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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), referred to as Man-Portable Air Defense Systems (MANPADS), 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 called for the installation of missile defense systems in all turbojet aircraft used in scheduled air carrier service. Homeland Security appropriations designated $60 million in FY2004, $61 million in FY2005, and $110 million in FY2006 to fund a program to develop and test prototype missile countermeasure systems for commercial aircraft based on existing military technology. It is anticipated that at the conclusion of this program, the Department of Homeland Security will be able to provide a detailed analysis of the suitability of such systems for use to protect commercial passenger aircraft.

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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 that might be used against commercial airliners. These missiles, affordable and widely available through a variety of sources, have been used successfully over the past three decades both in military conflicts[1] 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

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[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

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[5] Schaffer, Op Cit. 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. 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, use 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

Approximately 20 countries have manufactured MANPADS or their components, and it is estimated that a total of over 1 million of these systems have been manufactured worldwide.[10] 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 350,000[11] to 500,000[12] but disparities among nations in accountability, inventory control, and

[8] Timothy Gusinov, "Portable Weapons May Become the Next Weapon of Choice for Terrorists,", *Washington Diplomat,* January 2003, p. 2.

[9] "Land-Based Air Defence 2003-2004," *Jane's*, 2003, p. 37.

[10] "The MANPADS Menace: Combating the Threat to Global Aviation from Man-Portable Air Defense Systems." *Fact Sheet*. Bureau of Political-Military Affairs. U.S. Department of State. September 20, 2005.

[11] "Mombasa Attack Highlights Increasing MANPADs Threat," *Jane's Intelligence Review*, February 2003, p. 28.

[12] The 500,000 figure is found in multiple sources including Gusinov, p. 2 and Thomas

(continued...)

reporting procedures could make these figures inaccurate. 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.[13] As in the case of military arsenals, estimates of shoulder-fired SAMs in terrorist hands vary considerably. Estimates range from 5,000[14] to 150,000[15] 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.[16]

Some examples attest to the large numbers of these missiles in circulation. As of December 2002, coalition forces in Afghanistan had reportedly captured 5,592 shoulder- fired SAMs from the Taliban and Al Qaeda.[17] Some of these included U.S. Stinger and British Blowpipe missiles believed to have been left over from the Afghan-Soviet 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 forces.[18] 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.[19]

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.

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[12] (...continued)
Withington's "Terrorism: Stung by Stingers," *Bulletin of the Atomic Scientists,* May-June 2003, p. 1.

[13] Thomas B. Hunter, "The Proliferation of MANPADS," *Jane's,* November 28, 2002, p. 1.

[14] Soyoung Ho, "Plane Threat" *Washington Monthly*, April 2003, p. 2.

[15] "Mombasa Attack Highlights Increasing MANPADs Threat," p. 28.

[16] Ho, p. 2.

[17] "SAMs-The New Air Security Threat," *Travel Insider,* December 12, 2002, p. 6.

[18] "Shoulder-Fired Missiles Not too Hard to Find," *Associated Press,* August 17, 2003.

[19] "Shoulder-Fired Missiles Not too Hard to Find."

Table 1. Non-State Groups with Shoulder-Fired SAMs: 1996-2001[20]

Group	Location	Missile Type
Armed Islamic Group (GIA)	Algeria	Stinger (c)
Chechen rebels	Checnya, 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 Mujahedin (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)
Kosovo Liberation Army (KLA)	Kosovo	SA-7 (r)
Kurdistan Workers Party (PKK)	Turkey	SA-7 (c), Stinger (c)
Liberation Tigers of Tamil Eeelam	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.

[20] This table is taken from p. 43 of "The Proliferation of MANPADS," Thomas B. Hunter, *Jane's*, November 28, 2002.

Recent U.S. Military Encounters with Shoulder-Fired Missiles

Recent U.S. military encounters with shoulder-fired missiles in Iraq and Afghanistan can provide some useful operational insights which could be benefit government, industry, and civil aviation officials involved in the protection of civil aviation. In December 2003 an unidentified shoulder-fired SAM struck an engine of a U.S. Air Force C-17 Globemaster III cargo aircraft that had just departed Baghdad International Airport.[21] The aircraft, which was outfitted with missile defenses, made an emergency landing at Baghdad International Airport.[22] In January 2004, a C-5 Galaxy transport aircraft - also having an antimissile system -was hit by a shoulder-fired SAM and the aircraft was able to and successfully.[23] One senior Air Force official reportedly stated that "for whatever reason, the [defensive] systems on the airplanes didn't counter [the attacks]. We don't have any indications that it was a system malfunction."[24] The official speculated that sensor placement, and aircraft altitude and maneuvering played a role in these systems not functioning as they were intended.[25]

