# SHOULDER LAUNCHED MISSILES (A.K.A. MANPADS):

## The Ominous Threat to Commercial Aviation

by

James C. "Chris" Whitmire

The Counterproliferation Papers

Future Warfare Series No. 37

USAF Counterproliferation Center

Air University

Maxwell Air Force Base, Alabama

# SHOULDER LAUNCHED MISSILES (A.K.A. MANPADS):

## The Ominous Threat to Commercial Aviation

James C. "Chris" Whitmire

December 2006

The Counterproliferation Papers Series was established by the USAF Counterproliferation Center to provide information and analysis to assist the understanding of the U.S. national security policy-makers and USAF officers to help them better prepare to counter the threat from weapons of mass destruction. Copies of No. 37 and previous papers in this series are available from the USAF Counterproliferation Center, 325 Chennault Circle, Maxwell AFB AL 36112-6427. The fax number is (334) 953-7530; phone (334) 953-7538.

Counterproliferation Paper No. 37

USAF Counterproliferation Center

Air University

Maxwell Air Force Base, Alabama 36112-6427

The Internet address for the USAF Counterproliferation Center is:

http://cpc.au.af.mil/

# Contents

Page

Disclaimer ..... *ii*

Acknowledgements ..... *iii*

About the Author ..... *v*

I. Introduction ..... 1

II. Recent Events—Relevancy and Present Danger ..... 5

III. MANPADS—Defined and Quantified ..... 11

- MANPADS Basics ..... 11
- Lethality ..... 15
- Proliferation ..... 17

IV. Economic and Psycho-Social Repercussions ..... 21

- Economic ..... 21
- Psycho-Social ..... 24

V. Solution Strategies and the Way Ahead ..... 27

- Striking and Capturing Terrorists ..... 28
- Preventing MANPADS Proliferation ..... 28
- Interdiction ..... 32
- Border Security ..... 32
- Airport Security ..... 34
- Tactics ..... 36
- Technical Countermeasures ..... 37
- The Department of Homeland Security ..... 46
- Vulnerability Reduction – Minimizing Damage from a Missile Hit ..... 51
- Minimizing Consequences ..... 52

VI. Conclusion and Recommendations ..... 55

Notes ..... 61

## Disclaimer

The views expressed in this publication are those of the author and do not reflect the official policy or position of the U.S. Government, Department of Defense, or the USAF Counterproliferation Center.

## Acknowledgements

Several individuals were noteworthy in their support of the research and execution of this publication. Of particular note, I would like to thank Mr. Pat Ellis, a USAF Counterproliferation Center analyst, for his research assistance; Lt Col Lisa Carswell for her computer technical assistance which allowed me to overcome great geographical distances to efficiently accelerate completion of this work; and Dr. Barry Schneider, the USAF Counterproliferation Center Director, for his empowerment and leadership. Furthermore, Mrs. Jo Ann Eddy and Mrs. Brenda Alexander provided crucial administrative support to bring this project to fruition. Finally, Mrs. Abbey Plant, Associate Editor for CPC Publications, and Mr. Alan Reed provided outstanding and accelerated support in formatting and final publishing of this report.

