce man-portable air defense systems.² Shoulder-fired SAMs generally have a target detection range of about 6 miles and an engagement range of about 4 miles so aircraft flying at 20,000 feet (3.8 miles) or higher are relatively safe.³ Most experts consider aircraft departures and landings as the times when it is most vulnerable to shoulder-fired SAM engagement. There are a number of different types of shoulder-fired SAMs, primarily classified by their seekers.⁴

Types of Shoulder-Fired SAMS

Infrared (IR)

Infrared shoulder-fired missiles are designed to home in on a heat source on an aircraft, typically the engine exhaust plume, and detonate a warhead in or near the

¹ Shoulder-fired SAMs have been used effectively in a variety of conflicts ranging from the Arab-Israeli Wars, Vietnam, the Iran-Iraq War, to the Falklands Conflict, as well as conflicts in Nicaragua, Yemen, Angola, and Uganda, the Chad-Libya Conflict, and the Balkans Conflict in the 1990s. Some analysts claim that Afghan mujahedin downed 269 Soviet aircraft using 340 shoulder-fired SAMs during the Soviet-Afghan War and that 12 of 29 Allied aircraft shot down during the 1991 Gulf War were downed by MANPADs.

² Wade Bose, "Wassenaar Agreement Agrees on MANPADS Export Criteria", *Arms Control Today*, January/February 2001, p. 1.

³ Marvin B. Schaffer, "Concerns About Terrorists With Manportable SAMS", *RAND Corporation Reports*, October 1993, p. 4.

⁴ Seeker is a synonymous term for the missile's guidance system which acquires the target and guides the missile to its intended point of detonation.

heat source to disable the aircraft. These missiles use passive guidance, meaning that they do not emit signals to detect a heat source, which makes them difficult to detect by targeted aircraft employing countermeasure systems. The first missiles deployed in the 1960s were IR missiles. First generation shoulder-fired SAMs such as the U.S. Redeye, early versions of the Soviet SA-7, and the Chinese HN-5 are considered “tail chase weapons” as their seekers can only acquire and engage a high performance aircraft after it has passed the missile’s firing position. In this flight profile, the aircraft’s engines are fully exposed to the missile’s seeker and provide a sufficient thermal signature for engagement. First generation IR missiles are also highly susceptible to interfering thermal signatures from background sources, including the sun, which many experts feel makes them somewhat unreliable.

Second generation IR missiles such as early versions of the U.S. Stinger, the Soviet SA-14, and the Chinese FN-6 use improved coolants to cool the seeker head which enables the seeker to filter out most interfering background IR sources as well as permitting head-on and side engagement profiles. These missiles also employ technologies to counter decoy flares that might be deployed by targeted aircraft and also have backup target detection modes such as the ultra violet (UV) mode found on the Stinger missile.⁵

Third generation IR shoulder-fired SAMs such as the French Mistral, the Russian SA-18, and the U.S. Stinger B use single or multiple detectors to produce a quasi-image of the target and also have the ability to recognize and reject flares dispensed from aircraft - a common countermeasure used to decoy IR missiles.⁶ Fourth generation missiles such as the U.S. Stinger Block 2, and missiles believed to be under development in Russia, Japan, France, and Israel could incorporate focal plane array guidance systems and other advanced sensor systems which will permit engagement at greater ranges.⁷

Command Line-of-Sight

Command line-of- sight (CLOS) missiles do not home in on a particular aspect (heat source or radio or radar transmissions) of the targeted aircraft. Instead, the missile operator or gunner visually acquires the target using a magnified optical sight and then uses radio controls to “fly” the missile into the aircraft. One of the benefits of such a missile is that it is not as susceptible to standard aircraft mounted countermeasure systems which are designed primarily to defeat IR missiles. The major drawback of CLOS missiles is that they require highly trained and skilled operators. Numerous reports from the Soviet-Afghan War in the 1980s cite Afghan mujahedin as being disappointed with the British-supplied Blowpipe CLOS missile because it was too difficult to learn to use and highly inaccurate, particularly when

⁵ Schaffer, p. 2.

⁶ *Ibid.*, p. 3.

⁷ “Raytheon Electronic Systems FIM-92 Stinger Low-Altitude Surface-to-Air Missile System Family” *Jane’s Defence*, October 13, 2000, p. 3.

employed against fast moving jet aircraft.⁸ Given these considerations, many experts believe that CLOS missiles are not as ideally suited for terrorist use as are IR missiles, which sometimes are referred to as “fire and forget” missiles.

Later versions of CLOS missiles, such as the British Javelin, use a solid state television camera in lieu of the optical tracker to make the gunner’s task easier, and the Javelin’s manufacturer, Thales Air Defence Ltd., claims that their missile is virtually impervious to countermeasures.⁹ Even more advanced CLOS versions, such as the British Starburst, uses a laser data link in lieu of earlier radio guidance links to fly the missile to the target.

Laser Beam Riders

Laser beam riding shoulder-fired SAMs use lasers to guide the missiles to the target. The missile literally flies along the laser beam and strikes the aircraft where the missile operator or gunner aims the laser. These beam riding missiles are resistant to current countermeasure systems on military and civilian aircraft. Missiles such as Sweden’s RBS-70 and Britain’s Starstreak, can engage aircraft from all angles and only require the operator to continuously track the target using a joystick to keep the laser aim point on the target. Because there are no data links from the ground to the missile, the missile can not be effectively jammed after it is launched. Future beam riding SAMs may require the operator to designate the target only once and not manually keep a continuous laser aimpoint on the aircraft. Even though beam riders require relatively extensive training and skill to operate, many experts consider these missiles particularly menacing in the hands of terrorists due to the missiles’ resistance to most conventional countermeasures in use today.

