



**External Terrorist Threats to Civilian Airliners:  
A Summary Risk Analysis of MANPADS, Other  
Ballistic Weapons Risks, Future Threats, and Possible  
Countermeasures Policies**

**CREATE Report**

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**Terry O'Sullivan**  
USC Center for Homeland Security (CREATE)  
**University of Southern California**  
**3710 McClintock Ave., RTH 314**  
**Los Angeles, CA 90089-2902**

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## Executive Summary

The United States continues to struggle with analyzing terrorism risks, vulnerabilities, consequences and related public policy allocations comprehensively and comparatively. CREATE is developing a wide range of methodologies and tools for local, state and federal homeland security risk assessment and benefit-cost analysis. This report frames some of the potential costs and benefits for one slice of this potential terrorism threat to the airline industry – a large, critical economic sector – as well as micro-threats and countermeasures regarding specific airports, aircraft and associated people that might be terrorist targets.<sup>1</sup> These threats have been highlighted by a series of international ground-to-air missile attacks on airliners within the last 20 years – some civilian and some military, both within and outside of global conflict zones.

This assessment occurs in the context of a policy debate about responses to perceived growth in such threats, particularly since the U.S. Congress and the Department of Homeland Security have invested time and resources in exploring the protection of airliners from shoulder-fired “man-portable air defense systems” (MANPADS) missiles, tactically flexible, widely-proliferated weapons known to have been possessed (and used) by anti-Western terrorist groups such as al Qaeda.

This report and any other terrorism risk and response analyses must address the policy cost-benefit aspects of three main countermeasure areas, including those related to: 1) *proliferation, intelligence, and prevention*; 2) *vulnerability*; and 3) *survivability*. While there is some overlap between the latter two categories, vulnerability-reducing countermeasures should minimize successful attack in the event that weapons fall into terrorist hands. Survivability countermeasures are intended to minimize the loss to life and property in the event of successful deployment and a subsequent “hit” from a weapon. More than the first two, survivability presumes a certain measure of assumed risk of attack losses. This report preliminarily addresses the potential importance of assumed risk in maximizing countermeasure utility in the context of scarce dollars and adaptive terrorism threat systems.

Yet other external weapons systems, traditionally less widely discussed, are potentially significant, alternative threats to airports and airliners. Combat weapons, ranging from automatic assault weapons, high-caliber rifles and machine guns, to rocket-propelled anti-armor and anti-personnel weapons and mortars – and in the future, a variety of other emerging weapons technologies – might also damage or destroy aircraft *either* in the air or (along with infrastructure) on the ground (see figure 1, p.4). Any of these weapons might be used to damage public confidence in flying. In some instances, as with assault weapons such as the .50 caliber sniper rifle, these weapons may be cheaper and more easily available than traditional infrared-guided (IR) MANPADS, yet could still pose a significant risk to civil aviation even if the IR MANPADS threat were significantly reduced (or even eliminated) by related countermeasures efforts.

These alternative threats, which for now include *non-IR* MANPADS, might be used in tactically sophisticated ways, and possess high, increasing lethality potential, owing to advances in explosives and ordnance technology and to the unique vulnerabilities of civilian/commercial aircraft and airports.

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<sup>1</sup> As distinguished from broader comparative or macro-level, cross-sectoral risk and consequence analyses.

In addition, there are significant *economic* risks for the nation and the airline industry due to the elasticity of travel options and the flying public's own comparative risk analysis. Thus, while these weapons are capable of causing significant casualties (in the hundreds or thousands in a coordinated attack), their greater threat is the public terror, anxiety, and subsequent damage to a key industry and related sectors (e.g., tourism) that their deployment would engender. Accordingly, risk analyses of terrorism threats to the civilian airline industry must not only account for carefully weighed data and expert opinions, but also the public's analysis of risk and willingness to fly – whether or not such calculations are “rational.”

Lastly, policy response must consider not only significant potential threats to airborne planes, but on the ground to taxiing aircraft, airport terminals and other infrastructure. Both ground-based and close-proximity ground-to-air attack presents one or more alternative avenues to terrorism if other methods – such as the use of shoulder-fired infrared-guided missiles – are closed off or impeded.

This report is divided into three main parts. It first looks at the history of MANPADS and other external threats to civilian airliners. Part II then addresses the proliferation of and terrorist attack threat risk from portable surface-to-air missiles (MANPADS), surface-to-surface weapons (RPGs, assault weapons, mortars, and large caliber sniper or automatic weapons) and other advancing ballistic (high-yield thermobaric and other high-explosives) and non-ballistic (portable electromagnetic pulse- and high-intensity laser weapons) technologies. Part III analyzes broader civilian airline industry threats, susceptibility and vulnerability, and benefit-cost issues underlying preemption and response measures that might prevent or mitigate them. A sample of such countermeasures and strategies are discussed in brief.

Any significant policy response must be guided by comparative, integrated assessment of broader risks to both the airline transportation sector and society as a whole, across sectors, threat types and geography. Policy response should account for both likely and alternative targets, methods and consequences, collective incremental threats and vulnerabilities, and the possibility of dual- or multiple-benefit countermeasures that might span more than one specific possible threat. Therefore, it is critical to evaluate individual aviation threats – such as MANPADS – within the broader context of improving overall aviation safety and security.

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"Even older SAMs are deadly against civilian planes. They are big, fat, slow targets."<sup>2</sup>

"These heavy sniper rifles were originally intended as anti-materiel weapons for stand-off attack against high-value targets, such as...parked aircraft... It is their ability to shoot through all but the heaviest shielding material and their devastating effects, that make them valuable psychological weapons."<sup>3</sup>

"War is the realm of the unexpected."<sup>4</sup>

## Introduction

Among other concerns in the years since 2001 are fears of attacks of weapons capable of generating mass casualties or chaos (WMD). But a comprehensive, comparative analysis of risks, vulnerabilities, threats, consequences and related public policy allocations is still lacking.

Given the nature of the 9/11 murders and subsequent disruption of commercial aviation, a key industry in the American economy, overall aviation security has been another major focus. Policymakers have recognized a variety of growing risks to civilian aircraft and related critical infrastructure. These risks are functions of rising susceptibility (likelihood an aircraft and/or airport will be successfully hit, given increased proliferation and weapon system effectiveness) and vulnerability (more lethal weapons technology means reduced likelihood of surviving an attack). A series of international terrorist attacks on airliners – some civilian, some military, within and outside of global conflict zones – have further highlighted these issues.

In response to perceived growth in such threats, the U.S. Congress and the Department of Homeland Security have as of 2005 invested considerable resources in exploring the protection of airliners from shoulder-fired "man-portable air defense systems" (MANPADS), which are light, transportable surface-to-air anti-aircraft missiles (SAMs). Since the 1970s, these systems have been highly successful at downing military – and occasionally civilian – aircraft in combat zones. Beyond their proven effectiveness, MANPADS are viewed as tactically flexible and widely proliferated globally. At least some are known to be in the possession of anti-Western terrorist groups – and to have been used by al Qaeda on at least one occasion.

Less well known are potentially significant, alternative threats to the civilian airliner industry from other external weapons attacks. As discussed below, there are combat weapons, ranging from automatic assault weapons and high-caliber rifles and machine guns, to rocket-propelled anti-armor and -personnel weapons and mortars, to a variety of other emerging weapons technologies that could broaden the civilian airline threat spectrum and might be used successfully to damage or destroy aircraft in the air or on the ground.

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<sup>2</sup> Angelo Codevilla, former Senate Intelligence Committee senior staff member, quoted in *Los Angeles Times*, "A market in missiles for terror," *latimes.com*, March 6, 2003.

<sup>3</sup> U.S. Army's urban combat manual, quoted in "Sitting ducks: The threat to chemical and refinery industry from .50 caliber sniper rifles," Violence Policy Center website (2002).

<sup>4</sup> B.H. Liddell Hart, *Defense of the West* (1950), quoted in Ralph Kinney Bennett, "Think the Unthinkable," Tech Central Station, Aug. 14, 2003. Accessed at [www.techcentralstation.com/081403D.html](http://www.techcentralstation.com/081403D.html).

For U.S. domestic attack particularly, many of these weapons may be cheaper and more easily available than MANPADS, and *could*, hypothetically, pose almost as great a risk to civil aviation even if the MANPADS threat were significantly reduced (or even eliminated) by related countermeasures efforts. As discussed below, although MANPADS are clearly more militarily flexible and technologically advanced anti-aircraft weapons systems,<sup>5</sup> even far less sophisticated weapons might be used in *tactically* sophisticated ways as viable alternatives (or adjuncts). These “alternative” weapons possess high and increasing lethality potential, owing to advances in explosives and ordnance technology and to the unique vulnerabilities of civilian/commercial aircraft and airports. Although there are many valuable parallels and lessons to be learned from military combat defense against ground-based attackers, there are also significant uncertainties and unique vulnerabilities inherent in defense of civilian aircraft, airports, civilians on the ground, and the airline industry in general – and by extension, the airline-dependent economies which might be targeted.

This report frames the potential costs and benefits for one slice of a “mid-range” terrorism threat to the airline industry – a large, critical economic sector – as well as micro-threats and countermeasures to specific airports and aircraft that might be terrorist targets. It addresses some of the variables key to assessing these current and future external weapons attack risks and vulnerabilities of the American airline industry and the airline-dependent local, national and international economies. Although not the only external threats to civilian airliners, MANPADS may at the moment present the highest impact risk – that is, the greatest potential for loss of life and materiel – and might also pose the greatest risk for psychological repercussions among the flying public. However, given the ability of two individuals, a man and a boy, to generate terror with a gun and a simple, jury-rigged automobile in fall of 2002,<sup>6</sup> one must assume that a multitude of disruptive or even catastrophic scenarios are currently possible, especially given the inherent fragility of the airline industry.

Since one major component of terrorism is psychological, it also bears keeping in mind that the most significant *economic* risks for the airline industry are not just external weapons attacks with the greatest destructive or killing power, but those which most negatively capture the imagination of the public<sup>7</sup> – and thus discourage flying. For the moment, the threats discussed here are not from weapons of mass destruction, per se<sup>8</sup> – although few would quibble that close to 3,000 deaths on 9/11 did not represent massive loss of life. Nevertheless, for the most part these external weapons threats to airliners and airports are less capable of causing mass casualties than massive public terror and anxiety. Thus, risk analyses of terrorism threats to the civilian airline industry must not only account for carefully weighed data and expert opinion, but also the public’s analysis of risk as well – whether or not such calculations are “rational.” Flying is, after all, a voluntary activity with significant elasticity in choice. The collective desires

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<sup>5</sup> MANPADS use computer technology, and later generations possess advanced guidance systems, for instance - not true of a “dumb” gun or RPG round.

<sup>6</sup> The infamous 2002 Muhammad-Malvo “D.C. sniper” attacks that so terrorized the Capitol region for weeks.

<sup>7</sup> Death tolls and terror levels are often correlated, of course, but not proportionately causal. The “public” in this case is broadly construed to include the media (and others who might influence public opinion), government policymakers, business travelers, tourists and other would-be travelers.

<sup>8</sup> Although over time, predictable technological advances in non-nuclear explosives will begin to muddy this distinction.



and fears of aviation consumers have a dramatic effect on airlines and all related sectors – including the hotel, restaurant and tourism industries, which have become increasingly important to the U.S. and global economies.

Lastly, significant potential threats exist not only for aircraft in the air, but also those taxiing, at terminals, and to the airport terminals and infrastructure. As discussed here, ground-based vulnerabilities well beyond the needed screening of passengers complicate the allocation of scarce airline industry protection resources and present possible opportunities to terrorists who might have one or more other avenues of attack closed off or impeded. As illustrated in Figure 1, several of these weapons types may be employed *either* toward airborne *or* ground-based targets; thus, if not changing, then at least widening the collective calculus of countermeasures and protection beyond the most obvious, narrower threats from shoulder-fired man-portable missiles.