According to one report, from October 25, 2003 to January 2004, nine military helicopters were shot down or crashed landed in Iraq after having been hit by hostile ground fire, resulting in the deaths of 39 service members.[26] An Army study, commissioned after these incidents, reportedly revealed a number of findings. The study team reportedly concluded that RPGs,[27]and SA-7, SA-14, and SA-16 shoulder-fired SAMs were used in the attacks against the helicopters.[28] Another study finding revealed that the Iraqis had studied the helicopter flight patterns and had developed effective techniques to engage the aircraft.[29]

According to the Chief of the U.S. Transportation Command (USTRANSCOM), U.S. military cargo aircraft take ground fire in Afghanistan and Iraq from shoulder-fired SAMs, anti-aircraft artillery and small arms on almost a

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[21] Ron Laurenzo, "Air Force Says Enemy Fire Damaged C-17," *Defense Week,* December 22, 2003, p. 15.

[22] Ibid.

[23] David A. Fulghum, "SAMs Threaten," *Aviation Week & Space Technology,* February 2, 2004, p. 43.

[24] Ibid.

[25] Ibid.

[26] Eric Schmitt, "Iraq Rebels Using More Skill to Down Copters," *New York Times,* January 18, 2004, p 1.

[27] Rocket Propelled Grenades (RPGs) are shoulder-fired grenades that are primarily intended for use against ground targets. They are simple to use, fairly accurate, and are widely proliferated throughout the world.

[28] Schmitt. Op cit.

[29] Ibid.

daily basis.[30] USCENTCOM officials were unable to provide an unclassified update on shoulder-fired missiles attacks against U.S. military aircraft in Afghanistan and Iraq as of September 2004, although classified data of this nature is being tracked by USCENTCOM and DOD.[31] Some analysts believe that the U.S. has significantly improved aircraft countermeasures and defenses and modified aircraft operating procedures, resulting in fewer successful attacks, but others suggest that attacks with shoulder-fired SAMs have become so commonplace that they no longer garner the attention that they once did.

Civilian Aviation Encounters with Shoulder-Fired Missiles

Estimates vary, but the most widely reported statistics on civilian aircraft experience with shoulder-fired missiles indicate that, over the past 26 years, 35 aircraft have come under attack from these weapons.[32] Of those 35, 24 were shot down resulting in more than 500 deaths.[33] 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.[34] 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

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[30] Nathan Hodge, "Airlifters 'Routinely' Take Ground Fire, General Says," *Defense Today*, July 29, 2004, p. 1.

[31] CRS requested this data from the USCENTCOM Legislative Affairs Office on September 22, 2004. USCENTCOM was willing to share this classified data with appropriately-cleared CRS staff but the use of classified data in these reports is not permitted.

[32] The State Department estimates that since 1970, over 40 civilian aircraft have been hit by MANPADS, causing about 25 crashes and over 600 deaths. *Fact Sheet*, OpCit.

[33] 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. [http://www.crows.org/ADVOCACY/Legislative/ManPads/AOCpositionManPADS07292004.pdf].

[34] Bill Sweetman, "The Enemy down Below," *Air Transport World*, September 2003, 34-36.

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 36 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.[35] While most of these historical examples do not provide any particular insight into the political motivation behind shootings of civilian aircraft in the current context of the global war on terrorism, 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 36 attacks over the past 26 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 33%. 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 six incidents where large turbojet airliners were reported to have been attacked by shoulder-fired missiles. These incidents are listed in **Table 2**.[36] Whether all of these incidents were in fact attacks using shoulder-fired missiles is still a matter of considerable debate as conclusive evidence supporting such a finding is lacking for most of these incidents. Of these six encounters identified, there was a wide range of outcomes. Only two of the six shootings resulted in catastrophic losses of the airplanes — killing all on board. In three other incidents, the airplanes received significant damage — but no one was killed. Finally, in the widely reported November 2002 attempt to shoot down an Israeli charter jet in Mombasa, Kenya, the aircraft was fired upon by two missiles but was not hit.

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[35] See Federal Aviation Administration, *Criminal Acts Against Civil Aviation* (1996-2000 Editions).

[36] **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_reports.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).