Shoulder-Fired SAM Proliferation

Unclassified estimates of the worldwide shoulder-fired SAMs inventory are widely varied. Published estimates on the number of missiles presently being held in international military arsenals range from 350,000¹⁰ to 500,000¹¹ but disparities among nations in accountability, inventory control, and reporting procedures could make these figures inaccurate. Legal transfer of shoulder-fired SAMs is not governed by an international treaty. The Wassenaar Arrangement¹² is the only international

⁸ Timothy Gusinov, “Portable Weapons May Become the Next Weapon of Choice for Terrorists”, *The Washington Diplomat*, January 2003, p. 2.

⁹ “Land-Based Air Defence 2003-2004”, *Jane’s*, 2003, p. 37.

¹⁰ “Mombasa Attack Highlights Increasing MANPADs Threat”, *Jane’s Intelligence Review*, February 2003, p. 28.

¹¹ The 500,000 figure is found in multiple sources including Gusinov, p. 2 and Thomas Withington’s “Terrorism: Stung by Stingers”, *Bulletin of the Atomic Scientists*, May-June 2003, p. 1.

¹² The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use (continued...)

agreement that addresses shoulder-fired missiles sales and provisions governing these sales were not adopted by its 33 members until December 2000. Recent actions by the Administration may, however, renew emphasis on nonproliferation. According to press reports and a White House Fact Sheet¹³ President Bush obtained commitments from 21 Asian and Pacific Rim members of the Asia Pacific Economic Group (APEC) to “adopt strict domestic export controls on MANPADs; secure stockpiles; regulate MANPADs production, transfer, and brokering; ban transfers to non-state end users; and exchange information in support of these efforts.” APEC leaders meeting in Bangkok also agreed to strengthen their national controls on MANPADs and review progress at next year’s APEC meeting in Chile.¹⁴ While it is not clear if the Administration intends to pursue similar commitments in other regions or with other countries in the future, some analysts believe that such efforts could possibly serve as the starting point for a comprehensive MANPADs nonproliferation agreement.

Tracking proliferation to non-state actors is considered even more difficult by many analysts. There are a variety of means that terrorist organizations use to obtain missiles, including: theft, black market, international organized crime, arms dealers, and transfers from states willing to supply missiles to terrorists. Often times, the only verification that a non-state actor has a shoulder-fired SAM is when a launcher or fragments from an expended missile are recovered after an attack.¹⁵ As in the case of military arsenals, estimates of shoulder-fired SAMs in terrorist hands vary considerably. Estimates range from 5,000¹⁶ to 150,000¹⁷ of various missile types, but most experts agree that the vast majority of them are IR guided and are likely SA-7 derivatives, versions of which are reportedly possessed by at least 56 countries.¹⁸

Some examples attest to the large numbers of these missiles in circulation. As of December 2002, coalition forces in Afghanistan had captured 5,592 shoulder-fired SAMs from the Taliban and Al Qaeda.¹⁹ Some of these included U.S. Stinger and British Blowpipe missiles believed to have been left over from the Afghan-Soviet

¹² (...continued)

Technologies was established in 1995 to promote greater transparency and responsibility with regard to transfers of armaments and sensitive dual-use goods and technologies. For detailed information see [<http://www.wassenaar.org>].

¹³ “New APEC Initiatives on Counterterrorism” *Fact Sheet from the Office of the Press Secretary, the White House*, Bangkok, Thailand, October 21, 2003; Philip Shenon, “U.S. Reaches Deal to Limit Transfers of Portable Missiles”, *New York Times*, October 21, 2003; Joseph Curl, “Asian Nations Agree to Aid Effort to Battle Terrorism”, *Washington Times*, October 22, 2003.

¹⁴ “New APEC Initiatives on Counterterrorism”.

¹⁵ Thomas B. Hunter, “The Proliferation of MANPADS”, *Jane’s*, November 28, 2002, p. 1.

¹⁶ Soyoung Ho, “Plane Threat” *The Washington Monthly*, April 2003, p. 2.

¹⁷ “Mombasa Attack Highlights Increasing MANPADs Threat”, p. 28.

¹⁸ Ho, p. 2.

¹⁹ “SAMs-The New Air Security Threat”, *The Travel Insider*, December 12, 2002, p. 6.

War. Shoulder-fired missiles continue to be seized routinely during coalition raids, suggesting that Taliban and Al Qaeda forces operating in and around Afghanistan still have access to an undetermined number of these systems. In Iraq, recent press reports indicate that 4,000 to 5,000 shoulder-fired SAMs may be available to Iraqi insurgent forces²⁰ who are credited with 19 shoulder-fired SAM attacks against planes in and around Baghdad International Airport since May 2003.²¹ Africa, the region where most terrorist attacks with these missiles have occurred, reportedly also has a large quantity of shoulder-fired SAMs left over from Cold War sponsorships and the numerous civil wars of that era.²²

Non-State Groups With Shoulder-Fired SAMs

Unclassified estimates suggest that between 25 and 30 non-state groups possess shoulder-fired SAMs. Table 1 depicts non-state groups believed to possess shoulder-fired SAMs through the 1996-2001 time period. Additional groups may have obtained missiles since 2001 but details at the unclassified level are not known. Actual or estimated quantities of these weapons attributed to non-state groups at the unclassified level are also unknown.