Not addressed in this report are either attacks within airport perimeters (that evade or occur before security checkpoints, such as car- or suicide bombers, gunmen, etc.); or what might be called “internal” or onboard threats (from hijacking, smuggled bombs, aircraft- or air traffic control system sabotage, biological or chemical weapons dispersed onboard or in airports, or other in-flight risks that rely for prevention on Transportation Security Administration security screening of passengers, baggage, airport personnel or intruders, etc.). It is also beyond the scope of this report to analyze thoroughly the economics of countermeasures, though some effort is made to frame the issues as broad comparative risks and analyze some of the costs, benefits, trade-offs, etc.<sup>9</sup>

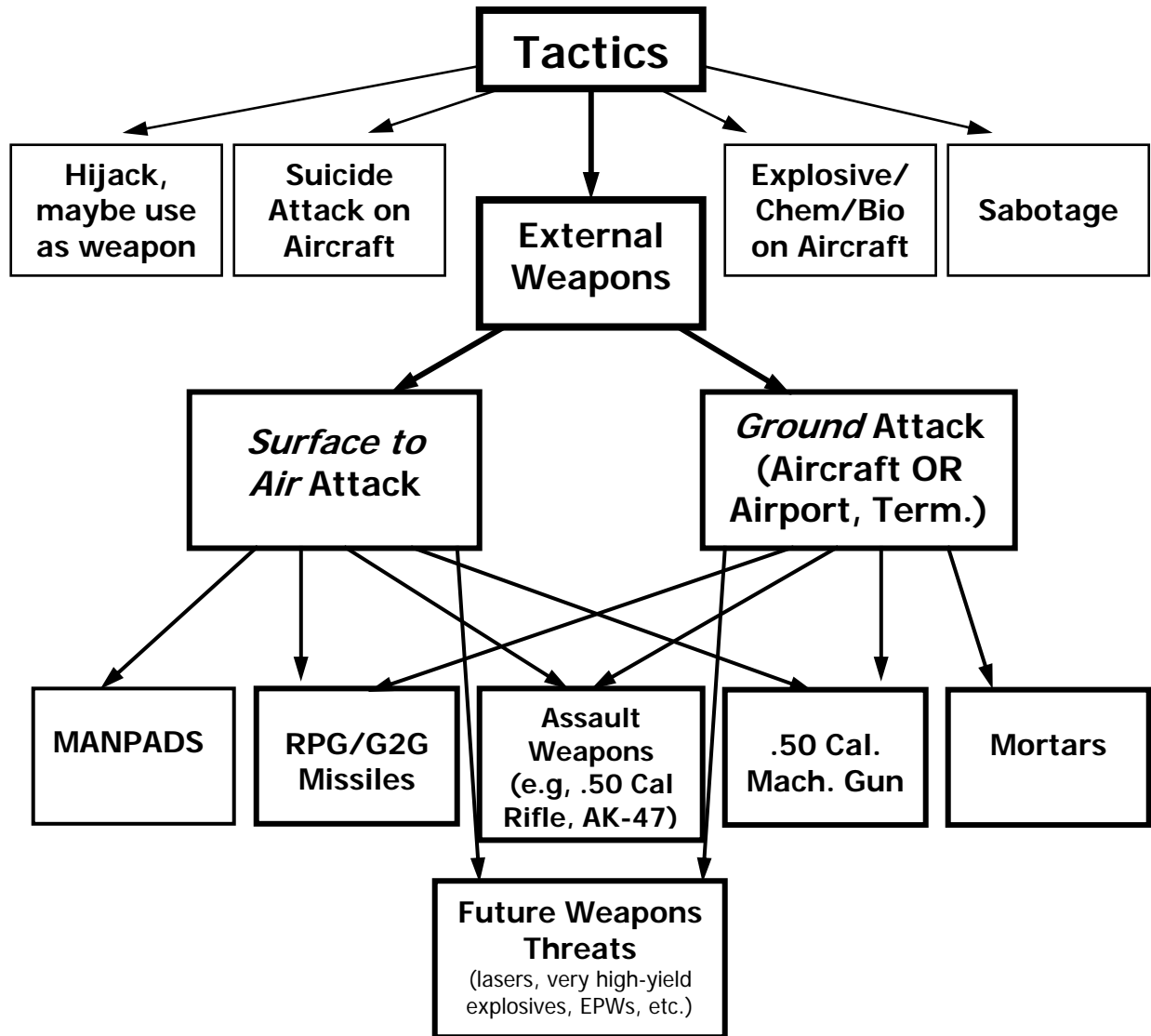
This report is divided into three main parts. The first looks at the history of MANPADS and other external threats to civilian airliners. Part II addresses the proliferation of and terrorist attack threat risk from portable surface-to-air missiles (MANPADS), surface-to-surface weapons (RPGs, assault weapons, mortars, and large caliber sniper or automatic weapons) and other advancing ballistic high-yield explosives (including thermobaric, fuel-air, high energy-density materials and others) and non-ballistic weapons (including portable electromagnetic pulse- and high-intensity laser weapons) technologies. Part III analyzes civilian airline industry threats, susceptibility and vulnerability, and benefit-cost issues underlying preemption and response measures that might prevent or mitigate them, including a brief description of current efforts by the Department of Homeland Security (DHS) to develop low-cost, reliable and effective counter-MANPADS systems for deployment on large civilian aircraft, as well as other onboard or ground-based countermeasures.

Among the countermeasures that will be considered in Part III are various electronic technologies, on the aircraft and on the ground, to detect, preempt or jam incoming missiles. Also being weighed are a multitude of non-electronic measures involving non-proliferation and anti-smuggling, airport perimeter security, pilot evasion or crash-landing emergency training, aircraft “hardening” and critical systems redesign or retrofitting, anti-IR paint and gels, flight path adjustments, extra-perimeter security improvements, coordination and cooperation among key security or response agencies, and a host of other possible ways to avoid vulnerability (a weapons hit) or improve survivability after or during an attack.

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<sup>9</sup> None of this report’s analysis is based on access to classified data or reports, and is all from open sources.

**Figure 1: Terrorist Options, External Weapons Attacks on Commercial Aviation.**



This report concludes with a brief discussion of some issues and scenarios arising from these specific threats in the broader context of overall homeland security. While difficult to gauge precisely, the risk to civil aviation from MANPADS and other external weapons attacks is clearly rising and is among the many potential significant terrorism threats on the horizon. But policy responses must not occur in a vacuum and should account for comparative risk and benefit-cost analyses across the spectrum of possible terrorist risks for society.

## I. The History of MANPADS & Other External Terrorist Threats to Civilian Airlines

In October 2003 Secretary of State Colin Powell told the Asia-Pacific Economic Cooperation (APEC) Forum that “no threat is more serious to aviation than man-portable air defense systems.”<sup>10</sup> Yet given the number of compact, shoulder-fired missiles potentially available to would-be terrorists, there have been surprisingly few external terrorist attacks on civilian airlines. Notably, there have been no confirmed MANPADS attacks on U.S. soil.

The majority of catastrophic airliner attacks have been due to hijacking (e.g., 9/11), on-board bombings (e.g., 1988 Pan Am 103 bombing over Lockerbie), accidental missile fire (e.g., 1988 Stark attack on an Iranian Air A-300), and/or occurred in theaters of low-level conflict or war (e.g., numerous incidents during the Angolan civil war).<sup>11</sup> Nevertheless, there have been dozens of incidents in which civilian aircraft were attacked – often successfully, sometimes not – with shoulder-fired MAN-portable Air Defense Systems (MANPADS).

According to the FBI, at least 29 civilian planes have been hit by MANPADS, with up to 550 deaths.<sup>12</sup> Alternatively, the RAND Corporation believes there have been up to 760 deaths in 40 civilian aircraft (fixed wing and rotor) downed by shoulder-fired SAMs between 1975 and 1992.<sup>13</sup> Estimates of MANPADS-specific deaths from civilian aircraft attacks range roughly from 500 to 1000. Most stem from attacks on smaller aircraft, but in at least five instances large civilian jet aircraft were targeted. In two of the five, the attacks led to catastrophic crashes with no survivors.<sup>14</sup> Broader estimates including all methods of attack (not just MANPADS) show that, since 1980, at least 33 civilian and/or commercial aircraft were attacked, resulting in over 1800 civilian deaths. (See Figure 4, Civilian Airline Fatalities, below.)<sup>15</sup> One possible point of confusion is that some reported MANPADS attacks may have been perpetrated by attackers wielding rocket-propelled grenades (RPGs), and not SAMs. *Jane’s Intelligence Review* asserts that some governments have reported MANPADS attacks that on aircraft below 1,000 ft. were probably RPGs, just like the weapons that downed the American MH-60 Black Hawk helicopters in Somalia in 1994.<sup>16</sup>

Figure 2 (Global Aviation Disasters, 1978-2003, Intentional), further compares the death toll from deliberate civilian aircraft attacks, broken down by those shot down by external weapons attacks, blown up with onboard explosives, or hijacked.<sup>17</sup> In addition, Table 1

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<sup>10</sup> Dirk Beveridge, “APEC Nations Agree to Limit Sales,” Associated Press (18 October 2003).

<sup>11</sup> See chart, Civilian Airline Fatalities from Aircraft Shoot-downs, All Types, below

<sup>12</sup> Thom Shanker. “Ideal Terror Weapons: Portable Deadly, Plentiful Missiles.” *New York Times*. November 29, 2002.

<sup>13</sup> Marvin B. Shaffer. *Concerns about Terrorists with Manportable SAMs*. RAND. Santa Monica, CA. October 1993. p.3.

<sup>14</sup> “Mitigating the threat from MANPADS,” Threat Resolution, Limited, January 2004.

<sup>15</sup> USC Homeland Security Center for Risk and Economic Analysis of Terrorism Events (CREATE) database (2004).

<sup>16</sup> Reported in Mark Phelps, “Do SAMs pose a real threat to civil aviation?” *Aviation International News*, January, 2003.

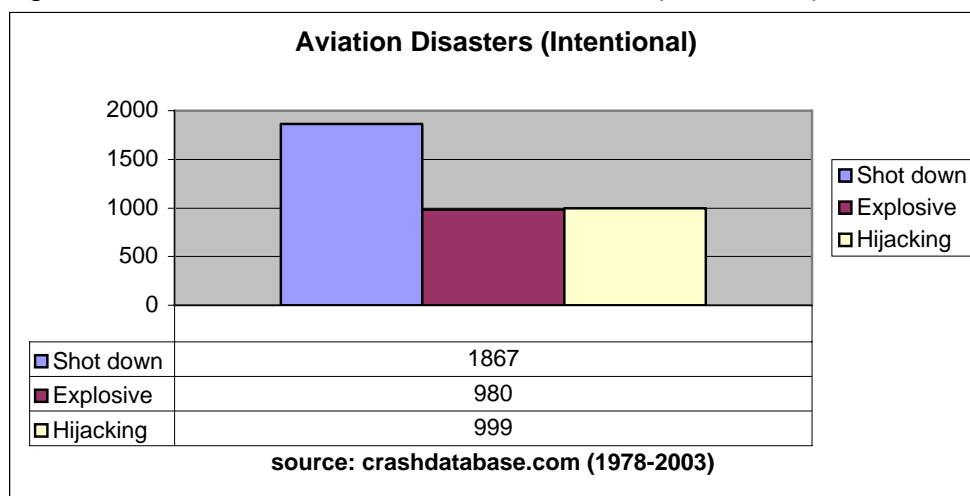
<sup>17</sup> All data from CrashDatabase.com Airline Accident database ([www.crashdatabase.com](http://www.crashdatabase.com)).

below lists examples of Civilian Airline Shoot-Down Fatalities from the 1970s to 2001, which are included among the broader statistics of those caused by non-state and nation-state military forces (the latter comprises approximately 901 of 1867 total deaths).<sup>18</sup> None of the confirmed MANPADS-related crashes or fatalities have occurred within the United States borders.<sup>19</sup>

### A. Nation-States Making, Possessing (and Sometimes Passing on) MANPADS

Although estimating the proliferation of MANPADS is always difficult, from 500 to 750 thousand are believed to have been produced thus far, and it is possible that up to 27 militia groups and terrorist organizations possess shoulder-fired SAMs.<sup>20</sup>

Figure 2: Global Aviation Disaster Casualties (Intentional), 1978-2003



It is believed that at least 15 nations currently manufacture MANPADS, including Pakistan, Egypt, China and Russia, among others – all possible direct sources for terrorists. Yet the potential for secondary or tertiary supply to states or non-state groups is also great: over 100 countries actually possess these systems, and could easily act as trans-shipment conduits for supply to various interested parties.

For example, one unconfirmed news report suggests that Syria, which already possesses SA-14 and SA-16 SAMs, may have acquired advanced “third generation” infrared-guided SA-18 MANPADS from Belarus. “The sources said Damascus received the systems in three separate deliveries in a deal estimated at more than \$100 million.”<sup>21</sup> Iraq also has become a major source of MANPADS potentially available for terrorism. As of summer 2003, 4000-5000 MANPADS reportedly stockpiled by Saddam Hussein’s regime were still unaccounted for, despite aggressive American military intelligence and interdiction efforts.<sup>22</sup> Many of the systems uncovered in hidden weapons caches have been advanced second and third generation weapons. At a

<sup>18</sup> USC Center for Risk and Economic Analysis of Terrorism Events (CREATE) database (2004).

<sup>19</sup> Despite whatever controversy may remain about the crash of Flight 800 off of Long Island.

<sup>20</sup> Thomas B Hunter, “The proliferation of MANPADS,” *Jane’s Intelligence Review*, November 28, 2002. www.janes.com.

<sup>21</sup> “Syria obtains SA-18 missiles,” *Middle East Newslines*, November 12, 2003. Accessed www.menewslines.com

<sup>22</sup> “Shoulder-fired missiles not too hard to find,” *Associated Press*, August 17, 2003.

minimum, al Qaeda and Hezbollah are both believed to possess first-generation infrared/heat-seeking SA-7bs and second-generation infrared Stinger missiles, according to *Jane's*. (See Table 4, below.)<sup>23</sup>

## B. Smuggling of MANPADS

Smuggling is another likely avenue for proliferation of terrorist-accessible SAMs. Even before 9/11, there was a robust black market for MANPADS. They appear to have been offered for sale for as little as \$500 for old first generation SA-7s and as much as \$125,000 for advanced SA-18 Iгла systems. As with all weapons available legally and illegally on the global black market, price is gauged by what the market will bear. Deployment of civilian MANPADS electronic countermeasures and counter-terrorism “sting” efforts might drive up the costs for leading edge systems such as the Russian SA-18,<sup>24</sup> but it will not eliminate the market.