Table 2. Suspected Shoulder-Fired Missile Attacks Against Large Civilian Turbojet Aircraft (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 climb out. 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.
10-Oct-1998	Democratic Republic of Congo	Boeing 727	Congo Airlines	Catastrophic: 41 fatalities of 41 people on board.
28-Nov-2002	Kenya	Boeing 757	Arkia Israeli Airlines	Miss: Two SA-7's were fired at the aircraft during climb out, but missed. No fatalities.
22-Nov-2004	Iraq	Airbus A300	DHL Cargo	Hull Loss: Aircraft wing struck by missile departing Baghdad. Aircraft suffered a complete loss of hydraulic power and departed the runway during an emergency landing.

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.[37] All 130 people on board were killed, potentially making this the deadliest single incident involving a shoulder-fired missile attack against a civilian aircraft. However, investigation of the incident failed to produce any conclusive evidence of missile or gunfire damage on any of the aircraft wreckage.

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

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 climb out. 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 a total loss but no one was killed.[38] Investigators found evidence leading them to suspect that a bomb detonation in the forward hold, rather than a missile, was responsible for the damage observed. However, press accounts reporting that the aircraft was struck by an SA-7 fired by UNITA guerillas have led some to conclude that this incident was, in fact, a shoulder-fired missile attack.[39]

In the September 21, 1984, incident, an Ariana Afghan Airlines DC-10 was struck causing damage to two of the airplane's three hydraulic systems. While some sources[40] defined this incident as a shoulder-fired missile attack, another account indicated that the DC-10 was hit by "explosive bullets."[41]

The most recent catastrophic loss of a civilian aircraft from a suspected MANPADS attack 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 final call from the Captain indicated that the aircraft had been hit by a missile and had an engine fire. It was reported that a missile struck the airplane's rear engine. The ensuing crash killed all 41 persons on board.[42]

The most recent attempted shooting of a passenger jet was the November 28, 2002, incident involving an Israeli-registered Boeing 757 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 focused the attention of 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.[43] 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.

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

[39] See Schaffer, Op cit.

[40] See Schaffer, Op cit.; Sweetman, Op cit.

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

[42] Federal Aviation Administration, *Criminal Acts Against Civil Aviation* (1998 Edition).

[43] Sweetman, Op cit.

Amid this heightened concern over the threat of shoulder-fired missiles to commercial aircraft, a DHL cargo airplane was struck by a missile on November 22, 2004, while departing Baghdad International Airport in Iraq. The aircraft's left wing was struck outboard from the engine. Damage from the missile severed the airplane's hydraulic lines. However, the flight crew was able to return to the airport applying differential thrust on the two engines to maneuver and operating manual cranks to lower the landing gear. The aircraft, an Airbus A300-B4, departed the runway on landing causing additional damage, including extensive engine damage from ingesting sand and debris.[44] While no one was killed or injured, the airplane was determined to be a total loss.

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.[45] 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.[46] According to FAA forecasts, there will be about 6,839 passenger jet aircraft in service in 2006, including 3,692 large narrow body airplanes, 599 large wide bodies, and 2,098 regional jets. Additionally, there are expected to be 1,011 all-cargo jets deployed in air carrier operations in 2006.[47] 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

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[44] David Hughes and Michael A. Dornheim, "No Flight Controls," *Aviation Week & Space Technology,* December 8, 2003, pp. 42-43.

[45] 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.

[46] 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.

[47] Federal Aviation Administration, *FAA Aerospace Forecasts Fiscal Years 2005-2016.*

accomplish these installations. An analysis by the RAND Corporation found that, in addition to an initial purchase and installation cost of about $11 billion, it would cost about $2.1 billion annually in terms of both direct and indirect or incidental costs to maintain and sustain aircraft-based IR countermeasures on a fleet of 6,800 passenger jets.[48]

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.

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.

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.[49] Because IR-guided SAMs are difficult to detect, MAWS performance is a key factor in the overall effectiveness of the aircraft's protection system. DIRCM reliability and maintainability has also frequently been cited as a key factor that will determine the cost effectiveness of these systems for commercial use. Some estimate that current DIRCM system reliability will have to improve by a factor of 10 before they will be cost effective in a commercial setting.[50]

"Camouflaging" commercial aircraft, (i.e. reducing their optical and IR reflectivity and emissivity) would make it more difficult for terrorists to employ most shoulder-fired missiles. Suppressing or otherwise mitigating the engine's hot exhaust may be the most effective way to "camouflage" commercial aircraft. DOD and industry studies indicate that the IR signature of large aircraft engines can be

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[48] James Chow, James Chiesa, Paul Dreyer, Mel Eisman, Theodore W. Karasik, Joel Kvitky, Sherrill Lingel, David Ochmanek, and Chad Shirley. *Protecting Commercial Aviation Against the Shoulder-Fired Missile Threat.* Santa Monica, CA: RAND Corporation, 2005.