**Table 1. Non-State Groups with Shoulder-Fired SAMs:
1996-2001²³**

Group	Location	Missile Type
Armed Islamic Group (GIA)	Algeria	Stinger (c)
Chechen rebels	Chechnya, Russia	SA-7 (c), Stinger (c), Blowpipe (r)
Democratic Republic of the Congo (DRC) rebel forces	Democratic Republic of the Congo	SA-16 (r)
Harkat ul-Ansar (HUA)	Kashmir	SA-7 (c)
Hizbullah	Lebanon	SA-7 (c), QW-1 (r), Stinger (r)
Hizbul Mujahideen (HM)	Kashmir	Stinger (r)
Hutu militiamen	Rwanda	Unspecified type (r)
Jamaat e Islami	Afghanistan	SA-7 (c), SA-14 (c)
Jumbish-i-Milli	Afghanistan	SA-7 (c)
Khmer Rouge	Thailand/Cambodia	Unspecified type (r)

²⁰ “Shoulder-Fired Missiles Not too Hard to Find”, *Associated Press*, August 17, 2003.

²¹ “Coalition Says Hundreds of Surface-to-Air Missiles in Iraq” *Agence France Presse*, October 9, 2003.

²² “Shoulder-Fired Missiles Not too Hard to Find”.

²³ This table is taken from p. 43 of “The Proliferation of MANPADS”, by Thomas B. Hunter *Jane’s*, November 28, 2002.

Group	Location	Missile Type
Kosovo Liberation Army (KLA)	Kosovo	SA-7 (r)
Kurdistan Workers Party (PKK)	Turkey	SA-7 (c), Stinger (c)
Liberation Tigers of Tamil Eelam	Sri Lanka	SA-7 (r), SA-14 (r), Stinger (c), HN-5 (c)
Oromo Liberation Front (OLF)	Ethiopia	Unspecified type (r)
Palestinian Authority (PA)	Palestinian autonomous areas and Lebanon	SA-7 (r), Stinger (r)
Popular Front for the Liberation of Palestine-General Command (PFLP-GC)	Palestinian autonomous areas and Lebanon	Unspecified type (r)
Provisional Irish Republican Army (PIRA)	Northern Ireland	SA-7 (c)
Revolutionary Armed Forces of Colombia (FARC)	Colombia	SA-7 (r), SA-4 (r), SA-16 (r), Redeye (r), Stinger (r)
Rwanda Patriotic Front (RPF)	Rwanda	SA-7 (r), SA-16 (r)
Somali National Alliance (SNA)	Somalia	Unspecified types (r)
Al Qaeda/Taliban	Afghanistan	SA-series (c), Stinger (c), Blowpipe (c)
National Liberation Army (ELN)	Colombia	Stinger (r), Unspecified types (r)
National Liberation Army (UCK)	Macedonia	SA-18 (c)
National Union for the Total Independence of Angola (UNITA)	Angola	SA-7 (c), SA-14 (r), SA-16 (r), Stinger (c)
United State Wa Army	Myanmar	SA-7 (c), HN-5N (c)
United Somali Congress - Somali Salvation Alliance (USC-SSA)	Somalia	Unspecified types (r)

Note: (c) is possession confirmed through intelligence sources or actual events; (r) is reported but not confirmed.

Civilian Aviation Encounters with Shoulder-Fired Missiles

The most widely reported statistics on civilian aircraft experience with shoulder-fired missiles indicate that, over the past 25 years, 35 aircraft have come under attack from these weapons. Of those 35, 24 were shot down resulting in more than 500 deaths.²⁴ While these statistics have been frequently cited, at least one report has suggested that these figures may significantly overstate the actual numbers of civilian-use aircraft that have been attacked by shoulder-fired missiles.²⁵ That report instead concluded that only about a dozen civil-registered airplanes have been shot down during this time period and further notes that some of these aircraft were operating as military transports when they were shot down. On the contrary, available statistics may underestimate the total number of civilian encounters with shoulder-fired missiles. It is possible that some aircraft shootings may have been attributed to other causes for various reasons and are not included in these statistics. Also, it is possible that some failed attempts to shoot down civilian airliners have either gone undetected or unreported.

For many incidents considered to be a shoulder-fired missile attack against a civilian aircraft, there is scant information to make a conclusive determination if that was, in fact, the case. In some instances, while it is widely recognized that the incident was a shooting, there is no conclusive determination regarding the weapon used. For example, in some instances of aircraft shootings there are discrepancies among accounts of the event, with some reporting that the aircraft was brought down by a shoulder-fired missile while others claim that anti-aircraft artillery was used. Also, in many instances there are questions as to whether the flight operation was strictly for a civilian use or may have been for military or dual use (civilian/military) purposes. Therefore, there is no universal agreement as to which incidents should be included in the tally of civilian aviation encounters with shoulder-fired missiles.

Based on our review of available reports and databases on the subject, the statistic of 24 catastrophic losses out of 35 aircraft appears to be a reasonable estimate, but not a definitive count, of the total worldwide civil aviation shootings with shoulder-fired missiles or similar weapons. However, since most of these incidents took place in conflict zones, they are not typically considered to be politically motivated because the targeted aircraft may have been perceived as being used for military purposes.²⁶ While these historical examples do not provide any particular insight into the political motivation behind shootings of inflight aircraft, they do provide some indication of the possible outcomes of such an attack. Based on the commonly cited statistic of 24 aircraft destroyed out of 35 attacks over the past

²⁴ Phillip O'Connor, "Planes are easy targets for portable missiles." *Saint Louis Post-Dispatch*, June 1, 2003, p. A1.; Association of Old Crows, "AOC Position Statement: 'Missile Defense Systems for the American Commercial Airline Fleet', Revised August 15, 2003. Alexandria, VA: Author [<http://www.crows.org/advocacyManpads.htm>]

²⁵ Bill Sweetman, "The enemy down below." *Air Transport World*, September 2003, 34-36.