**Table 1: Civilian Aircraft Shoot-Down Incidents, Fatalities (Examples)<sup>25</sup>**

Date	Airline	Location	Aircraft	Deaths	Details
02/12/79	Air Rhodesia	Kariba	Viscount	48	Shot on takeoff by SA-7
02/09/84	Angolan Airlines	Angola	Boeing 737	130	Shot on takeoff by unknown weapon
09/22/93	Trans Georgia	Sukhumi Georgia	Tu- 154	106	Shot on takeoff by unknown weapon
10/10/98	Congo Air	Kindu, Congo	Boeing 727	41	Shot on takeoff by SA-7
11/19/02	Israel Arkia Airlines	Mombasa, Kenya	Boeing 767	0	2 SA-7's fired on takeoff: both missed.

Among publicly-known smuggling attempts involving MANPADS missiles and the United States, three incidents are notable. In 1997, American federal authorities arrested in Florida members of a Russian smuggling group attempting to ship a load of MANPADS from Bulgaria into the United States. In 2003, three men, including a British national arms dealer, Hemant Lakhani, were arrested in a joint U.S.-Russian operation for plotting to smuggle up to 50 SA-18s into the United States. According to the FBI, the men knew it was "specifically for the purpose of shooting an American commercial airliner out of the sky."<sup>26</sup> And in August 2004, two leaders of an Albany, New York mosque were arrested in an FBI sting on charges of plotting to purchase a shoulder-fired missile that allegedly would have been used to assassinate the Pakistani ambassador in New York.

Since the 1970s, hundreds of thousands of Soviet MANPADS have been sold to dozens of nations. In addition, the United States has notably supplied an estimated 900-1000 Stinger A MANPADS to Afghan rebel mujahideen fighting Soviet occupation during the 1980s and trained the rebels in their use. Hundreds of these missiles remain unaccounted for, despite an aggressive American “buy-back” effort launched after the post-9/11 U.S. invasion of Afghanistan. These Afghan-originated Stingers are often

<sup>23</sup> Thomas B. Hunter, “Proliferation of MANPADs,” *Jane's Intelligence Review*, Nov 28, 2002.

<sup>24</sup> Especially its most recent 2002 iteration, the Iгла-S (for “super”), which is night firing-capable and purported to be highly resistant to countermeasures.

<sup>25</sup> See chart, Civilian Airline Fatalities from Aircraft Shoot-downs, All Types (below).

<sup>26</sup> Quoted in “Feds: Deal involved 50 missiles,” CBS news, [www.cbsnews.com](http://www.cbsnews.com), August 13, 2003.

discounted as a major threat because of assumptions about the limited “shelf life” of such weapons – believed to be no more than 25 years with careful storage. But one school of thought opines that such estimates of American or Russian-made MANPADS wrongly discounts the relative ease with which such shelf-life might be extended.<sup>27</sup>

A variety of opinions exist about the type and number of MANPADS made in the former Soviet Union that might be available on the global black market. There have been reports of rebellious Republic of Georgia soldiers who, during the 1998 uprising, seized SAM missiles from a weapons depot. Similarly, Chechen rebels have looted at least one Russian armory of MANPADS and used them with some success against Russian Army helicopters. One security analyst asserts, “There are credible reports that, after the fall of the Soviet Union, Russian soldiers simply walked into their armories and took whatever they wanted off the shelves to sell.”<sup>28</sup> Whether that is true or not, clearly there have been tens of thousands of Soviet MANPADS “legally” sold to dozens of nations, and some of these nations have either deliberately passed them on to secondary recipients, or lost them to theft and pilferage.

### C. Increase in Lethality and Growing Death Toll

Early versions of MANPADS, which are a subset of the generic Surface to Air Missiles (SAMs) category of military air defense weapons, first came into being in the 1960s with production of the Soviet SA-7a and -7b and the American Redeye infrared seeker-based MANPADS. Subsequent generations of IR – and later, command-line-of-sight (CLOS) and laser beam-rider – MANPADS increased range, accuracy, lethality, reliability and ease of use, steadily increasing the threat to military and all aircraft (see Table 5, Comparison of MANPADS/SAMs Capabilities for specific examples).

**Table 2: Sample MANPADS Potentially Available to Terrorists**

<u>Missile &amp; Manufacturer</u>	<u>Guidance System</u>
■ SA-7b (Strela-2: Soviet)	Passive Infrared (IR)
■ SA-16 (Igla-1: Soviet)	IR
■ SA-18 (Igla: Soviet)	IR
■ Stinger A (U.S.)	IR
■ RBS-70 & -90 (Sweden, Pakistan)	Laser Beam Rider, operator-controlled (pedestal-fired)

Of 360 confirmed mujahideen Stinger missile attacks in Afghanistan, it is believed that they brought down at least 240 Soviet aircraft. In the early 1990s, during Operation Desert Storm, 80% of American fixed-wing military aircraft losses were due to infrared-guided SAMs.<sup>29</sup>

<sup>27</sup> Although deterioration of actual missile propellant might cause irreparable deployment problems, generally the most cited issue is deterioration of batteries and coolant units for launchers. Both of the latter issues could be addressed with cheap replacement parts – and especially in the case of batteries it is plausible these might be successfully jury-rigged with an alternative power source.

<sup>28</sup> Chris Hellman, spokesman for the Washington, D.C.-based Center for Defense Information, quoted in Mark Phelps, “Do SAMs pose a real threat to civil aviation?” *Aviation International News*, January, 2003.

<sup>29</sup> Richard Ehrlich, “For sale in Afghanistan, U.S.-supplied Stingers,” *The Washington Times* (22 May 1992).

The vulnerability to missile hits of large commercial aircraft will be further discussed below. The size, slow movement and lack of maneuverability make them easier targets – even as the large target size presented by a wide-body commercial jet may also, ironically, allow for survivability scenarios which confound assumptions based on military aircraft vulnerability.

#### **D. Growing Fears of Civilian MANPADS Attacks**

A combination of factors, including rising weapons system and training proliferation, data on terrorists' intent to use MANPADS gleaned from intelligence, and actual attacks have highlighted the rising external threats to civilian airliners. By the end of 2004, numerous specific incidents had raised awareness of the MANPADS risks, including an unsuccessful 2002 attack on an Arkia Airlines passenger jet in Mombasa, Kenya, and the 2003 attack of a DHL cargo jet at the Baghdad airport, among others.

The aforementioned Arkia Airlines attack is one the most notorious incidents involving civilian aircraft. On November 28, 2002, al Qaeda terrorists fired at least two SA-7b MANPADS missiles at an Israeli Arkia Airlines tourist jet as it took off from Kenya's Mombasa airport. In a coordinated attack, a suicide vehicle bomb simultaneously struck a local hotel that catered to Israeli tourists.

A year later, in November 2003, a German DHL Airbus cargo jet made an emergency landing just after takeoff from the Baghdad, Iraq International Airport after being fired upon by a MANPADS. The weapon was believed to be an SA-14 (Russian Strela-3), a "second-generation" heat-seeking IR missile. Coincidentally, the DHL pilot had only a few days earlier seen a video addressing unconventional landing in such emergencies, and his new "skills" were clearly put to the test by the missile damage. The missile penetrated the left wing fuel tank of the jet and at least partially disrupted functioning of the corresponding engine and flaps. More important was the fact that the wing nearly burned off before the pilot, using single engine power and limited steering capability, was able to successfully crash-land, ending in a sandy field adjacent to the airport runway. Had this event occurred at a crowded airport in an urban residential area, the margin for error would have been considerably less.

The dangers from MANPADS in Iraq have been shown in a multitude of cases. In November 2003, an Illinois National Guard Chinook helicopter – which apparently did possess a basic anti-missile system – was shot down in Iraq using a shoulder-mounted MANPADS missile. The attack killed 16 soldiers, including the pilot. In December 2003, another MANPADS missile hit an Air Force C-17 troop transport plane, forcing it to land at Baghdad Airport. And on September 15, 2004, a U.S. Air Force C-5 transport jet with 63 passengers and crew was struck by an indeterminate SAM in its number four engine as it also took off from Baghdad Airport; it safely landed as well.<sup>30</sup>

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<sup>30</sup> "Cargo plane hit by missile," *Agence France Presse*, Sept. 15, 2004, accessed at news.com.au.

**Table 3:**

<b>GROUP</b>	<b>LOCATION</b>	<b>MISSILE TYPE</b>
Armed Islamic Group	Algeria	Stinger
Harkat-ul-Ansar	Kashmir	SA-7
Hizbullah	Lebanon	SA-7, Stinger
Jamaat-e-Islami	Afghanistan	SA-7
Jumbish-i-Milli	Afghanistan	SA-7
Al Qaeda	?	SA-7, Stinger

**Non-State Terrorist Groups Believed to Have Possessed MANPADS at One Time**

Source: Thomas B. Hunter, "Proliferation of

MANPADs," *Jane's Intelligence Review*, Nov 28, 2002

### **E. Global Non-Proliferation Efforts Are Slow, But Moving in the Right Direction**

Despite the growing interest in external risks to commercial air traffic from terrorism, the progress at the international level has been disappointing and slow. Treaty law addressing MANPADS threats was virtually non-existent until recently and is still comparatively weak. This global equivalent of "gun control" still does little to discourage legal and illegal exchanges of these systems. Currently, most counter-proliferation progress is in the area of MANPADS "buy-back" and anti-smuggling sting operations (see History above). Nevertheless, awareness and concern is rising, and some effort to control shoulder-fired SAMs has begun.

Probably the most important venue for the control of MANPADS proliferation has been the Wassenaar Arrangement's (WA) 22 Elements for Export Controls of MANPADS, and the Elements for Export Controls of MANPADS adoption. Caffera notes:

The WA's 33 participating states agreed to a set of criteria for evaluating potential MANPADS exports. The agreement discourages MANPADS transfers to end-users other than states, and to governments that are unwilling or unable to protect against theft, loss, misuse, or diversion of the MANPADS themselves or related technical information. It also identifies several safeguards that importing governments should implement, including storing the firing mechanism and the missile in separate locations, taking monthly inventories of imported MANPADs, and re-exporting imported systems only after receiving prior consent from the exporting government.

In June 2003, the Group of 8 (G8) major industrialized democracies meeting in Evian, France, supported strengthened efforts to control MANPADS proliferation through additions to the Wassenaar Arrangement. The G8 added provisions for MANPADS export controls and, among other aspects, agreed to:

- 1) Do a feasibility analysis on installing launch control mechanism and other design features that might prevent unauthorized use of MANPADS;
- 2) Collect and exchange data on "uncooperative countries and entities";
- 3) Assist all nations in locating, interdicting and destroying black market or other unauthorized stockpiles; and
- 4) Make the process continuous, reporting on implementation at the 2004 G8 meeting.<sup>31</sup>

The Organization for Security and Co-operation in Europe (OSCE) Forum for Security

<sup>31</sup> "Mitigating the threat from MANPADS," Threat Resolution, Limited, January 2004.



Co-operation, Decision No. 7/03 noted “Man-portable Air Defense Systems” report on July 2003 pushed states to “propose projects for tackling MANPADS-related problems” by improving stockpile security and boarder controls. The OSCE committed to systematic data collection on MANPADS sales and distribution, which they pledged to gather from member states by their June 2003 information exchange on small arms. The deadline was 10 October 2003, but there had been some question about follow up implementation.

In October 2003 at the Asia-Pacific Economic Cooperation (APEC) Summit in Bangkok, a Declaration on Partnership for the Future document was drafted at the Leaders Meeting in which APEC’s 21 member states agreed to enhanced controls on MANPADS production, exports, and stockpile security. Inspired in part by the similar G8 agreement, the Declaration most notably calls to ban MANPADS transfers to sub-national groups, to exchange information regarding member nations’ implementation and to examine the feasibility control enabling (unauthorized launch prevention) devices.

## **II. Risks to External Civilian Airline from MANPADS or Other Weapons Attacks: Proliferation, System Capabilities and Aircraft Susceptibility**

Changes in three major variables, two of which relate to proliferation and all of which to technology, are particularly responsible for what is a clear, present and growing external threat to civilian airline passengers – and by extension to the economics of this critical American service industry. First, weapons such as MANPADS missiles, rocket propelled grenades or .50 caliber sniper rifles that might bring down or destroy on the ground a passenger jet are increasingly available to terrorists through legal sales, theft, sales on the global black market, or through sympathetic intermediary nations who can legally purchase or manufacture them. Because of this, the susceptibility (likelihood of being hit) of civilian aircraft is increasing. Second, the technology and expertise needed to train a potential assailant in proper use of such devices are also increasingly available via similar avenues. So there is increasing likelihood of competent use of certain weapons – particularly those which may not be addressed by current counter-MANPADS R&D – with increasing proliferation of more technologically advanced training equipment and methods, as well as trained users who might be available for the right price or cause.<sup>32</sup>

Third, there are continuing advances in technology for improved lethality, accuracy, firing rate, “counter-countermeasures,” and other variables that increase the likelihood that terrorist attacks from MANPADS and other weapons systems might succeed in both hitting and destroying the intended target. Accordingly, the incidence of injury and loss of life proportionately increases. Thus, beyond sheer numbers of weapons systems available, there is growing risk from second, third and even fourth generation missiles, rockets and other ballistic weapons being sold at arms bazaars or illegal black markets, or manufactured by greater numbers of countries.