[49] MAWS are also employed on aircraft that use flares and IRCMs.

[50] Conversation between CRS and DHS representatives, February 6, 2004, DHS Headquarters, Washington, DC.

reduced by as much as 80% by shielding or ducting the engine exhaust, or mixing ambient air with hot jet exhaust.[51] These measures may adversely affect engine performance or aerodynamic drag. Also, integrating these measures into existing aircraft may cause problems with aircraft weight and balance. Regardless, DOD has conducted numerous studies on IR-signature reduction, and the exploration of this body of work may merit investigation for commercial applications.[52]

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*.[53] 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.

Infrared signature reduction techniques appear worth examining. However, it should be recognized that these measures cannot make aircraft completely invisible in the IR spectrum. An airplane's IR signature will always be much stronger than that of the surrounding sky. Thus, like many other options discussed in this report, IR signature reduction techniques may be able to reduce an aircraft's vulnerability to IR-guided weapons and mitigate the IR missile threat to some degree, but they cannot completely eliminate the threat. Regardless, some in Congress recognize that IR-signature reduction may be one tool to help mitigate IR-guided missiles. In their FY2006 report (H.Rept. 109-359) appropriations conferees added $1.3 million to the Navy's $42.6 million request for electronic warfare development. The purpose of this added funding was to pursue "infrared signature reduction to mitigate terrorist missile threats."(p.393).

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.[54] The survivability of passenger jets following missile strikes is largely unknown, although DOD's Joint Live Fire program and the Air Force have initiated a multi-year effort to test the vulnerability of large turbofan engines, such as those that power commercial aircraft,

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[51] *Fact Sheet on Large Aircraft IR Signature*, Department of the Air Force, Office of the Secretary Legislative Liaison. (SAF/LLW) for CRS, November 17, 2003.

[52] See, for example, Kellie Unsworth, "Next Generation IR Engine Suppression," *Aircraft Survivability*, Joint Aircraft Survivability Program Office, Department of Defense, Fall 2003. "Chopper Tests Stealth Exhaust," *Defense News*, June 28, 2004.

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

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

to shoulder-fired missiles.[55] 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.[56] 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.

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.[57] Consequently, most observers concur that evasive

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[55] Robert Wall, "Research Accelerates Into Hardening Aircraft Against Manpads Strikes," *Aviation Week & Space Technology,* August 23, 2004, p.59.

[56] Bill Sweetman, Op cit.

[57] 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

(continued...)

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.[58] 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.[59]

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 climb outs 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

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[57] (...continued)
[http://www.airbus.com/customer/fastspecial.asp]. (Also published in Boeing Aero No. 3).

[58] Marvin B. Shaffer, Op cit.

[59] Robert Wall & David A. Fulghum, Op cit.

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 climb out. 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-predicable 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.[60]

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

[60] Marvin B. Schaffer, Op cit.

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.

Terrorist acts are preceded by planning activities, much of which is observable. Because law enforcement officers can't be everywhere, public education and neighborhood watch programs in high risk areas may also be effective means to mitigate the threat. The Air Force has instituted a "neighborhood watch"- type program that might serve a model for broader application. Civilians and servicemembers are trained in the "Eagle Eye Program" to recognize elements of potential terrorist activity, and how to most effectively report their observations.[61]

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.

Detecting and eliminating a terrorist threat before an attack is initiated is the optimal solution. If terrorists are not detected prior to launch, rapid detection and accurate identification of a missile attack would be a critical step in an effective defense. In 2004 DOD evaluated ground-based warning systems composed of networked arrays of different kinds of sensors (e.g., electro-optical, radar). Such ground-based sensor grids could potentially warn and cue aircraft-based, or ground-based missile countermeasures.

Ground-based missile countermeasures could potentially take many forms. 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 directed energy weapons like the Army's tactical high-energy laser (THEL). The THEL has successfully intercepted rockets and artillery shells in tests.[62] 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. Industry is also exploring, and promoting, the potential deployment of

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[61] 2nd Lt. Ashley Conner. "Eagle Eyes in Action." *Air Force Print News.* September 14, 2005.