²⁶ See Federal Aviation Administration. *Criminal Acts Against Civil Aviation* (1996-2000 Editions).

25 years, the odds of surviving an attack are not particularly encouraging. Using these numbers, the odds of surviving an attack may be estimated to be only about 30%. However, it is important to note that these incidents include a wide variety of aircraft types including small piston-engine propeller airplanes, turboprop airplanes, helicopters, and business jets, as well as large jet airliners. Since the current legislative proposals and administration efforts to date have been aimed at addressing ways to protect large commercial jet airliners from shoulder-fired missiles, it is useful to examine past incidents involving these types of aircraft in order to gain further insight regarding the threat.

CRS reviewed various sources and found only 5 incidents where large turbojet airliners were believed to have been attacked by shoulder-fired missiles. These incidents are listed in Table 2.²⁷ Of these 5 encounters, there was a wide range of outcomes. Only 2 of the 5 shootings resulted in catastrophic losses of the airplanes — killing all on board. In two other incidents, the airplanes received significant damage — but no one was killed. In the most recent incident, the aircraft was fired upon but not hit.

Table 2. Probable Large Civilian Turbojet Aircraft Encounters with Shoulder-Fired Missiles (1978-Present)

Date	Location	Aircraft	Operator	Outcome
8-Nov-1983	Angola	Boeing 737	Angolan Airlines (TAAG)	Catastrophic: 130 fatalities of 130 people on board
9-Feb-1984	Angola	Boeing 737	Angolan Airlines (TAAG)	Hull Loss: aircraft overran runway on landing after being struck by a missile at 8,000 ft during climbout. No fatalities with 130 on board.
21-Sep-1984	Afghanistan	DC-10	Ariana Afghan Airlines	Substantial Damage: Aircraft was damaged by the missile, including damage to two hydraulic systems, but landed without further damage. No fatalities.

²⁷ Sources: Marvin Schaffer, *Op. cit.*; <http://aviation-safety.net/database/index.html> (Visited on 9/30/2003); [http://www.airdisaster.com/cgi_bin/database.cgi (Visited on 9/30/2003); [http://www.b737.org.uk/accident_report.htm] (Visited on 9/30/2003); Thomas B. Hunter. "The proliferation of MANPADS." *Jane's Intelligence Review*, November 28, 2002.; Federal Aviation Administration. *Criminal Acts Against Civil Aviation* (1996-2000 Editions); The RAND-MIPT Terrorism Incident Database (<http://www.rand.org/psj/rand-mipt.html>, visited October 8, 2003].

Date	Location	Aircraft	Operator	Outcome
10-Oct-1998	Democratic Republic of Congo	Boeing 727	Congo Airlines	Catastrophic: 41 fatalities of 41 people on board.
19-Nov-2002	Kenya	Boeing 767	Arkia Israeli Airlines	Miss: Two SA-7's were fired at the aircraft during climbout, but missed. No fatalities.

In the first instance, the official findings by Angolan authorities attributed the November 8, 1983, crash of a TAAG Angolan Airlines Boeing 737 to a technical problem with the airplane, but UNITA rebels in the area claimed to have shot down the aircraft with a surface to air missile.²⁸ All 130 people on board were killed making this the deadliest single incident involving a probable shoulder-fired missile attack against a civilian aircraft.

In the February 9, 1984 attack of a TAAG Angolan Airlines Boeing 737, the airplane was struck at an altitude of 8,000 feet during climbout. The crew reportedly attempted an emergency landing at Huambo, Angola, but were unable to extend the flaps because of damage to the airplane's hydraulic systems. Consequently, the crew was unable to slow the airplane sufficiently before landing and overran the runway by almost 600 feet. The airplane was totaled but no one was killed.²⁹

In the September 21, 1984 incident, an Ariana Afghan Airlines DC-10 was struck causing damage to two of the airplane's 3 hydraulic systems. While some sources³⁰ defined this incident as a shoulder-fired missile attack, another account indicated that the DC-10 was hit by "explosive bullets."³¹

The most recent catastrophic loss of an aircraft from a surface to air missile was the October 10, 1998 downing of a Congo Airlines Boeing 727 near Kindu, Democratic Republic of Congo. The aircraft was reportedly shot down by a missile, possibly an SA-7, that struck one of the airplane's engines. Tutsi rebels admitted to the shooting, claiming that they believed the airplane to be carrying military supplies. The ensuing crash killed all 40 persons on board.³²

The most recent attempted shooting of a jet airliner was the November 19, 2002 incident involving an Israeli-registered Boeing 767 aircraft operated by Arkia Israeli Airlines. Two SA-7 missiles were fired at the airplane on departure from Mombasa, Kenya but missed. While the threat of shoulder-fired missiles has long been recognized by aviation security experts, this incident has focused the attention of

²⁸ [<http://aviation-safety.net/database/1983/831108-0.htm>] (Visited 10/9/2003).

²⁹ [http://www.b737.org.uk/accident_reports.htm] (Visited 9/30/2003);

³⁰ See Schaffer, *Op. cit.*; Sweetman, *Op. cit.*

³¹ [<http://aviation-safety.net/database/1984/840921-0.htm>] (Visited 10/9/2003).