Thank you,

James C. "Chris" Whitmire, Maj, USAFR

## The Author

**Major James C. "Chris" Whitmire, USAFR,** is an Individual Mobilization Augmentee (IMA) assigned to the USAF Counterproliferation Center (CPC). He received his commission from the U.S. Air Force Academy in 1990 where he graduated in the top one percent of his class with military and academic honors. He is a senior pilot with over 3,800 hours in military and commercial aircraft and 21 combat sorties. He holds an FAA Airline Transport Pilot certificate with type ratings in the Boeing 707/720 and multiple Learjet models. He served on full-time active duty from 1990 to 2000 with three operational flying assignments including two as a KC-135 tanker pilot and one as a C-21 VIP airlift pilot. During this time he received numerous airmanship awards and served in many leadership capacities including training chief, evaluator, functional check pilot, flying general instructor, and interim operations officer. Since transitioning to the reserve component, he has served as the USAF CPC Homeland Security Officer where his primary duties include developing, administering, and instructing the Air War College's highest rated elective, the Homeland Security Course. In addition to his homeland security duties, he is an elected official serving on the Transylvania County, NC Board of Education, a realtor and furloughed American Airlines pilot and experiences the security challenges facing the nation firsthand. His education includes a Bachelor of Science Degree in Civil Engineering from the U.S. Air Force Academy where he was the department's top graduate. He also has a Master of Science Degree from the Institute of Aerodynamic Flight Structures, Columbia University, which he completed as a Guggenheim Scholar. He was the Air War College IMA of the Year for 2003 and an Air Education and Training Command finalist. He has contributed to numerous USAF CPC publications. Most notably, he was the lead editor and contributing author to *The Homeland Security Papers: Stemming the Tide of Terror*. *The Homeland Security Papers* was reviewed and acted on by the United States House Select Committee for Intelligence. It was also selectively republished by McGraw-Hill in their best-selling undergraduate and graduate text, *Homeland Security: Controlling the New Security Environment.*

# Shoulder Launched Missiles (A.K.A. MANPADS):

## The Ominous Threat to Commercial Aviation

James C. "Chris" Whitmire

## I. Introduction

The United States faces a multitude of security challenges in today's post-September 11, 2001, (9/11) era. One glaring threat to the nation's economic well-being and public safety is the commercial aviation industry's vulnerability to shoulder launched missiles, also known as MANPADS (Man Portable Air Defense Systems). This industry sustains the flow of goods and services in today's globally connected economy and is critical to the American way of life. Currently, 27 terrorist groups including Al Qaeda[1] have confirmed or reported possession of MANPADS.[2] Since 1994, there have been ten high profile attempts to target commercial aircraft with four being shot down-including one carrying the Presidents of Rwanda and Burundi.[3] Furthermore, MANPADS fit Al Qaeda's mode of operation[4] perfectly and are relatively easy to use, convenient to transport, widely available, inexpensive, and certainly lethal.[5] This capability coupled with Al Qaeda's direction from its leader, Osama bin Laden, "to kill Americans and their allies—civilians and military," is a potentially catastrophic combination.[6]

With the means and motive to inflict harm in place, and its propensity to favor economic, symbolic, and mass casualty targets such as passenger aircraft, all that remains is opportunity.[7] Ultimately, it is only a matter of time before Al Qaeda penetrates a seam and strikes a United States carrier. This may occur at home or abroad and the terrorists have the advantage of choice. It is they, and not the victims, who pick their time and place of choosing to employ their sinister tools of terror. Ultimately, time is of the

essence and a scenario that could exceed the economic impact of 9/11 lies in the balance.

With Al Qaeda dictating the pace and courses of action, one can expect them to select targets that are of highest value to the United States and that best fit their mode of operation. Aviation, the most visible symbol of America's riches and carrying culture and influence to all corners of the globe, definitely fits this equation. Additionally, its potential for mass casualties and its tremendous economic impact make it extremely appealing. Furthermore, Al Qaeda has long displayed an intrigue for airborne disasters as evidenced by the events of 9/11 and Ramsey Yousef's plot to down multiple passenger aircraft in the mid-1990s. In the United States alone, aviation directly accounts for over one million jobs and more than $150 billion in annual revenue.[8] Also, aviation's vital importance to global trade and just-in-time delivery, along with its leadership status in the world's largest industry, travel and tourism, make it even more attractive.[9] All total, when one considers indirect attributable economic impact, civil aviation exceeds $1.0 trillion in economic activity and more than 10 million jobs.[10] A January 2005 RAND Study cites air travel as integral to many Americans' professional and personal lives and goes on to say that "a credible threat to the viability of America's commercial airline industry could have profound effects on the nation's economy and on Americans' way of life."[11] Couple all this with bin Laden's understanding that the American economy is the source of its military strength and his 2004 strategy to "bleed America dry," one can quickly surmise that the commercial aviation sector is a prime target.[12]

One leading expert, Mr. Charles V. Peña, Director of Defense Policy Studies at the Cato Institute, says that the "MANPADS threat to civilian commercial aircraft is known and predictable."[13] When one ponders such an attack with Al Qaeda operatives firing multiple, simultaneous attempts at several large, passenger aircraft arriving and departing airports in the major metropolitan areas of the United States, the pain and suffering of 9/11 quickly comes into focus. Such a scenario involving New York, Washington D.C., Miami, Atlanta, Chicago, Dallas, Denver, Los Angeles, Seattle, and points elsewhere, is quite conceivable with staggering repercussions. Regardless of the success in terms of planes knocked out of the sky, just the mere execution of a well orchestrated attack would

inevitably shut down the nation's airspace and spawn psychological and economic chaos.