[62] Marc Selinger, "Laser to Target Large-Caliber Rockets for First Time, U.S. Army Says," *Aerospace Daily & Defense Report,* April 19, 2004.

microwave-based countermeasures. Ground-based antennas could emit a microwave pulse intended to defeat a terrorist missile by "jamming" or confusing its electronic systems. Again, costs, potential side-effects, and unintended consequences of all of these potential approaches would have to be assessed. The risk of interfering with, or actually shooting down a commercial aircraft, for example, may be of primary concern.

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.

Nonproliferation and Counterproliferation Efforts

Legal transfer of shoulder-fired SAMs is not governed by an international treaty. The Wassenaar Arrangement[63] is the only international agreement that addresses shoulder-fired missiles sales and provisions governing these sales were not adopted by its 33 members until December 2000. In December 2003, the Wassenaar Arrangement adopted strengthened guidelines over control of shoulder-fired SAM transfers.[64] Recent actions by the Administration may, however, renew emphasis on nonproliferation. According to press reports and a White House Fact Sheet[65] 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.[66]

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[63] The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use 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].

[64] See [http://www.wassenaar.org/2003Plenary/MANPADS_2003.htm] for recently-adopted MANPADS export controls.

[65] "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.

[66] "New APEC Initiatives on Counterterrorism."

Since September 11, 2001, the G-8 countries[67] have given increased emphasis to multilateral efforts to reduce the proliferation of and risk from MANPADS in terrorist hands. At the 2003 G-8 summit, member countries agreed to promote adoption of Wassenaar's strengthened MANPADS export guidelines by non-Wassenaar countries. The G-8 also implement the following steps to prevent terrorist acquisition of MANPADS:

- "To provide assistance and technical expertise for the collection, secure stockpile management and destruction of Manpads surplus to national security requirements;
- To adopt strict national export controls on Manpads and their essential components;
- To ensure strong national regulation of production, transfer and brokering;
- To ban transfers of Manpads to non-state end-users; Manpads should only be exported to foreign governments or to agents authorised by a government;
- To exchange information on uncooperative countries and entities;
- To examine the feasibility of development for new Manpads of specific technical performance or launch control features that preclude their unauthorized use;
- To encourage action in the International Civil Aviation Organization (ICAO) Aviation Security (AVSEC) Working Group on Manpads."[68]

At their 2004 Summit, G-8 countries agreed upon an action plan to implement and expand the scope of the 2003 recommendations.[69]

The International Civil Aviation Organization (ICAO), a United Nations Specialized Agency, has also increased efforts to limit the proliferation of MANPADS. ICAO has proposed that all 188 member countries adopt the Wassenaar Arrangement MANPADS export guidelines, and develop a "universal regime of control for MANPADS."[70]

The U.S. State Department has undertaken a number of bilateral and multilateral efforts to reduce the number of shoulder-fired SAMs that could conceivably fall into

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[67] The G-8 is composed of the major industrial democracies that meet annually to address the major economic and political issues facing their domestic societies and the international community. The six countries at the first summit in 1975 were Britain, France, Germany, Italy, Japan and the United States. Canada joined in 1976 and the European Union joined in 1977. Membership in the G7 was fixed and the USSR and then Russia participated in a post-summit dialogue with the G7 since 1991. Russia fully participated in the 1998 Summit, giving birth to the G8.[http://www.g7.utoronto.ca/what_is_g8.html].

[68] [http://www.g8.fr/evian/english/navigation/2003_g8_summit/summit_documents/enhance_transport_security_and_control_of_man-portable_air_defence_systems_-_manpads_-_a_g8_action_plan.html].

[69] [http://www.g8usa.gov/d_060904f.htm].

[70] [http://www.icao.int/ICAO/EN/atb/fal/fal12/AssadKotaite_en.pdf].

the hands of terrorists.[71] Through the Small Arms and Light Weapons Destruction Program[72] the State Department is working with countries or regions where there is a combination of excess shoulder-fired SAMs, poor control, and a risk of proliferation to terrorist groups or other undesirable groups to destroy excess stocks and develop security and accountability measures.

Promising agreements have been reported. On February 24, 2005, for example, the United States and Russia announced an agreement to facilitate efforts to destroy obsolete MANPADS and cooperate in reducing the potential for future proliferation.[73] The United States has also worked with its NATO partners to reduce MANPADS stockpiles. On February 18, 2005, the NATO Partnership for Peace Trust Fund Project was established to help the Ukraine destroy its stockpiles of excess munitions, including MANPADS. Other countries, such as Serbia, Bosnia-Herzegovina, Cambodia, Nicaragua, and Liberia have pledged to destroy excess MANPADS in their possession.