³² Federal Aviation Administration. *Criminal Acts Against Civil Aviation* (1998 Edition).

many in Congress and the Bush Administration on this threat and options to mitigate it. Unlike the prior attacks on jet airliners that occurred in war torn areas, the Mombasa attack was clearly a politically motivated attack, believed to have been carried out by terrorists with links to Al Qaeda.³³ That fact, coupled with already heightened concerns over aviation security in the aftermath of the September 11, 2001 terrorist attacks, has made the shoulder-fired missile threat a key issue for homeland security.

The Bush Administration has formed a task force to assess the vulnerability of U.S. airports to SAMs. Many in Congress are concerned about the threat shoulder-fired SAMs could pose to airliners. Specific concerns include protecting civilians and mitigating the potential financial burden for an already besieged industry. Legislation is being proposed, as are hearings on the subject.³⁴ On February 5, 2003 Representative Steve Israel and Senator Barbara Boxer introduced legislation (H.R. 580, S. 311) directing the Secretary of Transportation to issue regulations requiring airliners to be equipped with missile defense systems.

Options for Mitigating Missile Threats

Most observers believe that no single solution exists to effectively mitigate the SAM threat to airliners. Instead, a menu of options may be considered, including improvements or modifications to commercial aircraft, changes to pilot training and air traffic control procedures, and improvements to airport and local security.

IR Countermeasures and Aircraft Improvements

Military aircraft employ a variety of countermeasures to mitigate the threat posed by SAMs. With few exceptions, commercial airlines today do not employ these protective systems.³⁵ Historical arguments against fielding countermeasures on airliners include their acquisition cost, cost and difficulty of integrating them into the aircraft, life cycle costs, environmental constraints on their use, and the fear that they may promote perceptions that flying is not safe. Estimates of the cost of acquiring and installing IR countermeasures on commercial aircraft range between \$1 million and \$3 million per aircraft.³⁶ According to FAA forecasts, there will be about 5,575 passenger jet aircraft in service in 2004, including 3,455 large narrowbody airplanes, 638 large widebodies, and 1,482 regional jets. Additionally, there are expected to be

³³ Sweetman, *Op. cit.*.

³⁴ Marc Selinger. "Lawmakers push anti-missile systems for commercial aircraft." *Aerospace Daily*. January 21, 2003. and Walt *Op. cit.*

³⁵ It has been reported that the Israeli airline El Al has deployed or is in the process of equipping some or all of its 34 aircraft with missile countermeasure systems.

³⁶ David Learmount. "Can Countermeasures Work?" *Flight International*. December 10, 2002. Robert Wall & David A. Fulghum. "Israel to Protect Airliners; U.S. on the Fence." *Aviation Week & Space Technology*. December 9, 2002. p.26.

1,082 all-cargo jets deployed in air carrier operations in 2004.³⁷ Estimates on equipping the air carrier jet fleet with IR countermeasures vary because of assumptions regarding the type of system, whether they would be installed directly into the aircraft or attached via a pod, and the overall number to be procured. Some IR countermeasures could increase the airline's operating costs by increasing the aircraft's weight and drag and thus the amount of fuel consumed. Another issue for installing IR countermeasures on passenger jets is the logistics of equipping the fleet and the potential indirect costs associated with taking airplanes out of service to accomplish these installations.

For decades, military aircraft have ejected inexpensive flares to foil IR-guided SAMs. When a white-hot flare passes through an IR-guided SAM's field of view, its intense IR energy can confuse the missile and cause it to lose its lock on the targeted aircraft. Although effective against older shoulder-fired SAMs, flares often cannot fool newer models, which use more sophisticated sensors. Also, most flares pose a fire hazard to combustibles on the ground, and may be too risky for urban areas. DoD has recently developed new flares and similar decoys that may be more effective against modern IR-guided missiles, and pose less of a fire hazard.

Figure 1. C-141B Starlifter Ejecting Flares on Takeoff



Military aircraft also use a variety of transmitters — known as IR countermeasures, or IRCMs — to create fields of IR energy designed to confuse shoulder-fired SAMs. Unlike flares, IRCMs do not pose a fire hazard to combustibles on the ground. Like flares, however, they are only effective against older IR-guided missiles. Recent advances in lasers have led to the development and employment of directed IRCMs (DIRCMs), that focus their IR energy directly on the incoming SAM. DIRCMs are able to generate more jamming power than IRCMs, and may offer the most effective defense against modern shoulder-fired SAMs. DIRCM weight, size, cost, and reliability, however, may not yet make them attractive for commercial airlines.

³⁷ Federal Aviation Administration. *FAA Aerospace Forecasts Fiscal Years 2003-2014*. Available at: [<http://api.hq.faa.gov/clientfiles/CONTENT.htm>]

Military aircraft use flares and IRCMs preemptively: in anticipation of a SAM launch, a pilot can eject numerous flares, or turn on the IRCM to foil a potential threat. However, environmental considerations may make the use of flares difficult for commercial airlines. DIRCM's can't be used preemptively. They must be aware that a missile has been launched, and use missile approach and warning systems (MAWS) for that function.³⁸ Because IR-guided SAMs are difficult to detect, MAWS performance is a key factor in the overall effectiveness of the aircraft's protection system. DoD is also developing paint that is designed to reduce an aircraft's IR reflectivity and visual profile. IR camouflage paint would not reduce an engine's heat signature, but it might make it more difficult for terrorists to visually see the aircraft, and thus could avert a SAM launch. The Navy is studying IR camouflage paint on the V-22 *Osprey*.³⁹ The cost and maintainability of this paint is still being studied, but the paint might actually be lighter than conventional aircraft paint. Today, IR paint appears to offer few complications for airline application compared to other potential countermeasures.