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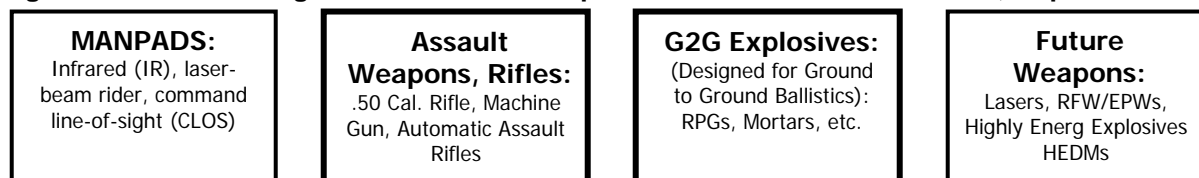
<sup>32</sup> This will be addressed below, but includes not only the number of potential experienced operators capable of training a terrorist in use of such devices, but also increasingly sophisticated, realistic computer simulation systems that approximate actual firing.

In other words, the threshold for deployment and effective use of increasingly sophisticated versions of such weapons for terrorism is falling steadily.

Although there are numerous other potential high-tech military weapons systems on the horizon that may threaten civilian aircraft,<sup>33</sup> there are three main immediate, generic threats currently existing: (1) MANPADS; (2) RPGs, mortars and related ground-to-ground-designed explosive, ballistic/projectile weapons; and (3) “smaller” arms fire, ranging from standard high-velocity automatic assault weapons to higher caliber military sniper rifles with incendiary and/or armor-piercing rounds, and heavy machine guns.

Overlying many of these ballistic weapons threats is the reality of what in some instances are geometrically expanding explosives-yield technologies, which may renew and improve existing or even comparatively obsolete delivery systems. In a fourth “future threats” category are additional high-technology, non-ballistic weapons currently existing or under development by various military establishments, which may at some future time become man-portable and available to terrorists. I will briefly address those as well. All three current, generic ground-based aircraft threat categories are dangerous in varying degrees because of the high portability, ease of concealment, and potential range, accuracy and overall lethality the weapons afford. Once again, these risks increase as technology improves and proliferation worsens.

**Figure 3: General Categories of External Weapons Threats to Civilian Airliners, Airports**



### **A. Rocket Propelled Grenade (RPG), Anti-Tank and Similar Missiles**

Much has been written about the simple, deadly effectiveness of the cheap, portable “first generation” rocket-propelled grenade weapon, such as the Soviet/Russian-made RPG-7. Such weapons have been the bane of modern fighting forces because of their proliferation: over 40 nations possess them, and manufacturers include Bulgaria, China, Iran, Iraq, Romania and Pakistan. In addition to sheer numbers – as of 2002, it is estimated that at least 9 million RPG-7s had been produced from all sources – these weapons are attractive for armies as well as guerrilla fighters because of their portability, ease and reliability of use (equivalent to the long track record of the Russian AK-47 assault rifle). In addition, when properly deployed, these weapons can destroy anything from lightly armored vehicles, such as humvees, to heavily armored battle tanks and armored personnel carriers.<sup>34</sup>

Domestic U.S. availability is unknown, but based on the wide availability of first generation RPG-7s around the world and the ease with which such rockets can be

<sup>33</sup> Including offensive precision high-energy laser weapons modeled after those currently under development by the United States for counter-missile defense.

<sup>34</sup> See Globalsecurity.org; and “The RPG-7 On the Battlefields of Today and Tomorrow,” by Lester W. Grau, *Infantry* (May-August 1998).

cheaply purchased and concealed, it must be assumed that it would not be any more difficult to smuggle such weapons into the United States than it would a MANPADS. There is little question that at some U.S. airports, it is still possible to use roads, parking lots, bicycle paths or even residential areas under and adjacent to takeoff and landing routes to get within a few hundred yards of taxiing or airborne passenger jets.

First introduced in 1962, the entire RPG-7 assembly (launcher and grenade) is cheap, small,<sup>35</sup> and man-portable, weighing +/- 40 pounds. The standard model's projectile reaches around 140 meters/sec, has an average effective range of 300-500 meters (up to 900+ meters against fixed area targets), and can penetrate 330-500mm of armor (more for recent iterations) and over a meter of reinforced concrete. An operator can fire up to 6 rounds per minute, which could result in multiple hits against a building or slow-moving vehicle – presumably including large aircraft on the ground. With skilled operation, RPGs also may be used for standard direct horizontal fire, as ground-to-ground mortars, and ground-to-air missiles.<sup>36</sup> In addition, as with small arms fire (see below) at close range and with competent operation, low-tech RPG missiles could plausibly damage or destroy an aircraft on the ground, or airport terminals.

Although the MANPADS threat extends far beyond the boundaries of most airports, an RPG threat is particularly sensitive to airport perimeter and surveillance security measures, given the smaller (though still significant at 500-900 meters) effective range and accuracy of these rockets. Presumably, terrorists might get close enough to a perimeter fence to launch an RPG at a taxiing jet on the runway. Such a ground attack with multiple RPG warheads might be capable of destroying an airliner fully loaded with fuel on the runway or just after take-off. In addition, RPGs may soon achieve exponential increases in destructive power. Aside from current fragmentation rounds, also under manufacture in Russia and elsewhere are *incendiary* RPG rounds (including the Romanian PGI 70mm warhead, with maximum velocity of 350m/sec.)<sup>37</sup>, which would be particularly effective against fuel-laden aircraft. Even more destructive are the handheld RPGs with “highly energetic explosive” thermobaric warheads, which are far more powerful than standard RPGs and which are now manufactured and marketed by Russia, Bulgaria, Poland, and soon possibly China.<sup>38</sup> And dwarfing all of these in terms of potential destruction are high-energy-density materials (HEDMs), which U.S. and Russian researchers expect to perfect in 10-15 years, and which possess per unit volume explosive power “somewhere between conventional explosives and [nuclear] fissile material – without the accompanying radiation and fission products.”<sup>39</sup>

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<sup>35</sup> Roughly 3-4 feet in length, although certain models may be disassembled for transport into half that length.

<sup>36</sup> Although not originally designed for such purposes, the RPG-7 has been used to significant effect against low-flying aircraft. Among the most infamous examples of such weapons being used against fixed-wing or rotor aircraft include the 1994 American “Blackhawk down” incident in Mogadishu, Somalia, and although we know of no confirmed instances in which RPGs have downed in-flight civilian aircraft, *Jane's* analysts believe many RPG-related incidents are often reported falsely as MANPADS-caused aircraft crashes. There are other instances since the 2003 American invasion of Iraq in which RPGs were believed to have downed American or Coalition helicopters, though no instances of fixed-wing aircraft attacks are publicly known.

<sup>37</sup> “RPG-7 Knut...,” *Jane's*, *ibid.*

<sup>38</sup> For instance, Russia's TBG-7V thermobaric round, introduced in 1997 and subsequently used in Chechnya, is claimed by its Russian manufacturer to be equivalent in explosive power to a 120mm artillery round.

<sup>39</sup> Howard Sequine and Charles Burgess, “Evolving and asymmetric threats,” *Aircraft Survivability*, (Spring 2003) pp. 43-44.

Lastly, it is presumably as easy to smuggle man-portable RPGs or other anti-tank missiles into the United States as it would be to smuggle MANPADS, given the compactness and global availability of either weapons type. Included in these systems are disposable light anti-armor weapons (LAW missiles), many of which operate via semi-automatic command to line of sight, wired (SACLOS) firing in which the operator must keep the target in the launcher cross hairs.<sup>40</sup> Other man-portable military projectile weapons also pose potential threats. While the list is too long to catalog here, examples include other types of multiple-shot grenade launchers, like the Russian GM-94, and the Russian RPO shoulder-fired flamethrower infantry missiles. It is certainly possible to imagine that such systems may have been captured or looted from Russian forces by Chechen guerrillas, or might be bought on the black market – perhaps sold by underpaid Russian troops.

## **B. Light- to Medium-Weight Mortars**

As devastatingly accurate and effective as portable RPGs and other rocket-propelled weapons can be, they still possess comparatively short-range capability and may give at least some visual and audible warnings. Thus, effective airport perimeter security can reduce such threats considerably. In contrast, light or medium-weight, high-angle, smooth-bore, muzzle-loaded, indirect fire mortars – also man-portable – are capable of projecting large volumes of ordnance rapidly. Mortar range varies from 1 mile (~1800m) to 3.5 miles (~5800m), though generally with far less accuracy than RPGs. In addition, these would only function for ground (not air) attack. But despite this less reliable accuracy, a mortar's long range and broad potential firepower can make it a very effective hit-and-run terror weapon. Under optimal attack conditions, they can cause substantial damage and casualties within a large area in just a few minutes.

As an external threat to commercial airlines, mortars could be used to attack either aircraft on the runway, or fixed airport terminal or fuel storage facilities. Moreover, they are effective from distances well beyond most standard airport perimeters. These weapons are widely available to potential assailants from black or gray arms markets as well as from variety of national military sources. They are cheap, simple to operate, and difficult to detect or interdict.

Mortars have been used extensively as hit-and-run weapons against U.S. and Coalition troops and fixed military positions by guerrilla fighters in Iraq. Given their range and portability, perpetrators can set up mortars quickly, fire several rounds, and escape all within a few minutes (“shoot and scoot,” as the military tactic is known). One analyst notes:

[T]he mortar gives the terrorists a crude remote control weapon that is virtually undetectable. One of the oldest weapons of the gunpowder age, a mortar fires what is in effect a mini-ballistic missile. A mortar shell, usually loaded with several pounds of high explosive (HE) falls, as it were, out of the blue with no warning other than what some soldiers report is a slight hissing sound. And they are ready at hand -- by the thousands, mostly Soviet-made.<sup>41</sup>

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<sup>40</sup> Kit OK, British Army Vehicles and Equipment website ([http://www.army.mod.uk/equipment/pw/pw\\_law.htm](http://www.army.mod.uk/equipment/pw/pw_law.htm)).

<sup>41</sup> See, for instance, Ralph Kinney Bennett, “Terror Out of the Blue,” *Tech Central Station* (July 2, 2004) ([www.techcentralstation.com](http://www.techcentralstation.com)).

An experienced team of three could set up in a minute or less. With sufficient advanced research on target location, a GPS device, and a vacant alley or parking lot or rooftop, assailants could fire off five shells in 10 seconds or so, throw the mortar tube in the back of their vehicle and disappear before the last rounds even land.<sup>42</sup>

### **C. “Small” Arms Fire: Standard Assault Weapons, Large-Caliber Sniper Rifles and Heavy Machine Guns**

In certain circumstances, MANPADS and other propelled missiles present the higher probability for consequences/impact in the event of successful deployment, but one must consider the surprisingly high consequences from lower-technology, readily available ballistic weapon threats. Homeland security policy must weigh the overall trade-offs between higher-probability, lower-impact threats (such as conventional explosives) versus lower-probability, higher-impact WMD threats (from chemical, biological, radiological, nuclear weapons, etc.). There is considerable range within this loose probabilities spectrum, and potential (and often unexpected) consequences may vary greatly – as vividly seen in the 9/11 murder of thousands with planes carrying hundreds of victims.

There are no documented cases in which a specialized sniper rifle has led to a civilian airline crash, but there have been instances documented overseas, usually in civil conflict areas, in which aircraft have been downed by small arms fire – generally from the omnipresent Kalashnikov AK-47 assault rifle. Both sniper rifles and low-tech assault weapon attacks are highly plausible threats, as the following scenarios demonstrate.<sup>43</sup>

#### **1. Standard Automatic Assault Weapons**

Incidents in post-invasion Iraq and other past military conflict theaters have demonstrated that under the right circumstances (*e.g.*, proximity), concentrated automatic weapons fire from the widely available AK-47 or M-16 can down even military aircraft. In one widely reported instance, concentrated ground fire from automatic weapons and RPG fire disrupted a large-scale, low-altitude air assault by Apache Longbow attack helicopters in Iraq in 2003, resulting in the crash of at least one aircraft and significant damage to many others. In contrast to high-speed, armored military aircraft, large, slow-moving civilian aircraft would be particularly vulnerable to similar attacks at low altitude, especially if being targeted by multiple attackers.

Attacks would not have to down the aircraft to cause passenger deaths and/or impose significant psychological effects on the flying public, and thus affect the airline industry. It might be difficult (though not impossible) to damage multiple engines on a large, slow-moving jet, but concentrated fire (aimed via tracer rounds in day or night) could kill or disable pilots and/or damage critical flight systems, potentially leading to catastrophic failure and crash. Al Qaeda training manuals are reported to have noted this easy availability of assault weapons in the United States.<sup>44</sup>

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<sup>42</sup> Bennett, “Terror Out of the Blue,” *ibid.*

<sup>43</sup> There are undoubtedly other situations we have not anticipated, although we believe the scenarios outlined here capture the main vulnerability and response variables.