These formal and informal agreements have led to a reduction in MANPADS. As of September 20, 2005, the State Department reported a total of 17,000 excess or illicitly held MANPADS have been destroyed world-wide. When countries have balked at implementing their pledges, economic and diplomatic pressure have been brought to bear. The Bush Administration, for example, threatened to withhold military aid to Nicaragua until that country destroyed approximately 1,000 SA-7s[74]

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.[75] According to one press report, 317 shoulder-fired missiles had been turned over to U.S. military authorities in Iraq since May 1 2004, with the U.S. paying out over $100,000 in rewards for the missiles.[76] Other formal options could include infiltrating black market, organized crime or terrorist groups,

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[71] Information in this paragraph is from a U.S. State Department information paper titled "Department of State's MANPADS Threat Reduction Efforts," dated September 30, 2004, [http://www.state.gov/t/np/acw/c12759.htm].

[72] See [http://www.state.gov/t/pm/wra/] for program details.

[73] The "United States-Russia Arrangement on Cooperation in Enhancing Control of Man-Portable Air Defense systems" facilitates mutual destruction of obsolete or excess MANPADS, exchange information on controlling MANPADS including improving measures to enhance physical security, and to share information about MANPADS sales and transfers to third countries." State Dept. *Fact Sheet*. OpCit.

[74] Pablo Bachelet. "U.S. Withholds Aid Over Missing Weapons." *Miami Herald.* March 22, 2005.

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

[76] 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.

and seizing or destroying these missiles or setting up "sting" operations to arrest arms brokers and seize their missiles.

Shoulder-Fired Missile Design and Manufacture

It may be possible to incorporate specific characteristics in the design and manufacture of new shoulder-fired missiles that would make it more difficult for terrorists to use them. While these measures would have no effect on the shoulder-fired missiles that have already been manufactured and proliferated, they could be part of a long-term strategy for reducing the threat to commercial aviation.

Permissive Action Links (PALs) is one example of a technology that could be incorporated in future shoulder-fired missiles to "tamper-proof" them. PALs are essentially microchip-based cryptographical "trigger locks" that ensure that only authorized personnel can use a given weapon system. Congress has shown interest in exploring PALs for Stinger missiles (H.R. 3576, p.219), but a lack of implementation suggests resistance on the part of the Army. It may be that Army representatives fear that PALs could complicate legitimate use of a shoulder-fired missile. Incorporating PALs could potentially raise the cost of a weapon system. Thus, incorporating them on a multi-lateral basis may be required so U.S. manufactures are not put at an export disadvantage vis-a-vis foreign manufacturers.

Congressional Action on Shoulder-Fired Missiles

Many in Congress have expressed concern about the threat MANPADS could pose to civil aircraft. Specific concerns include protecting civilians and mitigating the potential financial burden for an already besieged airline industry. Legislation has been proposed, and congressional committees have received classified briefings on the subject in closed door hearings.[77] During the 108th Congress, 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.[78]

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 such missile protection systems for commercial aircraft. This program was subsequently funded in appropriations legislation and is progressing. The program is described in detail below in the section of this report addressing Administrative Plans and Programs.

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[77] Marc Selinger, "Lawmakers Push Anti-missile Systems for Commercial Aircraft," *Aerospace Daily*, January 21, 2003 and Walt, Op cit.

[78] S. 311 was read twice and referred to the Committee on Commerce, Science, and Transportation on February 5, 2003.On February 28, 2003 H.R. 580- was referred to the House Armed Services Committee Subcommittee on Total Force. Executive comment was requested from DoD, and unfavorable comment was received on May 14, 2003.

The National Intelligence Reform Act of 2004 (P.L. 108-458) directs the President to urgently pursue international treaties to limit the availability, transfer, and proliferation of Man-portable Air Defense Systems (MANPADSs), such as shoulder-fired missiles, worldwide. The act further directs the President to continue to pursue international arrangements for the destruction of excess, obsolete, and illicit MANPADS stockpiles worldwide. The act requires the President to report on diplomatic efforts to address MANPADS non-proliferation and requires the Secretary of State to provide the Congress with annual briefings on the status of these efforts. The act also requires the FAA to establish a process for expedited certification of airworthiness and safety for missile defense systems that can be mounted on commercial aircraft. The act also requires the DHS to provide a report within one year assessing the vulnerability of aircraft to MANPADS attacks and plans for securing airports and aircraft from this threat.