Statistically, a MANPADS scenario is daunting with thousands available on the black market at affordable prices.[14] While hard data documenting availability and cost varies widely, multiple sources corroborate the fact that these missiles are well within the reach of terrorists. An equally alarming metric is their lethality when employed against unprotected commercial aircraft. Again, sources vary considerably, but probability of kill percentages approach 70 percent when properly employed against unprotected aircraft.[15] Currently none of the commercial fleet is protected, and a large, lumbering, passenger aircraft without countermeasures in the crosshairs of a MANPADS has only a minimal chance of survival. Ultimately, whether or not an Al Qaeda attack were to yield a high kill percentage or only a single crash, the damaging outcome is obvious.

Certainly Al Qaeda's leadership is pondering such a scenario and would relish the world publicity associated with such an event. For an organization such as Al Qaeda with its tremendous operational experience, broad array of sophisticated weapons, and financial backing, the acquisition of a few black-market MANPADS is a small price to pay and more than likely already in their possession.[16] The potential payoff on such an investment is incredible with returns greatly exceeding 1,000 to 1. For example, the downing of a single passenger aircraft carrying approximately 300 passengers approaches $1 billion in expenses after hull loss and insurance claims are assessed, not to mention the tremendous emotional loss of life.[17] Contrast this with the cost of an infrared guided MANPADS available on the black market for $5,000 to $250,000.[18] Clearly in light of the aftermath of 9/11 in which the stock market declined $1.7 trillion in value within one week, the immeasurable carnage, economic impact, and psycho-social repercussions that would follow a simultaneous MANPADS attack is motivation for Al Qaeda to attempt a strike and for the United States to aggressively seek solutions.[19]

Given the lucrative incentives and the vulnerability of the United States commercial aviation industry and Al Qaeda's means, motive, and eventual opportunity to conduct a MANPADS attack, the question is not if, but when, an attack will occur. This said, the federal government must accelerate its security efforts within the confines of good stewardship,

limited personnel, resources, and funds. The countermeasures presently available have tremendous technological, reliability, and financial shortcomings. Therefore, while pursuing defensive measures, care must be taken not to play into the terrorists' hands by overspending on minimally capable countermeasures. In many ways, the MANPADS threat presents several "catch-22s," but necessity drives invention and in this case, failure is not an option.

The chapters that follow look first at recent events and then define the MANPADS threat. This section drills into the technical aspects of various systems and attempts to quantify known non-state groups, their capabilities, MANPADS proliferation, and cost. Next, expected economic and psycho-social repercussions are explored. Economic losses from 9/11 and psycho-social lessons learned from other catastrophes form a basis for this discussion. The final section looks at solution strategies and the way ahead. This is followed by the author's recommendations and conclusion.

## II. Recent Events—Relevancy and Present Danger

To emphasize the relevance and present danger of the MANPADS threat, one need look no further than recent events. Since late 2002 numerous civilian and military aircraft have been targeted and evidence indicates that Al Qaeda, its sympathizers, or other non-state entities have often been directly involved. In addition to actual attacks, Al Qaeda training and acquisition measures have aggressively increased as evidenced by captured training videos and MANPADS movements in Europe, the Arabian Peninsula, and the Horn of Africa.[20] United States military tactics also reflect a growing concern for the threat which has outpaced current strategy and available countermeasures.[21] General John W. Handy, Combatant Commander of U.S. Transportation Command during Operation Iraqi Freedom, commented that the danger posed by MANPADS "is perhaps the greatest threat that we face anywhere in the world."[22] Clearly, civilian aviation is at risk if military transport aircraft designed for war and protected with defensive countermeasures are threatened.