<sup>44</sup> See for instance “Assault weapons ban to expire on Monday,” CNN.com, Monday, September 13, 2004.

## **2. Large-Caliber Sniper Rifles**

A second potentially high-risk assault weapon scenario might involve one or more gunmen wielding high-powered .50 caliber sniper rifles and attacking a low-altitude aircraft. Large caliber sniper rifles are viewed by many analysts as “extremely destructive and have the capability of crippling the national critical infrastructure.”<sup>45</sup> Until recently, such .50 caliber weapons have been almost completely unregulated and available to terrorist organizations in many countries, including the United States.<sup>46</sup> They have been sold to al Qaeda,<sup>47</sup> the Irish Republican Army (IRA) – which used them against British armored police and army vehicles in Northern Ireland – and domestic U.S. extremist groups, among others. They are available legally at U.S. gun shows, although California recently became the first U.S. state to ban such sales.<sup>48</sup> These weapons were extremely effective against the Iraqi Army in the 1991 Gulf War, and Iraqi insurgents may have successfully used the same types of sniper rifles against U.S., Iraqi and coalition forces (though this information is currently classified by the U.S. military). In addition to being a significant danger to aircraft, as discussed below, .50 caliber sniper rifles are believed to be capable of causing catastrophic damage to power-generating plants and other electrical infrastructure, oil or gas pipelines and refinery storage tanks, and hazardous materials facilities such as chemical plants.<sup>49</sup> Compounding the danger of high-velocity, high caliber weapons are advances in the destructive power of related ammunition and reported improvements in sequential, multiple-fire accuracy (*e.g.*, dampening mechanisms now reduce recoil “kick” and thus improve the speed of multiple-round, telescopic sniper firing).

## **3. Heavy Machine Guns**

With proper training and ammunition, a large-caliber automatic assault weapon such as a .50 caliber heavy machine gun could seriously threaten an airborne civilian plane within range.<sup>50</sup> No information regarding a terrorist’s ability to procure such weapons was available for this report. They fall into one of the few classes of assault weapons that are illegal for sale in the entire Western world. In principle, smuggling such a weapon into a Western country might be marginally more difficult than smuggling in other military/assault guns, RPG/anti-armor and MANPADS weapons, given the slightly greater size and weight. But these weapons are specifically designed for attacking low-

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<sup>45</sup> “Regulation of .50 Caliber Sniper Rifles,” Physicians for Social Responsibility (PSR), website.

<sup>46</sup> See for example “Voting From the Rooftops: How the Gun Industry Armed Osama bin Laden, Other Foreign and Domestic Terrorists, and Common Criminals with 50 Caliber Sniper Rifles” by the Violence Policy Center (2001).

<sup>47</sup> In the *United State v. Usama bin Laden*, transcripts indicate al Qaeda bought a minimum of 25 Barrett .50 caliber weapons, and a purported al Qaeda training document found abandoned in Kabul, Afghanistan after the U.S. 2002 invasion told jihadi mujahideen that “in some countries of the world, especially the USA, firearms training is perfectly legal to the general public and it is perfectly legal to obtain weapons such as assault rifles,” according to PSR.

<sup>48</sup> “California Leads Nation in War on Terror—Becomes First State in Nation to Ban .50 Caliber Anti-Armor Sniper Rifles,” press release, Violence Prevention Center, Sept. 14, 2004.

<sup>49</sup> On their website, Physicians for Social Responsibility notes that .50 caliber rifle-wielding terrorists with incendiary rounds could “shoot at a facility that handles explosive, toxic or volatile chemicals, and instantly turn that building into a weapon of mass destruction. Clearly this is a threat not only to national security, but the public health at large.” Accessed at [www.psr.org/home.cfm?id=pressroom21-16k](http://www.psr.org/home.cfm?id=pressroom21-16k).

<sup>50</sup> I am grateful to analysts at the U.S. Naval Postgraduate School in Monterey, California, for suggesting this variation in the large-caliber assault weapons threat scenarios.

flying aircraft and are capable of firing 485 - 635 rounds per minute,<sup>51</sup> so their existence should not be overlooked.

#### **D. Shoulder-Fired Surface-to-Air Missiles (MANPADS)**

Many in the security community believe that among the external threats to civil aviation, Man-Portable Air Defense Systems (MANPADS) surface-to-air missiles top the list. MANPADS are readily available around the world, legally and illegally. There is also no question that some terrorist groups – such as al Qaeda – have access to MANPADS. Groups that do not have direct access might still acquire them on the global black market at the right price or from sympathetic Islamic radicals in various nations. Nevertheless, how many and what type of these sophisticated weapons are truly available remains uncertain, as do their quality and effectiveness.

Analyst Robert Wall estimates the probability of downing a *military* aircraft with such missiles, absent countermeasures, is around 25 percent for first generation MANPADS and 40-60 percent for second and third generation SAMs (e.g., the SA-14 and SA-18).<sup>52</sup> The effectiveness of the newer (2002) SA-18 Iгла-S (for “super”) may be higher, though no publicly available reliable estimates and no data relating to civilian aircraft vulnerability and survivability could be obtained for this report.

Four main questions are most relevant for MANPADS-related U.S. civilian aviation threats: First, are any of these SAMs available for domestic U.S. terrorism, and if so, what counter-proliferation or anti-terrorism efforts might reduce this risk? Second, if available, what are the missile types and sophistication? Third, how well trained are would-be attackers in using them? And fourth, what countermeasures addressing threats and target vulnerability might be deployed in the air or on the ground, and against which MANPADS systems might these countermeasures be more or less effective?

#### **MANPADS MISSILE SYSTEMS AND CAPABILITY**

The three main existing types of MANPADS missiles, categorized by their guidance systems, are listed below. Although infrared (IR) MANPADS pose the most likely current threat, laser beam rider missiles manufactured in Pakistan also pose a significant potential threat.

*Infrared (IR):* A heat-seeking missile, the IR MANPADS detonates in or near a heat source (engine exhaust plume). These systems are the *most* commonly proliferated among state and non-state actors. Once the seeker “locks-on” & launches, the missiles are “fire-and-forget.” The operator has no control over the missile and can seek shelter. For a successful hit, the missile must maintain lock-on by continued LOS tracking of the target’s infrared signature. Less sophisticated IR missiles can lose lock-on due to atmospheric conditions, such as haze or clouds, or due to infrared interference from ground heat radiation or even the sun. As discussed below, IR countermeasures such as flares, chaff and electronic (including laser) jamming are designed to either passively or actively confuse the missile seeker so that it loses lock-on and misses the aircraft.<sup>53</sup>

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<sup>51</sup> U.S. Army Board Study Guide, version 4.02 (September 2004).

<sup>52</sup> Robert Wall, “Missiles vs. Airliners,” *Homeland Security* (Jan. 2004).

<sup>53</sup> See for instance “Infrared Countermeasures Systems,” at [www.GlobalSecurity.org](http://www.GlobalSecurity.org).

*Command line-of-sight (CLOS)*: These are guided visually by the operator via direct radio wave (or laser) data link with the missile. The missile strikes the aircraft where aimed.

*Laser beam riders (LBR)*: LBR MANPADS are guided visually by the operator (using a joystick) via laser beam targeting. They strike the aircraft where aimed. There is *no* direct data link between operator and missile. These are the *least* commonly proliferated among state and non-state actors. But these technologies potentially present one of the greatest challenges to counter-MANPADS measures for both civilian and military aircraft.

Increasing advances in man-portable air defense systems technology means that unless proliferation is significantly curtailed, expensive electronic countermeasures will continually become less effective against terrorist weapons' capabilities. But even if the cutting edge infrared or hybrid seeker MANPADS are kept out of hands of terrorists, the problem of non-IR missiles will remain. Al Qaeda and similar terror networks have shown various levels of adaptability that must be accounted for in assessing risk from particular types of attack.

As noted in Table 5, counter-infrared defense measures can range from effective to somewhat effective when deployed against proposed such as the Directed Infrared Countermeasures (DIRCM) systems currently under development through the auspices of the U.S. Department of Homeland Security. Although this will be discussed in more detail in Part III, the unavoidable fact remains that expensive countermeasures are only partly effective. Against CLOS or laser beam rider MANPADS, RPGs and other rockets, heavy machine guns, specialized sniper rifles and even cheap, omnipresent automatic assault rifles, such electronic countermeasures are irrelevant. Cheaper aircraft survivability measures, such as redundancy of key systems, aircraft hardening that protects fuel tanks, pilots or critical components, and other responses would apply to more scenarios and thus might be considered in tandem with other countermeasures.



**Table 5:**  
**COMPARISON OF SOME MANPADS/SAMS CAPABILITIES Vs. COUNTERMEASURES SUSCEPTIBILITY<sup>1</sup>**

<i>(n/a = not available)</i>												
MANPADS Missile System												
Seeker/Targeting Mechanism:	Infrared (IR) Seekers							Cmnd Ln Sight (CLOS)			Laser Beam Rider	
CAPABILITIES	SA-7b	SA-14	StingerA	SA-16	SA-18	Mistral	Igla-S	Blwpipe	Javelin	Starburst	RBS-70	Starstreak
1 <sup>st</sup> Year Mass-Productn	1971	1978	1981	1986	1983	1988	2003?	1968	1985	1990	1977	1997
Slant Range, meters	4,200	4,500	4,800	5,200	5,200	6,000	6,000	4,000	4,500	4,000	7,000	5,000
Max. Kill Altitude, m.	2,300	3,000	3,500	3,500	3,500	n/a	n/a	3,000	3,000	n/a	n/a	n/a
Proliferatn/Availability	V.High	High?	High	H/M	Med?	Med?	Low?	High	?	None?	High	None?
All-Angles of Attack		●	●	●	●	●	●	●	●	●	●	●
“Fire and forget”	●	●	●	●	●	●	●					
Warhead=Contact+:		●	●	●	●	●	●	●	●	●	●	●
...Proximity fuse				●	●	●	●	●	●	●	●	●
...Shaped Charge				●	●	●	●	●	●	Darts	●	Darts
...Propellant Explodes				●	●	n/a	●	●	n/a	n/a	●	n/a
Targets Aircraft Heat <sup>2</sup>	●	●	●	●*	●*	●*	●*					
Lvl Operator Training	Med	M/L	M/L	M/L	M/L	M/L	L?	High	High	High	High	High
Guidance	IR	IR	IR	IR	IR	IR	IR	Radio	Radio	Laser	Laser	Laser
<b>Countermeasures<sup>3</sup></b>												
DIRCM <sup>4</sup>	V	V?-M	M	M	M-S	S?	S?	I	I	I	I	I
ATIRCMS <sup>5</sup>	V	V?-M	M	M	M-S	S?	S?	I	I	I	I	I
Flares (most advncd)	V	M	M	M?	M-S?	S?	S?	I	I	I	I	I
Chaff	V	M	M	M-S	S	S	I?	I	I	I	I	I

<sup>1</sup> Representative sampling, estimates from open sources, currently available missiles. Does not cover all MANPADS systems which might pose a threat to commercial aircraft. Among those left out of this list are U.S. Redeye (obsolete), Stinger B, C, D & Block 2 missiles (assumed less available to terrorists) and copied versions of any above missiles, such as Pakistani versions of SA-7b, SA-14 & RBS-70, Chinese versions of the SA-14. Countermeasure (CM) effectiveness list above is based on best-approx. available information, and is thus neither precise nor accounts for any recent, classified technology advances that might change broad CM category (e.g., DIRCMs) effectiveness.

<sup>2</sup> The most advanced seekers, with multiple/two-color IR or focal plane array seekers better register the actual aircraft body, and thus may not just hit hot engines, decoy flares.

<sup>3</sup> Countermeasures that might be adapted for use with *civilian/commercial jets*, effectiveness against specific MANPADS systems:

**Effectiveness of Countermeasure vs. MANPAD:** V=Very, M=Moderately, S=Somewhat, I=mostly Ineffective, ?=Uncertainty

<sup>4</sup> Directed Infrared Countermeasures: Combination missile approach warning system (MWS, or MAWS) and directed, focused laser countermeasure

<sup>5</sup> Advanced Threat Infrared Countermeasures: Preemptive IR transmitters (*not* directed at a specific missile), usually high-powered lamps (though with laser upgrades planned).

## E. Other External Attack Threats, Current or Future

### 1. Radio Frequency Weapons (RFWs)/Electromagnetic Pulse (EPW) Weapons

These weapons, intended to overload or burn out (and thus to catastrophically disable) key aircraft or ground-based microelectronic digital circuits or components, generate bursts of microwave or lower frequency energy, generally via an explosion or electric energy pulse. They may be deployed as rockets, bombs or via other methods. Russia for one has developed and manufactured rocket-assisted projectiles potentially effective within hundreds of feet of proximity to target.