At least three other bills introduced during the 108th Congress addressed methods for mitigating the threat of shoulder-fired missiles to commercial aviation. H.R. 4056, H.R. 5121 Section 23, and H.R. 10 Section 4103 all called for the pursuit of further diplomatic and cooperative efforts (including bilateral and multilateral treaties) to limit availability, transfer, and proliferation of MANPADS. Additionally, they call for a continuation of current efforts to assure the destruction of excess, obsolete, and illicit stocks of MANPADS worldwide. These bills also called for the establishment of agreements with foreign countries requiring MANPADS export licenses and prohibiting re-export or retransfer of MANPADS and associated components to a third party, organization, or foreign government without written consent of the government that approved the original transfer.

Section 2241 of the State Department Authorization Bill (S. 2144) mirrored the provisions of the three bills described above. Section 2125 of the bill provided $10 million in the "Nonproliferation, Antiterrorism, Demining, and Related Programs" account for multilateral and bilateral efforts to reduce the threat of MANPADS. (P.L. 108-447.)

In FY2006, several committees considered legislation pertaining to counter-MANPADS programs. DoD requested $13.3 million in research and development funds for a "MANPADS Defense Program" (P.E. # 0604618D8Z). This is to investigate the development of a ground-based, electro-optical sensor grid that is hoped to provide launch detection and warning of shoulder-fired missiles. Key aspects of this program are to leverage commercially available technologies to lower cost, and to ensure that system is suitable for use in urban environments. Defense authorization conferees (H.Rept. 109-360, p. 600) matched the administration's funding request. Appropriations conferees (H. Rept. 109-359, p.444) provided $5.5 more than requested.

Administration Plans and Programs

In response to P.L. 108-11/H.Rept.108-76, DHS submitted a plan to Congress on May 22, 2003.[79] 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 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 FY2003 for administrative costs, $60 million in FY2004 for system development and initial testing, and an unspecified amount, not to exceed $60 million, in FY2005 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) fully funded the requested $60 million in FY2004 for this effort and an additional $61 million was appropriated in FY2005 (H.R. 4567/P.L 108-334). For FY2006, the requested amount of $110 million was fully appropriated for carrying the program into the next phase of more detailed system refinement, testing, and certification for deployment on a wide variety of commercial passenger jets. This effort is expected to conclude in FY2007.

The DHS established the system development program in a manner that would apply existing technologies from the military environment to the commercial airline environment rather than developing new technologies. In this manner, the DHS hopes to leverage military investment in counter-MANPADS technology in order to identify a technical solution that can be deployed in the civil aviation environment in a much faster time frame assuming that such a system can be tailored to meet the operational needs and requirements of civilian flight operations.

The DHS established a Counter-MANPADs Special Program Office (SPO) to manage the program which the DHS envisions will consist of three phases. Phase I, which was completed in July 2004, consisted 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. Three contractor teams led by Northrop-Grumman, BAE Systems, and United Airlines were awarded $2 million each to develop detailed systems descriptions and analysis of economic, manufacturing, maintenance, systems safety, and operational effectiveness issues for applying their systems in the commercial aircraft environment.

Following a DHS-led review of each contractor team's Phase I work and their proposals for Phase II, on August 25, 2004, DHS awarded $45 million to BAE Systems and Northrop Grumman to carry out Phase II of development.[80] Phase II

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[79] U.S. Department of Homeland Security, *Program Plan for the Development of an Antimissile Device for Commercial Aircraft,* Washington, DC.

[80] "BAE, Northrop Grumman Tapped for Counter MANPADS Development, Prototypes," *Defense Daily,* August 26, 2004.

consisted of an 18-month prototype development and evaluation based on existing technology. Both contractors received awards of about $45 million each for this effort which is currently wrapping up with the delivery of two complete countermeasure units per contractor. Both contractors developed systems that rely on laser-based directed IR countermeasures (i.e., DIRCM) to protect commercial aircraft from IR-guided MANPADS attacks. The United Airlines-led team which was not selected for Phase II, had instead proposed a system that would have used expendable flare decoys to divert incoming missiles.[81] According to DHS officials, two primary reasons why the United team was not selected was that there were safety issues on the flight line for the expendable pyrotechnic decoys and that there were issues with the system concerning false alarms.[82]