Most recently, in January 2006, a delegation of the United States House Armed Services Committee including Representatives Rob Simmons, Jeb Bradley, John Spratt, and Neil Abercrombie were targeted by one of the most sophisticated MANPADS available, a Russian-made SA-18.[23] This attack occurred while traveling from Baghdad to Kuwait in a military C-130 transport aircraft in a "lights out" (minimal emissions) configuration.[24] Fortunately the C-130's onboard countermeasures system was one of the most capable available and deflected the missile and the MANPADS failed.[25] This event is significant for several reasons. First, it involved a high profile target; second, it validated that SA-18s are available to non-state groups; and third, it showed that an existing onboard countermeasures system prevailed over a formidable weapon. These key illustrations along with others will be addressed from various angles as this discussion continues.

Perhaps the most notable civilian MANPADS event occurred shortly after the World observed the first anniversary of 9/11. An Israeli Arkia Airlines Boeing 757-300 experienced a near-miss when Al Qaeda launched its first known MANPADS attack on a civilian air carrier on November 28, 2002, in Mombassa, Kenya.[26] In accordance with their typical mode of operation, the perpetrators positioned teams at both ends

of the runway and then launched multiple missiles as the aircraft departed.[27] They fired two Soviet Strela-2M (SA-7b Mod 1 Grail) systems at the Israeli airliner carrying 261 passengers and 10 crew members.[28] Fortunately both missed; probably because the missiles were fired too early. Accounts from witnesses and crewmembers show that the aircraft experienced a slight "bump" when passing 500 feet above the ground and two smoke plumes simultaneously came into view. This would have been well below the minimum target altitude of 800 meters the Strela-2M requires, hence rendering the system ineffective.[29] While uncharacteristic of Al Qaeda to improperly employ a valued asset, one can rest assured that the same mistake will not be repeated given their training regiment and operational experience.

Another significant vector pointing to the severity of the MANPADS threat involved the airspace around Baghdad International Airport between May 2003 and November 2003.[30] During this time, 19 surface-to-air attacks on aircraft near the airport occurred.[31] While many of the aircraft hit were helicopters which are easier targets, it compounds the vulnerability of aviation in the eyes of the enemy. According to General Handy, "U.S. military cargo aircraft take ground fire in Afghanistan and Iraq from shoulder-fired SAMs, anti-aircraft artillery and small arms on almost a daily basis."[32] Whether it is a hovering helicopter or a slow-speed, minimally maneuverable, transport category, fixed-wing aircraft on approach or landing, Al Qaeda knows that they can take them down.

Of significant note regarding the Baghdad attacks was a civilian cargo carrier. A Belgium-based DHL Airbus 300, basically a passenger plane outfitted to carry cargo, sustained a MANPADS hit on November 22, 2003, while departing.[33] An SA-14, Strela-3 was the likely culprit and it significantly damaged the left wing, associated flight controls, and all three hydraulic systems.[34] The crew miraculously managed to crash land the badly damaged aircraft and survive, but the aircraft itself was a total loss. While the DHL aircraft was not a military chartered flight, this incident illustrates that MANPADS can inflict substantial damage even to large category aircraft.[35] Furthermore, with U.S. Transportation Command relying heavily on contracted airliners comprising the Civil Reserve Air Fleet (CRAF) to augment their cargo and troop transport capability in "non-threatening areas," the DHL incident provides strategic emphasis to the seriousness of the MANPADS threat. Historically, CRAF

aircraft transport 93 percent of troops and 41 percent of long-range air cargo in major contingencies.[36] Again, these CRAF contracted carriers are unprotected, commercial aircraft quite similar in make and model to the DHL Airbus. Since the United States, especially its military, is a constant target of the global Al Qaeda terrorist network, this is just another reason to take the MANPADS threat seriously.

Two other surface-to-air incidents involving large aircraft on departure from Baghdad International occurred near the same timeframe. In December 2003, a C-17 was hit and in January 2004 a C-5 was hit with both landing safely.[37] Of particular note is that both were equipped with missile defensive systems.[38] Specifics concerning the strikes and the defensive countermeasures involved were not substantiated. The U.S. Air Force only confirmed that these aircraft were engaged by "hostile fire."[39] Local news reports maintain that the strikes were by surface-to-air missiles and not some other armament.[40] In addition to the aforementioned MANPADS events, many others have occurred. Table 1 depicts several involving non-state groups occurring between 1996 and 2001.