In addition to equipping airliners with missile countermeasures, strengthening the airframe to better withstand missile strikes has been suggested. To date, the FAA's Commercial Aircraft Hardening Program has primarily focused on studying how hardened aircraft can better withstand internal bomb blasts.⁴⁰ The survivability of passenger jets following missile strikes is largely unknown. It is expected that developing hardened aircraft structures will be a challenging problem given that IR guidance systems seek hot engine exhaust and will likely detonate at or near an aircraft engine. Since most jet airliners have wing-mounted engines, hardening of surrounding aircraft structure will likely be infeasible, particularly with regard to modifying existing aircraft. However, some aircraft survivability experts believe that isolating critical systems, like redundant hydraulic lines and flight control linkages, and improving fire suppression and containment capabilities could prevent catastrophic failures cascading from the initial missile strike.⁴¹ While such options can be integrated into new aircraft type designs, they are unlikely to have any near term impact on reducing the threat since retrofitting existing air carrier jets with damage tolerant structures and systems is likely to either be technically infeasible or not economically practical. Moreover, aircraft hardening options will likely require extensive research and testing before their feasibility and effectiveness can be adequately assessed. Initial indications suggest that aircraft hardening and structural redesign, if feasible, will likely be very costly and could take many years to implement.

³⁸ MAWS are also employed on aircraft that use flares and IRCMs.

³⁹ Stephen Trimble. "Glitches Pose Little Threat to V-22 Flight Trial Results, Navy Says." *Aerospace Daily*. January 29, 2003.

⁴⁰ Howard J. Fleisher. "Commercial Aircraft Vulnerability Assessment and Threat Mitigation Techniques." *Aircraft Survivability*, Fall 2002, 24-25. Available at: [<http://www.bahdayton.com/surviac/asnews.htm>]

⁴¹ Bill Sweetman, *Op. cit.*

Improved Pilot Training and Air Traffic Procedures

Airline pilots already receive substantial simulator training on handling loss of power to one engine during critical phases of flight such as takeoffs and landings. This training should already prepare flight crews to handle a loss of engine power resulting from a missile strike. Therefore, additional training for handling missile attacks may be of limited benefit. On the other hand, specific simulator exercises using missile attack scenarios may be beneficial by preparing pilots to fly and land a damaged aircraft. Modern airliners are built with redundancy in avionics and flight control systems, and consequently, a missile strike that does not cause a catastrophic structural failure would likely be survivable if the flight crew is properly trained to handle such a scenario.

Another potential mitigation technique is training flight crews in evasive maneuvers if fired upon by a shoulder-fired SAM. However, this approach would not likely be effective and presents significant risks. Without a missile detection and warning system, it is unlikely that a flight crew would have any indication of a missile launch. Also, large transport category airplanes are generally not maneuverable enough to evade a shoulder-fired SAM. There is also concern that defensive maneuvering of large transport category airplanes could result in a loss of control or structural failure.⁴² Consequently, most observers concur that evasive maneuvering is not a viable option for mitigating the risk of missile attacks. However, properly trained crews may be able to use other special procedures to evade missile attacks. Examples of procedures that may be considered to reduce the airplane's heat signature and vulnerability to missile strikes include: minimizing the use of auxiliary power units and other heat sources when operationally feasible; minimizing engine power settings; and, if a missile launch is detected, reducing engine power settings to minimum levels required to sustain flight at a safe altitude. The effectiveness and safety risks associated with techniques such as these will need to be carefully assessed before procedural measures are implemented.

Another mitigation technique may be to alter air traffic procedures to minimize the amount of time airliners are vulnerable to missile launches and make flight patterns less predictable. Current arrival procedures rely on gradual descents along well defined and publicly known approach courses that place airplanes within range of shoulder-fired SAMs as far away as 50 miles from the airport.⁴³ Similarly, departing aircraft with heavy fuel loads operating at high engine power, often along predefined departure routes, may be particularly vulnerable and can be targeted up to 30 miles away from the airport before they climb above the effective range of shoulder-fired SAMs.⁴⁴

⁴² See Dave Carbaugh, John Cashman, Mike Carriker, Doug Forsythe, Tom Melody, Larry Rockliff, & William Wainwright, "Aerodynamic Principles of Large-Airplane Upsets." FAST Special: Airbus Technical Digest, June 1998. Available at [<http://www.airbus.com/customer/fastspecial.asp>] (Also published in Boeing Aero No. 3).

⁴³ Marvin B. Shaffer. *Op. cit.*.

⁴⁴ Robert Wall & David A. Fulghum. *Op. cit.*.

Military aircraft often use spiral descents from altitude above the airfield when operating in hostile areas. Using spiral descents may be an option for mitigating the threat of terrorist SAM attacks to airliners approaching domestic airports. Doing so can limit approach and descent patterns to a smaller perimeter around the airfield where security patrols can more effectively deter terrorist attacks. While spiral approaches may be implemented on a limited basis, wide scale use of spiral patterns would likely require extensive restructuring of airspace and air traffic procedures. This technique may present safety concerns by greatly increasing air traffic controller workload and requiring pilots to make potentially difficult turning maneuvers at low altitude. The use of spiral patterns could also reduce passenger comfort and confidence in flight safety. Also, this technique would not mitigate the risk to departing aircraft, which are generally considered to be the most vulnerable to missile attacks.