According to one source, such weapons, which include powerful microwave devices already in existence, are currently or potentially under development by a number of other nations, some of which might deliberately or otherwise provide terrorists access in the future. “RFWs operate at the speed of light, can be fired without any visible emanations, and are unaffected by gravity and atmospheric conditions,” and their overall threat credibility for military (and presumably civilian aircraft) is believed to be “increasingly high.”<sup>54</sup> Kopp notes that “...increasingly available and portable RFW/EPW systems increasingly hold the potential to jeopardize any system that relies on

<sup>54</sup> Howard Sequine and Charles Burgess, “Evolving and asymmetric threats,” *Aircraft Survivability*, (Spring 2003) pp. 41-44.

semiconductor technology – most notably, a critical, growing aspect of American integrated war fighting capability. From an aviation perspective, these weapons would increase the vulnerability not only of aircraft, but of ground-based radar and air traffic control systems.”<sup>55</sup> Kopp believes that damage can range from a “soft” kill, when electrical equipment is disrupted and must be reset, to a “hard” kill, when actual hardware or wiring is damaged and must be replaced. RFW/EPW weapons’ footprint is potentially so wide that they have been referred to as Weapons of Electrical Mass Destruction (WEMD).<sup>56</sup>

## **2. Offensive High Energy Laser (HEL) Weapons**

Until recently, lasers have been quite bulky, expensive and unreliable, but the technology has improved to the point where even man-portable laser weapons are on the horizon. High energy laser (HEL) weapons generate intense beams of monochromatic light via a variety of energy sources. Such system designs include solid-state, free-electron and chemical lasers. The latter is the most mature technology is being employed as one element in American ballistic missile defense – usually in large aircraft. According to open-source literature, there are no reliable tactical HEL weapons currently deployed, but such technology continues to improve and poses a medium- to long-term future threat to civilian and military aircraft.<sup>57</sup>

## **3. Highly Energetic Explosives (Thermobaric, SFAEs, HEDMs)**

These weapons are contrasted with standard chemical high explosives and include thermobaric weapons, solid fuel-air explosives (SFAEs), and reactive explosive material. Thermobaric weapons were deployed over 20 years ago and have been used by Russian forces in Chechnya. Reactive material and SFAE weapons are currently under development. Reactive material especially may be effectively deployed against aircraft via standard missiles and rocket-propelled grenades (RPGs – see above). Related explosives technology that will expand destructive power even more includes “high-energy-density materials” (HEDMs) with per unit volume explosive power “somewhere between conventional explosives and [nuclear] fissile material – without the accompanying radiation and fission products.”<sup>58</sup>

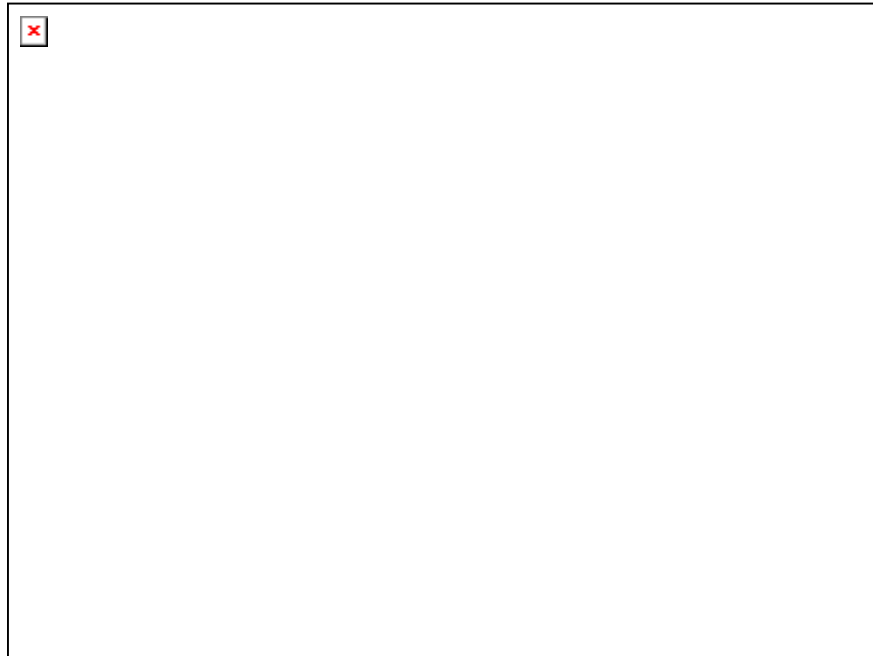
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<sup>55</sup> Kopp asserts that: “Importantly, the potential for terrorist, info-terrorist and special forces employment of [EM] weapons means that the probability of such attack may become very high and can no longer be considered a highly unlikely worst case scenario... As a result, the need for the electromagnetic hardening of assets will be a continuing and growing requirement for governments, defense forces and private industry.” Carlo Kopp, “An Introduction to the Technical and Operational Aspects of the Electromagnetic Bomb,” Paper Number 50, The Air Power Studies Center (November 1996), accessed 9/10/04 at <http://www.csse.monash.edu.au/~carlo/archive/MILITARY/APSC/wp50-draft.pdf>.

<sup>56</sup> Kopp, “An Introduction...,” 1996, *ibid.* pp. 1-2.

<sup>57</sup> Sequine and Burgess, “Evolving and asymmetric threats,” p. 43.

<sup>58</sup> Howard Sequine and Charles Burgess, “Evolving and asymmetric threats,” *Aircraft Survivability*, (Spring 2003) pp. 43-44.



### **III. Civilian Airlines & External Weapons Terrorist Attacks Reducing Susceptibility & Vulnerability through Countermeasures, and Increasing Survivability**

Most wide body civilian aircraft share certain unique characteristics that distinguish them from the average military combat aircraft, and even from large military transport or surveillance planes. Some of these characteristics (*e.g.*, slower speed and size) clearly increase vulnerability to external weapons threats such as MANPADS, RPGs and various assault weapons. Yet some contemporary design characteristics actually decrease civilian aircraft vulnerability in comparison to their military counterparts. Thus, what appears at first to be a *prima facie* case of greater susceptibility is in fact a complicated mix of variables. In addition, civilian airliners obviously fly within very different environments, they carry vulnerable civilian populations, and they present different issues to consider, such as efficiency, false alarms, cost-effectiveness and passenger comfort.

Many of the military SAM/MANPADS countermeasures deployed on combat aircraft possess design elements that may not be appropriate for civil aviation settings. A “lamp”-based infrared countermeasure system, for instance, while designed to project a continuous, preemptive counter-IR signal, can be highly disruptive to ground communications or other electronic systems in the urban environment of many major American airports. Traditional, white-hot burning counter-IR flares that are usable in combat settings can create worrisome fire and safety dilemmas for civilian use on a regular basis. Furthermore, issues like cost, maintenance schedules and reliability are less of an impediment for combat zones, but major considerations for commercial aircraft and the airline industry.

Thus, while there are counter-MANPADS technologies and tactics that will carry-over from military use and experiences, the cost-benefit calculations range from slightly to very different. The brief discussion below covers some of the current MANPADS infrared (IR) countermeasures that can be deployed on the aircraft or on the ground (airports, nearby in landing/takeoff paths, etc.).

### **A. MANPADS Susceptibility, Vulnerability and Survivability**

As noted, numerous variables affect the vulnerability of a commercial airliner to a successful “hit” by a MANPADS missile or other external terrorist weapon. Susceptibility, vulnerability, survivability, and other assumptions regarding a MANPADS attack are explored below. But the civilian aircraft vulnerability/survivability picture is complex and dependent on a variety of interacting variables (including the inherent features and performance of a particular type of MANPADS system as well as aircraft design issues), all of which combine to make a large commercial plane more or less capable of avoiding or surviving a missile hit.

From the attackers’ standpoint, the MANPADS weapons design and related civilian aircraft susceptibility issues were addressed briefly in Part I Proliferation, and Part II on threat and susceptibility variables, both in terms of terrorist tactics and specific missile types and expected performance (strengths and weaknesses, etc.). In contrast, this section examines an attack from the target aircraft’s perspective and suggest factors that might weigh in favor of or against the potential for a worst-case catastrophic aircraft downing due to a man-portable surface-to-air missile assault.

Among the aircraft vulnerability variables, survivability is one of the most important. Chances of survival depend on several key factors. One major factor is the location of the missile explosion in relation to the aircraft’s critical systems, fuel or structures. Another key factor is the ability of the pilot to land a damaged aircraft successfully before fire or other consequences render it unable to be flown.

It is commonly assumed that aircraft with wing-mounted engines – as opposed to tail-mounted engines – are better capable of surviving a surface-to-air missile attack. This is premised first on the assumption that a MANPADS attack will likely occur using an infrared (IR) seeker design, found on the majority of such missile systems. Second, it is assumed that because IR missiles tend to fly to the hottest point on an aircraft, usually the engine exhausts, a large wide-bodied civilian aircraft might be able to survive long enough to safely land if damage is to wing and/or wing engines rather than to tail structures or even body structure. That is, it is assumed that the farther away the engines from the body and wing, the higher probability of the aircraft surviving an IR missile hit (or near miss). The survival of the Baghdad, Iraq airport DHL Airbus-300 flight was due in part to the fact that the aircraft remained flyable despite progressively worse blast and fire damage to the wing.

One of the reasons military combat aircraft are more vulnerable to MANPADS damage is the positioning of engines flush to the aircraft, as well as the smaller size of a fighter jet or attack helicopter. Thus, outside the possibility of a lucky hit, exploding MANPADS warheads are not necessarily sufficient to outright destroy a large commercial (or military transport) aircraft, as they might a combat aircraft. Therefore, figures or

estimates for MANPADS “kill” percentages will not necessarily carry over to a civilian context. That is the good news. The bad news is that larger, slower civilian planes present a bigger infrared or other target, and generally there is a greater probability of IR MANPADS missile lock-on. For command-line-of-sight or laser beam rider MANPADS, the larger, slower target is also advantageous, and any infrared countermeasures will be irrelevant to such a non-IR MANPADS attack.

## **B. Possible Countermeasures against MANPADS and Various External Weapons Threats**

A number of possible countermeasures can reduce attack susceptibility or vulnerability and increase survivability even after an actual hit by an external terrorist weapon. Many of these measures are useful for a variety of threats, including MANPADS missiles and kinetic, explosive or incendiary projectiles. In many cases, they might also prove beneficial for prevention of or consequences from natural or accidental disasters.

### **1. Engineering Modifications to Aircraft**

Certain engineering modifications can improve the survivability of an aircraft struck by a missile. Some of the design modifications that airlines could make are:<sup>59</sup>

- Keeping flight control hydraulics away from locations likely to be hit. Still, as noted elsewhere, such location may vary considerably depending on the type – heat-seeker or not, e.g., if a MANPADS; sophistication of the MANPADS or other weapon(s) used; numbers or amounts of fire directed at the target (multiple attackers could improve likelihood of aircraft destruction); and operator skills/training and luck.
- Separating fuel systems from locations likely to be hit (see above)
- Using self-sealing fuel-feed lines.
- Incorporating fluid-shutoff mechanisms in the rear portions of engines.
- Using vapor-replacement or fuel cell system to prevent fuel tank explosions or fire in the event of penetration of wing or belly tanks. This would have added benefits for prevention of accidental catastrophes as well as deliberate, terrorist ones.
- Hardening or shielding critical components at or near infrared sources likely to be targeted – e.g., engines or surrounding structures such as wings.<sup>60</sup>

In many instances, aside from obvious benefit-cost issues, even the very rectitude of particular countermeasures is controversial. For example, despite a general belief among experienced counter-MANPADS analysts that wing-mounted engines appear to provide the greatest protection from catastrophic failure in an *infrared* missile attack, there appear to be dissenters who believe that for larger aircraft moving engines to the *rear* (to the fuselage and presumably tail area) and away from the wing fuel tanks would

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<sup>59</sup> Some of this list, aside from discussion, is taken from Paul. J. Caffera, “Air industries worst nightmare,” [www.newsfrombabylon.com](http://www.newsfrombabylon.com).

<sup>60</sup> The Israeli Air Force at one point reportedly increased significantly its combat aircraft survivability record against shoulder-fired SAM missiles by simply extending by several feet the exhaust cowlings on its combat jet engines – thereby ensuring that a warhead would detonate that much further away from the engine and other critical components.

minimize explosion or fire. This points to the often ambiguous and complex nature of commercial aircraft vulnerability/survivability analysis.

## **2. Fire Reduction**

As noted above, there may be considerable benefit in retrofitting of existing aircraft to reduce the probability of catastrophic fire or explosion in the event of attack – be it by MANPADS, RPGs, grenade launchers, large-caliber rifles or heavy machine guns with incendiary shells, etc. These fire-reduction measures would also be dual use – by reducing the consequences of accidental spark or on-board fire, such as that which likely caused the crash of TWA Flight 800 over Long Island. Such retrofits have been estimated to be in the neighborhood of \$200,000 per aircraft, although this could vary up or down depending on factors such as additional lost-service or maintenance and training costs on the one hand, or volume reductions to unit costs.

From the terrorism perspective, this type of onboard fuel system-based fire/explosion vulnerability reduction might be broadly effective in the event of various types of attack, from MANPADS, RPGs, and incendiary .50 caliber rifle rounds, and possibly prevent catastrophic aircraft loss for long enough to allow a life-saving aircraft landing.