## Reported Non-State Use of MANPADs: 1996-2001

*(Note: List includes some significant events reported by press outlets.)*

| Date | Non-State Group | Missile Type | Killed/ Injured | Aircraft | Notes |
|---|---|---|---|---|---|
| 23 Oct 00 | LTTE | Stinger | 4/0 | Mi-24 'Hind' | Shot down near Trincomalee harbor. |
| 04 Oct 00 | Chechen rebels | Stinger | 1/0 | Su-24MR | Shot down conducting near Urus-Martan. |
| 04 Oct 00 | Chechen rebels | Stinger | Unknown | Su-25 | Shot down on reconnaissance mission. |
| 10 Aug 00 | LTTE | Unknown | 0/0 | Fighter aircraft | Government aircraft fired at. No damage. |
| 25-30 Aug 00 | Chechen rebels | SA-7 | 0/0 | Unreported | Federal helicopters fired on. All missiles miss. |
| 07 May 00 | Chechen rebels | Unknown | 2/0 | Su-24MR | Shot down in the southern Chechnya. |
| 31 Mar 00 | LTTE | Unknown | 40/0 | An-26 | Transport craft downed possibly by MANPAD. |
| 10 Nov 99 | FARC | Unreported | 5/0 | DC-3 | FARC mistakenly downs civilian craft, press says. |
| 04 Apr 99 | Hezbollah | SA-7 | 0/0 | F-16s | Two missiles fired on Israel F-16s. Both miss. |

**Reported Non-State Use of MANPADs: 1996-2001 (cont.)**

| Date | Non-State Group | Missile Type | Killed/ Injured | Aircraft | Notes |
|---|---|---|---|---|---|
| 06 Mar 99 | PKK | Unknown | 20/0 | Puma helicopter | Helicopter shot down in southern Turkey. |
| 02 Jan 99 | UNITA | Unknown | 14/0 | C-130 | UN plane shot down in central Angola. |
| 26 Dec 98 | UNITA | Unknown | 9/0 | C-130 | UN-chartered plane shot down in central Angola. |
| 15 Dec 98 | UNITA | Unknown | 10/0 | An-12 | An-12 struck by missile en route to Luanda. |
| 10 Oct 98 | Tutsi rebels | Possible SA-7 | 40/0 | Boeing 727 | Airplane struck over DR of Congo. |
| 13 Aug 98 | LTTE | Unknown | 0/0 | Kfir fighter and surveillance aircraft | Missiles fired by rebels. No damage. |
| 01 Dec 97 | KLA | Strela 2M | 5/0 | Yugoslav Air Transport | Serb reports KLA shoot down craft near Pristina. |
| 07 Oct 97 | LTTE | Unknown | 0/0 | Mi-17 transports | Missiles reportedly fired from Tamil rebel boats. |
| 10 Nov 97 | LTTE | Unknown | 2/2 | Mi-17 transports and Mi-24 'Hind' | Missiles fired at – helicopter convoy. |
| 20 Aug 97 | LTTE | Stinger (reported) | 0/0 | Kfir fighters | Miss over Puliyankulam. |
| 18 May 97 | PKK | SA-7 | 2/0 | Super Cobra | Shot down during operations in Iraq. |
| May 97 | PKK | SA-7 | 11/0 | Cougar transport | Shot down during operations in Iraq. |
| 22 Jan 96 | LTTE | Unknown | 39/0 | Mi-17 | Unconfirmed MANPAD. |
| 30 Apr 96 | LTTE | Unknown | 94/0 | Unknown | Two air force transports downed. |
| Apr 96 | Hezbollah | Unknown | 0/0 | UAV | Unconfirmed MANPAD. |

**Table 1. Reported Non-State Use of MANPADS: 1996-2001**[41]

In addition to actual attacks, other recent events add emphasis to the threat. Trafficking is on the rise with reports of smuggling into Britain and a thwarted MANPADS attack against Heathrow International Airport in

February 2003.[42] In the United States, FBI agents arrested a British arms dealer, Hemant Lakhani, with Al Qaeda links for attempting to smuggle 50 shoulder-fired missiles from Russia into the United States.[43] This two-year sting concluded in July 2003 and included audio and video evidence that Lakhani's purpose was to "shoot down aircraft and cause economic harm to the United States."[44] Table 2 further illustrates MANPADS trafficking with 20 seizures and related illicit trafficking events involving various groups throughout the world that took place between 1999 and 2001.