Another technique used by military aircraft, particularly fighter jets, to reduce vulnerability on departure is to make steep, rapid climbouts above the effective range of surface to air missiles over a short distance. Like spiral descents, such a technique has limited application for civilian jet airliners. A typical climb gradient for these aircraft is between 400 and 500 feet per mile, which means that they remain in range of shoulder-fired missiles for about 40 to 50 miles after departure. Even if the airplane were to double its climb rate, which would probably be close to the maximum practically achievable climb rate for most jet airliners, the distance traveled before safely climbing above the range of shoulder-fired missiles would still be 20 miles or more. Climbing out at such a steep rate would also pose a risk to the aircraft since it may not provide an adequate margin of safety if an engine were to fail during climbout. Also, steep climb angles are likely to be perceived as objectionable by passengers.

Another option that may be considered is to vary approach and departure patterns. Regularly varying approach and departure patterns, in non-predictable ways, may make it more difficult for terrorists to set up a shoulder-fired SAM under a known flight corridor; and, may increase the probability that they will be detected, while trying to locate a usable launch site, by ground surveillance, local law enforcement, or civilians reporting suspicious activities. One challenge to implementing this technique is that aviation radio frequencies are not protected, and terrorists might gather intelligence regarding changing flight patterns. Also, flight tracking data are available in near real time from Internet sources and may be exploited by terrorists to gain information about aircraft position. Nonetheless, this approach could be a deterrent by making overflights of particular locations less predictable. Limitations to this approach include disruption of normal air traffic flow which may result in delays, increased air traffic controller workload, and possible interference with noise mitigation procedures. Varying air traffic patterns may be a viable mitigation technique, particularly at airports with low to moderate traffic and for approach and departure patterns that overfly sparsely populated areas. Also, maximizing the use of over water approach and departure procedures, when

available, coupled with measures to limit or restrict access to and increase patrols of waters under these flight paths has also been suggested as a mitigation alternative.⁴⁵

Other suggested changes to air traffic procedures include the increased use of nighttime flights and minimal use of aircraft lighting. However, this approach is likely to be opposed by the airlines and passengers since there is little demand for night flights in many domestic markets. Furthermore, minimizing the use of aircraft lighting raises safety concerns for aircraft collision avoidance. While the airspace system includes good radar coverage in the vicinity of airports and airliners are required to have collision avoidance systems, the last line of protection against midair collisions is the flight crew's ability to see and avoid other aircraft. Therefore, increased use of night flights and minimizing aircraft lighting is not thought to be a particularly viable mitigation option.

Improvements to Airport and Local Security

One of the most expedient measures that can be taken to mitigate the risk from shoulder-fired SAMs to airliners is to heighten security, surveillance, and patrols in the vicinity of airports served by air carriers. The difficulty with implementing these security measures is that the approach and departure corridors where aircraft operate within range of shoulder-fired SAMs extend for several miles beyond airport perimeters. Therefore, while heightening security in the immediate vicinity of an airport may reduce the threat from shoulder-fired SAMs, these measures cannot effectively mitigate the threat during the entire portion of flight while airliners are vulnerable to attack. Nonetheless, using threat and vulnerability assessments, airport and airspace managers can work with security forces to determine those locations beyond the airport perimeter that have high threat potential and where aircraft are most vulnerable to attack. Using this information, security can concentrate patrols and surveillance in these high risk areas. Airport security managers will likely need to work closely with local law enforcement to coordinate efforts for patrolling these high risk areas. Public education and neighborhood watch programs in high risk areas may also be effective means to mitigate the threat. Aerial patrols using sensor technology, such as Forward Looking Infrared (FLIR), may also be an effective tool for detecting terrorists lurking underneath flight paths. However, use of aerial patrols may significantly impact normal flight schedules and operations, particularly at the nation's larger airports.

In addition to increased security, some have suggested using ground based countermeasures in high risk locations. Randomly dispensing flares in the vicinity of airports has been suggested, noting that the Israeli airline El Al occasionally used this technique during periods of heightened tension in the 1980s. However, ground-based flares pose a risk of fires on the ground and therefore would not be suitable at many airports in the United States, particularly those surrounded by populated or wooded areas. Furthermore, dispensing flares may be annoying to some and may also diminish public confidence in the safety and security of air travel. Ground based interceptors are another option that has been suggested. These interceptors could be vehicle-mounted SAMs like the Marine Corps "HUMRAAM" system, or even

⁴⁵ Marvin B. Schaffer. *Op. cit.*

directed energy weapons like the Army's tactical high-energy laser (THEL). Cost, reliability, probability of intercept, and potential side-effects and unintended consequences would have to be weighed when considering these options. Older "lamp-based" IR countermeasures might also offer some missile jamming capability, by generating wide, if relatively weak, fields of IR energy near airports. Again, potential side-effects and unintended consequences would have to be assessed.

Another way to mitigate the threat of shoulder-fired SAMs is through intelligence and law enforcement efforts to prevent terrorists from acquiring these weapons, particularly terrorists operating inside the United States. Congress may consider ways to improve current missile non-proliferation efforts, and may also wish to debate ways to better share intelligence information with airport security managers so that appropriate security measures can be implemented to respond to specific threat information.