## **3. “Titanium Bathtub” for Pilot Protection**

Another possible survivability element that has not been discussed in the civilian context, but which might be incorporated in new passenger aircraft designs one that the stalwart close-air-combat support A-10 “Warthog” aircraft is know for: the “titanium bathtub.” This essentially encloses the A-10 pilot in a bulletproof covering below and to the sides, and reduces the effectiveness of small arms fire, heavy machine gun, and even RPG or other rocket attack at low altitudes. In civilian aircraft, this feature could prevent death or injury to the pilots and damage to critical flight systems and monitors from ground fire, allowing emergency landing after an attack. The potential costs of such a measure are unknown at this time.

Regardless of what measures might be taken, engineering modifications that might involve retrofitting the entire existing U.S. commercial aviation fleet would be costly. In some cases, specific aircraft models or classes might be targeted for survivability hardening. Ultimately, of course, the most cost-effective design elements are best considered when new airplanes are on the drawing board, before they are built.

## **4. Non-Reflective Paint or Anti-IR Gel Coatings**

Another proposal is that commercial aircraft could be coated with non-reflective paint that reduces the infrared signature on fuselage, wings and tail – an issue for more sophisticated IR missiles capable of targeting not only hot engines but the aircraft. As with all counter-IR measures, the hope is that as a result a MANPADS missile may be less able to locate or lock-on a target. However, coating a commercial aircraft with an additional layer of paint is expensive, and may add to the aircraft weight and fuel consumption. Alternatively, if such non-reflective paint were to replace existing coatings it would become esthetically unappealing, and poor medium for aircraft logos and advertising. Also, the highly visual measure of having what is essentially camouflage paint on civilian jets might act as a reminder of terrorism threats that could actually deter potential flyers. This countermeasure may require additional development to become a plausible addition for reducing vulnerability, but in addition it may have little or no affect

on either CLOS or laser beam rider MANPADS, or on other projectile warhead weapons as discussed.

Anti-IR gel is designed to minimize the heat signature in critical parts of an aircraft, such as that around the engine cowlings or other areas which might make infrared missile lock-on easier.

### **5. Controllable Enabling for MANPADS**

Design changes are not just limited to aircraft survivability. Future MANPADS missile systems can be designed with built-in chip which will require an electronic password to activate the missile – known as “controllable enabling.” This measure could raise the bar for terrorists lacking password or electronic control devices possessed only by authorized national armies’ personnel. This technique does not provide a solution for the large inventory of missiles already in the hands of terrorist groups, nor those already circulating around the world. Lastly, of course, if a particular terrorist group is resourceful enough to acquire a missile, it may be able to acquire the password or auxiliary device to enable and use it as well.

### **6. Pilot Training and Changes in Landing Techniques**

Pilots of large aircraft flown in combat zones are increasingly being trained in emergency landing techniques to be used in the event of a missile or other attack. The pilots of the DHL Airbus-300 hit by a shoulder fired SA-14 missile in Baghdad in 2003 were apprised just days before the incidents of emergency landing techniques in the event of severe systems failure, and even more elaborate training of this type has been proposed, thus far unsuccessfully, yet could be given to all commercial passenger jet pilots in the United States.

The DHL aircraft was hit at roughly around 8000 feet according to reports, and afterwards pilots’ websites were generally very complimentary about the difficult job the air crew had in very successfully landing the plane safely 16 minutes later, using engine thrust for steering. Lesser variations on this type of emergency maneuvers have already been incorporated into some commercial flight training programs after *non-terrorist* accidental airline crashes, but the specific aspects of missile attack scenarios might – not without expense – at least be further incorporated in simulator training modules. Estimates of such training could range into the tens of millions,<sup>61</sup> yet accomplish dual benefit duty terrorism or naturally occurring air disasters. Nevertheless, such non-traditional emergency landing training, which is likely to fall outside of aircraft manufacturers recommended parameters, may require both Congressional indemnification of air carriers against lawsuits, and federal funding, before the latter will be willing to adopt such methods.<sup>62</sup>

Additional possible measures to reduce the vulnerability to MANPADS during takeoff and landing are steep takeoff angles and spiral landing patterns. Once again, pilots in

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<sup>61</sup> For example, Kevin R. McCarthy and Matthew G. Devost at the National Center for Aviation Security (NCAS) have proposed to federal officials such a commercial pilot training program which would allow flight crews to respond to potential or even successful MANPADS or other weapons attacks.

<sup>62</sup> Discussed by Kevin R. McCarthy, National Center for Aviation Security (NCAS), in conversation with the author.

Baghdad, Iraq and other combat zones susceptible to SAM attacks maintain altitude above the reach of the missile until they are very close to the airport, and then land in a sharp spiral descent. On takeoff, ascent angles are steep, to climb out of vulnerable missile range as quickly as possible.

Unfortunately, these measures are highly impractical for commercial passenger aircraft. Not only would passengers be made very uncomfortable by the g-forces generated in a steep takeoff angle, or spiral descent pattern, but both types of evasive maneuvers are potentially dangerous comparatively ineffective. In the case of the spiral descent, it would significantly slow down airport landing rates, and given the long slant ranges of most MANPADS, even a spiral descent leaves plenty of aircraft vulnerability for a would-be attacker. Steep takeoff angles open a great possibility of catastrophic aircraft stalling, in addition to discomfort and the potential for reduced numbers of airline passengers for the beleaguered industry. Thus, at best any such measures could be partially implemented in a case of emergency – as say after an attack has already occurred somewhere in the country and follow up attacks are feared, in which case aircraft are being redirected to safe landing areas. But in terms of day-to-day countermeasures, radical take off and landing techniques are not likely to be implemented for commercial air.

Nevertheless, the possibility of survival after a missile hit would greatly be increased if the pilots had appropriate training in flying compromised or damaged aircraft. Counterterrorism non-proliferation and prevention is critical to risk reduction, but pilot training for survivability would have a dual purpose, extending beyond terrorism to accidental flight emergencies.

## **7. Airport Perimeter Security Improvements and/or Expansion: Routine and Emergency Setups**

With up to 450 primary airports in the United States,<sup>63</sup> significant improvements in airport perimeter security will be extremely expensive, and in some cases only marginally effective at best in reducing susceptibility to attack. Nevertheless, although such improvements may be less effective against MANPADS, which can be deployed from 20-30 miles away from an airport and still potentially reach aircraft overhead in airport flight paths, such measures would however have a greater impact on susceptibility or vulnerability to less versatile weapons like RPGs, rockets and large-caliber arms. It is more plausible to hope for measurable improvement in security against weapons effective in the 500-2000 meter horizontal range than it is for those able to travel 5000-6000 meters slant, and up to 5000 meters altitude.

Thus, serious consideration should be given to even such improvements as raising the height and impermeability of perimeter fences (e.g., double fencing with motion detection or other intruder alert capabilities), to create a larger buffer between taxiing or ascending/descending aircraft and would-be attackers.

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<sup>63</sup> Sarah Chankin-Gould and Matt Schroeder, “MANPADS Proliferation,” FAS homepage (January 2004), at [www.fas.org/asmp/campaigns/MANPADS/MANPADS.html](http://www.fas.org/asmp/campaigns/MANPADS/MANPADS.html).



## **8. Designated “Hardened” Emergency Airports: Multiple Attack Prevention and Consequences Management**

Nevertheless, although routine regular patrols to prevent MANPADS attacks are highly impractical beyond the immediate vicinity of most major airports (and would require patrolling hundreds of square miles for one airport alone), it may be possible to create designated airports that may be especially hardened for use in emergencies.

Hypothetically, such airports could provide enhanced, if not perfect security to enable airborne aircraft to safely land in the event of a confirmed or suspected MANPADS or other attack. But even more limited perimeter patrols around any major airport could help to deter or confound attacks with shorter-range (<2000 meter) weapons – and possibly even including a short-range MANPADS like the first generation SA-7).

Certain airports might be well suited to well-prepared, temporary refuge for the type of regional or system-wide grounding that occurred on September 11<sup>th</sup>. Airports surrounded by water or flat, featureless terrain would be more easily patrolled or monitored, for instance, than those in urban areas or heavily wooded or variable terrain better capable of hiding a would-be assailant. Emergency planning could allow the temporary expansion of the patrolled and secured perimeter – even beyond fenced and guarded standard perimeter boundaries, to reduce the areas of vulnerability for incoming aircraft.

## **9. MANPADS-Specific Susceptibility Reduction Countermeasures**

Current onboard aircraft countermeasures (CMs) generally cluster around two main types, though hybrid systems exist or under development. First, IR decoys ejected from aircraft, including IR chaff (hot, oxidizing metal) and burning phosphorus flares, traditional versions of which burn hotter than aircraft heat signature; and newer IR “smart” flare decoys, including pyrophoric devices that might avoid fire dangers.

Second, there are electronic countermeasures (ECMs), generally missile guidance jamming devices, including Advanced Threat Infrared Countermeasures (ATIRCMs – preemptive, high-powered lamp transmitters, which create fields of IR energy to counter missile IR seekers); and Direct-Infrared Countermeasures (DIRCMs – combination MWS detection system and laser-based, focused IR energy jammer which activates when MANPADS launch detected). Both IR decoys and ECM jammers generally are combined with a Missile Approach Warning System (MAWS or MWS),<sup>64</sup> a device designed to detect the IR signature of incoming missiles that tracks an incoming missile and coordinates with whatever countermeasure(s) onboard the aircraft. The MAWS detector can be combined with any combination of countermeasure system – be it chaff and traditional flares, smart flares, IR jamming lamps, or DIRCM.

Infrared countermeasure equipment is currently available for civilian aircraft, though not widely deployed. Business aircraft manufacturers offer systems such as the Gulfstream BAE Systems AN/ALQ-204 Matador for around \$3.5 million per plane (including installation and training), which have been installed on a number of smaller business

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<sup>64</sup> Although the old counter-IR flare systems did not necessarily come installed with sophisticated detection technology, but were used as preemptive measures during vulnerable landing or takeoff. Subsequent “smart” flare technology used in conjunction with MWS has improved the effectiveness of this type of comparatively cost-effective IRCM.

aircraft and some larger jets, including Boeing 747s and BAE 146s. This 350 lb. lamp-based jamming countermeasure system is said to be free of aerodynamic penalty, and can be easily installed during routine maintenance. In addition, Israel is installing electronic countermeasures on most (or all) of its flagship carrier, el Al, based on a combine MWS detector and smart flare technology used by the Israeli military (see below).<sup>65</sup>

The U.S. Air Force's Large Aircraft Infrared Countermeasures (LAIRCM) system is one variation on the DIRCM category that was initially developed for use in protecting military transport planes such as the C-130 and C-5 Galaxy, but has now become the starting point for at least one of the two main systems being explored for application to the civilian aircraft fleet (see below for Proposed U.S. Department of Homeland Security Counter-MANPADS Measures). LAIRCM is a multiple-sensor, full-coverage active laser (originally lamp-based) countermeasure that detects missiles and automatically directs high-intensity modulated laser energy into the seeker head, without requiring pilot intervention. The crew is informed of the action.<sup>66</sup>

In addition, a number of proposed future civilian MANPADS countermeasures are in the concept and/or R&D stages. These include IR electronic countermeasures (ECMs) missile guidance jamming systems potentially applicable to civilian settings, such as the Next Generation (NexGen) Missile Warning Subsystem (MWS), the Escort Directed Infrared Countermeasures (E-DIRCM), and Protected Landing and Take-Off (PLATO) systems. The NexGen MWS System is being developed jointly through U.S. Special Operations Command DIRCM Joint Program Office and the U.S. Air Force Large Aircraft Infrared Countermeasures (LAIRCM) Program Office. NexGen MWS would provide a technological upgrade to the current DIRCM and LAIRCM systems. The current open-loop infrared countermeasures jam missile seekers with false IR targets, causing missile wobble but not necessarily break-lock, and allow the missile to reacquire the target if the jammer disengages to track another target. The new closed-loop IR countermeasure (CLIRCM) will purportedly cost around half as much as the old open-loop LAIRCM, and be capable of more advanced and rapid assessment of missile seekers, including a "smart" assessment of each missile seeker and generation of a tailor-made jamming solution, enabling more successful defeat of the incoming MANPADS.<sup>67</sup>

Escort Directed Infrared Countermeasures (E-DIRCM) technology is still being explored, for application at specific airports, on a case-by-case basis. This would be an airborne platform (airport-based equipped aircraft, akin to airborne combat radar command-and-control planes) intended to protect either non-ECM or ECM-equipped aircraft when warnings (or actual first attack) indicate a possible MANPADS threat. E-DIRCM could eliminate the need for installation of an individual missile protection system on each aircraft, and would be designed to create an electromagnetic protection umbrella for aircraft on take-off and landing. Problems include the possibility that such a system could routinely interfere with civilian ground communication and equipment, and thus

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<sup>65</sup> See "Large Aircraft Infrared Countermeasures (LAIRCM)," [www.GlobalSecurity.org](http://www.GlobalSecurity.org)

<sup>66</sup> *ibid.*

<sup>67</sup> *ibid.*

practicality issues for all but emergency situations.<sup>68</sup>

Among other general airport-based detection and countermeasures is the proposed Protected Landing and Take-Off (PLATO) system. While in the concept stage only, PLATO uses a grid of arrayed sensors on the ground in the flight path of an airport to detect missiles and then send a signal to the control tower, which alerts aircraft in the flight path of the detection to deploy countermeasures or for evasive action. Drawbacks that must be overcome still include inflexibility of flight paths once sensors are installed and the vast area that must be included in the sensor grid. In addition, as with all ECMs, there are significant repercussions from false detections, and a likely requirement that all aircraft would still have to be equipped with their own onboard countermeasure devices – thus adding to what will be considerable costs.<sup>69</sup>

### **Proposed U.S. Department of Homeland Security Counter-MANPADS Measures**

Currently, the US commercial airline fleet does not have any specific deployed countermeasures against a potential MANPADS or other external weapon attacks. The technologies currently used to protect military attack aircraft from shoulder-fired missiles cannot directly be integrated and installed on commercial planes, particularly given their size and speed, as well as service and maintenance schedule requirements.