## MANPAD Seizure and Related Illicit Trafficking Events: 1999-2001

*Note: Weapon types provided below may include misidentification by government and/or press agencies. Weapons types are listed as reported by source(s).*

| Date | Type (quantity) | Comments |
|---|---|---|
| 5 July 01 | Stinger (1) | Missile (possibly a missile warhead) reportedly placed by terrorists for use as improvised device near Moharabad, Pakistan. Recovered by authorities prior to detonation. |
| 12-13 Jun 01 | Stinger (8-10) | Weapons reportedly airdropped to Chechen rebels in the mountains of Shatoyskiy District. |
| 10-16 May 01 | Igla (20/50) | Twenty launchers and 50 missiles reportedly seized by Serbian authorities from illicit traffickers in Kosovo and Metohija. |
| 11 May 01 | SA-18 (unreported) | Seized by KFOR peacekeepers in western Kosovo. |
| 22 Jan – 15 May 01 | Unknown (5) | Seized by Russian federal troops from arms caches in Chechnya. |
| 8 May 01 | SA-7 (4) | Intercepted by Israeli Navy aboard vessel delivering weapons to pro-Palestinian forces. |
| 2 Apr 01 | Stinger (1) | Pakistani anti-drug personnel discovered weapon during raid on illegal morphine distribution facility on Afghan border. |
| 23 Feb 01 | Igla (4) | Seized by Federal Security Service personnel from a resident near Chita. Reportedly stolen from a weapons storage facility in the Zabaikalsky military district in 1999. |
| 2 Nov 00 | SA-7 (4) | Four missiles and two launchers located on lorry by Russian forces in Khasavyurt District of Dagestan. Event confirmed by Chechen rebel leadership. |
| 31 Oct 00 | SA-7 (unknown) | Police discovered the weapons inside a building in the Chechen capital of Gronzy. |
| 28-29 Oct 00 | Unknown (8) | Unverified press report indicated Colombian Army discovered the missiles during a raid on an ELN hideout in the Sierra de Perija mountains. |
| 5 Sept 00 | SA-7 (3) | Russian authorities seize the weapons from a weapons cache near the Russian-Georgian border. |

**MANPAD Seizure and Related Illicit Trafficking Events: 1999-2001 (cont.)**

| Date | Type (quantity) | Comments |
|---|---|---|
| 6 July 00 | SA-7 (2) | Weapons seized following raid on rebel base near Urkyukhoi, Chechnya. |
| 01 Jan 00 | SA-7 (1) | Weapon captured during Russian assault on position near Vedeno, Chechnya. |
| 4 Nov 99 | Unknown (1) | MANPAD reportedly delivered from Bulgaria to Kinshasa, Zaire via airplane by arms smugglers. |
| 15 Aug 99 | Unknown (2) | Brazilian federal police reportedly confiscated the systems after an arms smuggling aircraft made an emergency landing in north-central Brazil. |
| 11 Aug 99 | Soviet-made SAMs (12) | Colombian press report states that 12 Soviet-made SAM launchers were 'detected' in FARC held territory. |
| 12 Apr 99 | N/A | Authorities recover SA-7 related equipment in Ulster. |
| 10 Apr 99 | SA-7 (2) | Missiles and launchers confiscated during Turkish government raids along the Turkey-Iraq border. |
| 25 Feb 99 | SA-7 (18) | Weapons seized by IFOR from Iorries near Brcko, Bosnia. |