Counterproliferation

There are a number of both formal and informal counterproliferation actions that could be undertaken. Informally, U.S. and coalition forces routinely seize and destroy caches of shoulder-fired SAMs during combat operations in Afghanistan and Iraq, thereby reducing the number of these systems available for terrorist use. Formally, the U.S. is offering \$500 for each shoulder-fired SAM turned over to authorities in both Iraq and Afghanistan.⁴⁶ According to one press report, 317 shoulder-fired missiles had been turned over to U.S. military authorities in Iraq since May 1, with the U.S. paying out over \$100,000 in rewards for the missiles.⁴⁷ Other formal options could include infiltrating black market, organized crime or terrorist groups, and seizing or destroying these missiles or setting up "sting" operations to arrest arms brokers and seize their missiles.

Program Plan and Funding for Missile Countermeasure Development

Language in the conference report accompanying the Emergency Wartime Supplemental Appropriations Act of 2003 (P. L. 108-11; H. Rept. 108-76) directed the Department of Homeland Security (DHS) Under Secretary for Science and Technology to prepare a program plan for developing an anti-missile device for commercial aircraft. DHS submitted the requisite plan to Congress on May 22, 2003.⁴⁸ The plan specifies a two year time frame for development, design, testing, and evaluation of an anti-missile device on a single aircraft type. The plan anticipates that a parallel FAA certification effort will coincide with this system development and demonstration leading to an FAA-certified system that can be

⁴⁶ "Rewards Offered for Missile Launcher", *USA Today*, August 1, 2003, p. 6.

⁴⁷ Raymond Bonner, "The Struggle for Iraq: Missing Weapons; U.S. Can't Locate Missiles Once Held in Arsenal of Iraq", *New York Times*, October 8, 2003.

⁴⁸ U.S. Department of Homeland Security. *Program Plan for the Development of an Antimissile Device for Commercial Aircraft*. Washington, DC: Author.

operationally deployed on commercial aircraft at the end of the two year project or soon thereafter.

The program plan submitted by DHS estimated that the costs to carry out this project would consist of \$2 million in FY 2003 for administrative costs, \$60 million in FY 2004 for system development and initial testing, and an unspecified amount, not to exceed \$60 million, in FY 2005 to complete development and demonstration of the system and obtain FAA certification. The Department of Homeland Security Appropriations Act for 2004 (P.L. 108-90, H. Rept. 108-280) fully funded the requested \$60 million in FY 2004 for this effort.

In anticipation of this funding, the DHS established a Counter-MANPADs Special Program Office (SPO) and published a pre-solicitation notice for prospective vendors on September 15, 2003.⁴⁹ DHS envisions the program to consist of two phases. Phase I will consist of an intensive six-month effort to assess proposed solutions based on threat mitigation capabilities, system costs, airframe and avionics integration, and FAA certification issues. Phase II will consist of an 18-month prototype development based on existing technology that will be demonstrated and evaluated. DHS indicates that they will be evaluating DIRCM and other existing technologies in this effort and point out that this program is not intended to develop new technologies, but to apply existing technologies from the military environment to the commercial airline environment. DHS indicates that there is a potential for multiple contract awards with the aggregate total of all Phase I and Phase II awards estimated to be about \$100 million.

Conclusion

No single solution can immediately and completely mitigate the shoulder-fired SAM threat. As Congress considers possible legislative and oversight approaches, it is likely that it may consider implementing various combinations of available mitigation alternatives in whole or in part. In addition, Congress may consider phasing in mitigation options to best respond to available threat assessments or other criteria. For example, if threat assessments indicate that large widebody airplanes are most at risk, Congress may consider whether initially equipping these airplanes would more effectively deter the threat of missile attacks. Congress may also consider whether it would be more effective to initially equip aircraft used on overseas flights, particularly those operating in countries or regions where the risk of missile attacks is greatest. Congress may also debate whether equipping only a portion of the air carrier fleet would be a sufficient deterrent, whether all-cargo jets should be equipped, whether passenger carrying regional jets should be equipped, or whether equipping the entire air carrier fleet is needed to adequately mitigate the threat.

⁴⁹ Department of Homeland Security. *Counter-MANPADS Demonstration and Development*. Solicitation Number HSSCST-04-R-AR001-2. Available at FedBizOpps: Federal Business Opportunities http://www2.epa.gov/spg/DHS-DR/OCPO/DHS%2DOCPO/postdate_1.html; last visited on 10/9/2003).

Equipping aircraft with missile countermeasure systems has advantages. Countermeasures are fixed to the aircraft, require little or no flight crew intervention, and can protect the aircraft even when operating in areas where ground-based security measures are unavailable or infeasible to implement. Down sides include a high cost, and potentially undermining passenger confidence in the safety and security of air travel. Also, because implementation will take time, countermeasures cannot immediately mitigate today's terrorist threat. Procedural improvements such as flight crew training, changes to air traffic management, and improved security near airports may be less costly than countermeasures and could more immediately help deter domestic terrorist attacks. However, these techniques by themselves cannot completely mitigate the risk of domestic attacks and would not protect U.S. airliners flying to and from foreign airports.

Congress and the Administration have initiated preliminary actions intended to provide a degree of protection to commercial airliners. Legislation introduced in the 108th Congress (H.R. 580, S. 311) calls for the installation of missile defense systems in all turbojet aircraft used in scheduled air carrier service. The Department of Homeland Security (DHS) appropriations for 2004 (P.L. 108-90) designated \$60 million for development and testing of a prototype missile countermeasure system for commercial aircraft. DHS anticipates a two year program totaling about \$100 million to develop, test, and certify a suitable system. These actions may constitute a starting point for the consideration of additional protective measures designed to address all aspects of the shoulder-fired SAM threat.