Currently only Israel is equipping its commercial aircraft with anti-missile countermeasures – a flare-based system using a pulse Doppler radar system that detects any incoming missiles by their motion, and coordinates flare deployment. This system automatically dispenses “safe flares” – charges of hot gas rather than burning solids, that are claimed to leave no residue to fall to the ground<sup>70</sup> - to divert the missile away from the aircraft. The cost of this technology is estimated to be \$700,000 per aircraft.

In the United States, the Department of Homeland Security (DHS) designated for Fiscal Year 2004, \$60 million for development and testing of a prototype missile countermeasure system for commercial aircraft. DHS anticipates a two-year program to develop, test, and certify a suitable system, which as of this writing were in Phase II FY 2005 Activities leading to testing and evaluation of the two remaining competitors, BAE and Northrop-Grumman.

### **Summary of Part III**

Complicating any cost-benefit exercise is a frustrating combination of uncertainties. In assessing risks from terrorist attack and of projecting the economic impact of such (especially domestic) attacks, some ongoing central problems must be borne in mind, including but not limited to the following. First, for protection from external weapons threats to airliners, there is no “silver bullet.” Even if the \$10-100 billion costs of developing, testing, evaluation, and deployment, as well as maintenance, training, security, liability, aircraft takeoff and landing delays because of equipment malfunction,

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<sup>68</sup> Howard Sequine and Charles Burgess, “Evolving and asymmetric threats,” *Aircraft Survivability*, (Spring 2003) pp. 41-44.

<sup>69</sup> Sequine and Burgess, *ibid.*, pp. 41-44.

<sup>70</sup> Globes online at [www.globes.co.il](http://www.globes.co.il) (last visited October 16, 2003).

etc. are borne, one must acknowledge that the current electronic MANPADS countermeasure (ECM) systems under development via DHS will not be effective against non-MANPADS threats available to terrorist groups such as al Qaeda. Second, such ECMs will not be effective against other, *non*-infrared MANPADS systems such as the RBS-70 or RBS-90 laser beam rider missiles, which, was used extensively in Iran (against Iraqi aircraft in the 1980s) and is manufactured in Pakistan. Non-IR missiles are plausible threat. Table 7 compares the general effectiveness of a sample of various countermeasures and categories of external threat. As shown, there is no one countermeasure that will address all threats, and therefore combinations of various countermeasures must be considered – very likely with different mixes for different airports, geographies or situations. Third, the airline industry is still in difficult economic straits, and it must be considered that the currently-considered ECM “immunization” – which, again, is only partially (or in) effective against many know MANPADS – could, hypothetically, in the short term be worse than the terrorism threat in purely *economic* terms. Ironically, the very act of deterring MANPADS attacks might lead to public backlash against countermeasures if the staggering costs don’t seem justified – that is, if there are no attacks to deter or counter<sup>71</sup> - or if it the mythically-resourceful al Qaeda network simply shifts to and exploits other vulnerable avenues for mayhem.

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<sup>71</sup> This is a common problem for the field of public health, in which success reduces the public policy “market” for disease prevention by creating a (falsely) perceived absence of threat.

**Table 7:**

EXTERNAL THREATS TO AIRLINERS, VERSUS SELECT COUNTERMEASURES: GENERAL EFFECTIVENESS							
Countermeasure/ Survivability Measure	MANPADS Missile – Guidance System Type			Air or Ground Attack, Ballistic Weapons			Ground Attack
	Infrared (IR) or IR/Ultraviolet	Command- Line Of Sight (CLOS)	Laser Beam Rider (LBR)	Rocket- Propelled Grenade	Assault Weapons	Large-Caliber Sniper Rifle	Mortar Attack
<b>Aircraft-Based CM</b>							
DIRCM*	Effective to Somewhat effective <sup>1</sup>	N/A	N/A	N/A	N/A	N/A	N/A
ATIRCM*	Effective to Somewhat effective <sup>2</sup>	N/A	N/A	N/A	N/A	N/A	N/A
Flares	- Same -	Some Effectiv	Ineffective?	N/A	N/A	N/A	N/A
Chaff	- Same -	Ineffective	Ineffective?	N/A	N/A	N/A	N/A
Non-reflec Paint or Anti-IR Gel coating	Some protection	If camouflage, some protect	N/A	N/A (some night protec)	N/A	N/A (or poss. night protection)	N/A
Pilot Survivability Flight Training	Some increase in survivab'ty (landing)	Some surviv increase	Some surviv. increase	Some surviv. increase	Some surviv increase poss.	Some survivability increase (landing)	N/A
Aircraft redesign <sup>3</sup>	Poss. Some protect	Some protectn	Some protectn	Some protectn	Some protectn	Some protection	N/A
Airframe harden'g							
Titanium bathtub <sup>4</sup>	Pilot protection	Pilot protectn	Pilot protectn	Some protect	Protects pilots	Some pilot protectn	Some pilot protec
Fuel Tank Fire Suppression Syst.	Can reduce fire, increase time for safe landing	Reduce fire, allow time for safe landing	Reduce fire, allow time for safe landing	Reduce fire, allow time for safe landng	Reduce fire probability, allow landing	Reduce fire prob., allow more time for safe landing	Reduce fire prob. Allow safer pass. evacuation
<b>Airport-Based CM</b>							
Airport Perimeter Expansion	Small reduction in vulnerability	Small vulner. reduction	Small vulner. reduction	Poss. signific reductn vulner	Poss. significant vulner. reductn	Signifcant to Some vulnerabil. reductn	Some vulnerabil. Reduction
Designated hardened Airports <sup>5</sup>	Some possible effectiveness	Some potentl effect	Some potentl effect	Effective	Some to Effective	Some to Effective	Some effect

\* **DIRCM = Directed Infrared Countermeasures**  
 \* **ATIRCM = Advanced Threat Infrared Countermeasure: Preemptive IR "lamp" transmitters not directed at specific missiles**

<sup>1</sup> Depends on the sophistication of both the MANPADS seeker and the directed infrared countermeasure.  
<sup>2</sup> Not likely to be practical to deploy on civilian airliners, given the interference with ground communications systems, etc. More likely to be deployed some version of PLATO, aircraft-based airport perimeter IR protection system rather than on individual commercial jets. Overall effectiveness depends on the sophistication of both the MANPADS seeker and the infrared countermeasure.  
<sup>3</sup> Particularly separation of or redundancy in critical systems needed in an emergency landing  
<sup>4</sup> Protection for pilots, possibly critical instruments, similar to bullet-resistance "titanium bathtub" enclosure for pilots on A-10 attack aircraft.  
<sup>5</sup> "Hardened" airports, in terms of increased security, possible permanent- or provision for temporary perimeter expansion, in the event of a confirmed first attack, to which to reroute airborne aircraft for safe landing in emergencies.

## CONCLUSIONS AND OBSERVATIONS

In the balance, of all the risks to civilian aircraft outlined in this report, the most likely possible consequences are primarily economic and psychological. That is, although unprotected flights and airports could risk the lives of hundreds and even thousands of travelers, the tremendous costs of countermeasures and various protection measures are disproportionately high compared to the physical threat. Resources spent on influenza vaccine research and distribution, for instance, might save more lives in a benefit-cost comparison,<sup>72</sup> but from an economic standpoint, the psychological impact of airliner and/or airport attacks could once again force policymakers to bring air travel to a halt, or terrorize the public sufficiently to cause severe damage to a key industry.

The risks to civilian airliners from asymmetric warfare – particularly external terrorist attacks employing various possible man-portable “standoff” weapons – are high and rising. Although some analysts have suggested that the costs of countermeasures to such risks “is trivial compared to the cost of allowing terrorist counter-airliner attacks to succeed,”<sup>73</sup> clearly there must at some point be limits on such investments in light of other pressing national and human security (social welfare) concerns. Nevertheless, given the pivotal role played by the airline industry in the United States and rest of the world, and the tremendous political, social and economic costs from public loss of confidence in its safety, it is imperative that there be substantial public investment in a wide variety of counter-terrorism measures now and in the future that might deter, prevent or mitigate the consequences of such attacks.

Significant disruption of airline travel would not necessarily require the deaths of dozens or hundreds of airline passengers in a catastrophic aircraft downing. Any such attacks that jeopardized the safety of passengers would generate alarm among the jittery flying public and damage the already economically fragile airline industry. Even a few deaths from snipers or low-tech automatic weapons fire, especially with the prospect of more to come if the perpetrators were not immediately caught, might suffice in this regard.

The most obvious benefit-cost calculations will assess electronic countermeasures versus other methods to decrease susceptibility & vulnerability, or increase security or survivability. However, economic reactions and risk perceptions of the American public – in this case, primarily their flying behavior – is also a major unknown. We simply do not know if deployment of expensive electronic infrared missile countermeasures systems on every major passenger jet in the U.S. will have a negative, neutral or positive impact on air passengers’ perceptions of airline security – even absent a successful (or unsuccessful) domestic MANPADS attack. Similarly, without survey data, it is difficult to know to what extent it will reassure the public even if such countermeasures appear to succeed in thwarting an attack, or whether the costs will have been well met if they do not.

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<sup>72</sup> Up to late 2004 (before the much-publicized flu vaccine shortage), for comparison, around \$250 million was allocated for improved vaccine research and government-purchased reserves; yet in a “normal” flu year around 40,000 people will die from the virus or related complications.

<sup>73</sup> “The real terrorist missile threat and what can be done about it,” *Journal of the Federation of American Scientists*, vol. 56, no. 3 (Autumn 2003), p. 2.

Two areas that in addition to MANPADS electronic countermeasures should also have high priority are 1) global non-proliferation efforts, and 2) aircraft vulnerability and survivability. Also important is making sure any systems installed on aircraft possess the ability to be regularly upgraded as newer counter-MANPADS technologies come online.

As always with homeland security, it will be important to rationally assess the benefits and costs of any measures in the context of other terrorism protection policies (such as port security, emergency response, public health, etc.) and other social and security welfare. However, although the MANPADS threat is not the only potential external terrorism risk to airlines, clearly single or multiple successful MANPADS attacks are among the worst-case scenarios. Globally, there is a high risk of future MANPADS terrorism attacks against Western airliners, assuming current proliferation and security conditions. And at some point in the near to long term future, it seems inevitable that MANPADS or other weapons will be smuggled into the United States, or acquired internally, and used in a domestic terrorist attack against civilian aircraft. There are simply too many cheap and comparatively easy methods available to attack, cause casualties, and damage and even destroy aircraft in the air and on the ground.

### **Beyond ECMs, Other Additional Measures to Consider**

One critical investment should be in prevention, particularly non-proliferation of such weapons systems and the training capability to use them. At the international level, this will require a balance of carrot and stick, including diplomatic will and international pressure,<sup>74</sup> and heavy investment in anti-smuggling, infiltration and intelligence operations, and buy-back programs for existing weapons in circulation. At the domestic level, tough assault weapons and military sniper rifle bans, such as that enacted by California in Sept. 2004, considered, funded and enforced. MANPADS counter-proliferation should address the manufacture and availability of the newest weapons systems, as well as proliferation of advanced computer training technologies for these more sophisticated SAMs, since those are the missiles most likely to be capable of thwarting even the aircraft-based electronic countermeasures currently under development.

In conclusion, the growing availability to terrorists of sophisticated versions and types of counter-airline weapons, training technology and expertise, and the presumed ability of terrorists to organically adapt to counter-terrorism and security measures makes the threat ongoing and significant, regardless of investments. Overall terrorism risk must be evaluated as a total system – in which there is the potential to transfer threat to other areas.

Thus, in addition to counter-MANPADS technology, investments should consider a range of defensive electronic countermeasures, target (aircraft) hardening and survivability, and airport ground security – including perimeter, detection and interdiction measures, and emergency rerouting to secured designated airports in the event of likely follow-up attacks of any kind. Even if total prevention is impossible, the overall goal is deterrence, though without allowing terrorists to shift to even more costly attack scenarios if possible. Aside from the immediate costs to passengers, crash

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<sup>74</sup> To reduce the transfer of weapons and training technology by and to sovereign states, to reduce the likelihood that current and future cutting-edge weapons will fall into the hands of terrorist organizations.

consequences on the ground and overall local losses, there would be significant, national post-attack economic implications alone for the already fragile airline industry.