The BAE Systems team, which also includes American Airlines and Honeywell, and the Northrop Grumman team, which includes Federal Express and Northwest Airlines, have developed prototypes over an 18 month period that are being tested on commercial aircraft. The Northrop Grumann prototype system, called Guardian, and the BAE Systems prototype, dubbed JetEye, both underwent airborne testing on widebody airliners to determine their effectiveness. Final flight testing and completion of Phase II, originally targeted for January 2006, has been delayed until late February or early March 2006, although representatives from both companies stated that initial data indicate both systems have been able to meet test requirements specified by DHS.[83] Both firms, BAE Systems and Northrop Grumman, have also developed directed energy infrared countermeasures systems for the U.S. military. [84] Northrop Grumman is currently delivering its Large Aircraft IRCM system for installation on U.S. Air Force C-17 and C-130 transports while BAE is developing and delivering an IRCM system for U.S. Army aircraft.[85]

That next phase of the DHS counter-MANPADS program for commercial aircraft was funded in FY2006 appropriations and the intent of this additional funding is to gain further experience installing and testing the systems on a broader array of commercial aircraft types and improve the robustness of the systems under operational conditions encountered in the commercial aviation environment. The FY2006 DHS Appropriations Act (P.L. 109-90) provides $110 million to award contracts for Phase III of the civilian airline counter-MANPADS program. This phase will include delivery and installation of pre-production equipment on commercially operated aircraft by U.S. cargo carriers similar to those aircraft dedicated to meet the Civil Reserve Air Fleet (CRAF) requirement. To foster competition, the funds are planned to be used to maintain two contractors in Phase

[81] Ibid.

[82] Ibid.

[83] "Anti-missile Bids Set for Next Stage." *Flight International*, January 31, 2006.

[84] Calvin Biesecker, "Counter-MANPADS Challenge Is Making the Commercial Fit, Firms Say," *Defense Daily*, August 27, 2004, pp. 5-6.

[85] Ibid.

III.[86] During the Phase III effort, both companies will install test systems on a variety of aircraft types and obtain certification for use on additional aircraft types. The goals of Phase III include live-fire testing, improving system reliability to meet performance specifications for commercial airline applications, adding ground notification alerting capabilities, and developing security features to safeguard sensitive military technology in units installed on aircraft that travel internationally or are exported to foreign countries.[87]

A House proposal to designate $10 million of the FY2006 appropriation for the DHS counter-MANPADS program toward emerging alternative counter-MANPADS technology was not included in the final FY2006 appropriation. That proposal, contained in House report language, expressed concern that counter-MANPADS technologies currently being pursued under the DHS program "will not be sufficiently able to meet the challenges of commercial application at a cost that is economically feasible" and recommended that some funds be directed toward assessing other emerging technologies, principally ground-based countermeasures, that "may be simpler and more cost effective, but are far from fully developed."[88] While annual operating and support (O&S) costs — estimated by the RAND Corporation to be a little over $300,000 per airplane[89] — has raised significant concerns among both commercial airplane manufacturers and airlines over the use of aircraft-based counter-MANPADS systems, policymakers have not directed the DHS to formally examine alternative technologies, although the House did recommend doing so. However, as previously noted, FY2006 DoD appropriations included R&D funding for ground-based electro-optical sensor arrays to detect and warn of shoulder-fired missile attacks.

The FY2007 President's budget request includes $4.88 million for the Counter-MANPADS SPO to continue oversight and evaluation of the Phase III contracts expected to be awarded in FY2006 and carried out in the FY2006-FY2007 time frame. The FY2007 President's budget does not seek any additional funding for new DHS Counter-MANPADS initiatives beyond or in addition to the Phase III contracts.

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

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[86] *Budget-in-Brief Fiscal Year 2006.* Department of Homeland Security. Washington, DC. p.77

[87] "Anti-missile Bids Set for Next Stage." OpCit.

[88] H.Rept. 109-79, p. 116.

[89] James Chow, James Chiesa, Paul Dreyer, Mel Eisman, Theodore W. Karasik, Joel Kvitky, Sherrill Lingel, David Ochmanek, and Chad Shirley. *Protecting Commercial Aviation Against the Shoulder-Fired Missile Threat.*RAND.

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.

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) called 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 and DHS initially envisioned a two year program totaling about $100 million to develop, test, and certify a suitable system. Congress provided an additional $61 million to continue the program in FY2005 (P.L.108-280), and for FY2006, designated $110 million to conduct a more extensive third phase of the project that is anticipated to be carried out over the next two years. 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.