**Table 2. MANPADS Seizure and Related Illicit Trafficking Events 1999 to 2001**[45]

In general, Al Qaeda is consistently working to better train its operators and to upgrade its MANPADS inventory to more sophisticated, newer generation versions.[46] This is evident with movements from black market sources by militant Islamic affiliates in the Arabian Peninsula and the Greater Horn of Africa.[47] These desolate Al Qaeda safe havens make surveillance and capture difficult and rely on indigent sympathizers who use fishing boats, cows, and mules to covertly move their cargo.[48] This region also serves as a training ground with hands-on familiarization and instruction. A video instructional tape used in the training camps detailing operation of the SA-7 Strela-2 was traced to this region during the investigation of a failed attempt at Prince Sultan Air Base in Saudi Arabia against an F-15 in 2002.[49] This was the same MANPADS used in the Mombassa attack latter that year.[50]

As the ever adaptive terrorist mind of Al Qaeda seeks new targets, these recent events indicate soft, commercial aviation assets are high on the list. Amid growing anti-American sentiment throughout the Islamic world, the symbolic icon of American culture and technological prowess faces a clear and present danger. Eventually, a propitious time will come with operatives and MANPADS in place and Al Qaeda will strike. Next, this discussion will take a detailed look at the MANPADS threat in an attempt to define and quantify its lethal capability, vast availability, and affordability.

# III. MANPADS—Defined and Quantified

Man–Portable Air Defense Systems (MANPADS) are relatively simple, short range, surface-to-air missiles normally designed for single-person or small group operation to track and shoot down aircraft in flight.[51] According to the U.S. Department of State, more than 20 countries manufacture MANPADS or their components and more than one million have been manufactured to date.[52] These missiles are easily concealed, affordable, and widely available on the black market and have been successfully employed since the Vietnam era[53] Radical Islamic fundamentalist terrorist groups such as Al Qaeda find MANPADS particularly attractive because of their ability to strike high value aviation targets and inflict terror. They are quite lethal and account for essentially half of the combat losses worldwide since 1973.[54]

Twenty-seven non-state guerilla and terrorist organizations have confirmed or suspected possession.[55] Al Qaeda possesses significant numbers including some later generation, countermeasure-resistant versions.[56] Russian SA series missiles and U.S. Stingers are the most widely proliferated with the SA-7 leading the way.[57] Worldwide, over 6,000 MANPADS are outside the control of any government with most of these available on the black market to the highest bidder at prices starting at $5,000.[58]

## MANPADS Basics

In basic terms, the typical MANPADS system consists of: (1) a missile packaged in a tube which includes a seeker head, (2) a launching mechanism commonly called a "gripstock," and (3) a battery. See Figures 1 and 2 for illustrations. Under optimum conditions, an expert operator can assemble, shoulder, and launch a missile in 30 seconds.[59] Most versions are effective against fast-moving targets up to 15,000 +/- feet in altitude and three-to-five miles in range.[60]

In terms of logistical convenience, most are five to six feet in length and weigh between 35 and 40 pounds.[61] They are normally hermetically sealed in launchers and designed for field conditions and rough handling to minimize environmental degradation.[62] In terms of shelf life, some MANPADS are advertised with 22 years of operability under factory-specified conditions.[63]

While field conditions are generally not conducive to maximum lifespan, the SA-7B Strela-2Ms used in the Mombassa attack were approximately 28 years old.[64] Battery life is probably the single-most restrictive component of a MANPADS. A popular misconception once followed that some of the Afghan-era Stingers were obsolete because of battery failure and this was not true![65] The original batteries for these systems can be replaced with commercially available substitutes found on the open market, thus making many weapons once believed to be obsolete, very much a threat.[66]

Once launched, a MANPADS tracks and impacts its target in approximately five seconds. Most accelerate to velocities approximately twice the speed of sound, Mach 2, in less than two seconds and maneuver at G-loadings far greater than any transport category aircraft is capable of attempting.[67] While they vary tremendously in terms of capability, most use an infrared (IR) seeker to detect an aircraft's IR signature against the cold sky and home into the heat emitted from hot metal sections of the aircraft engines and exhaust.[68] The seeker head of a MANPADS serves as its brains and defines the overall system in terms of guidance. Three main types of seekers exist including IR, command line-of-sight (CLOS)—meaning radio controlled, and laser beam riders.

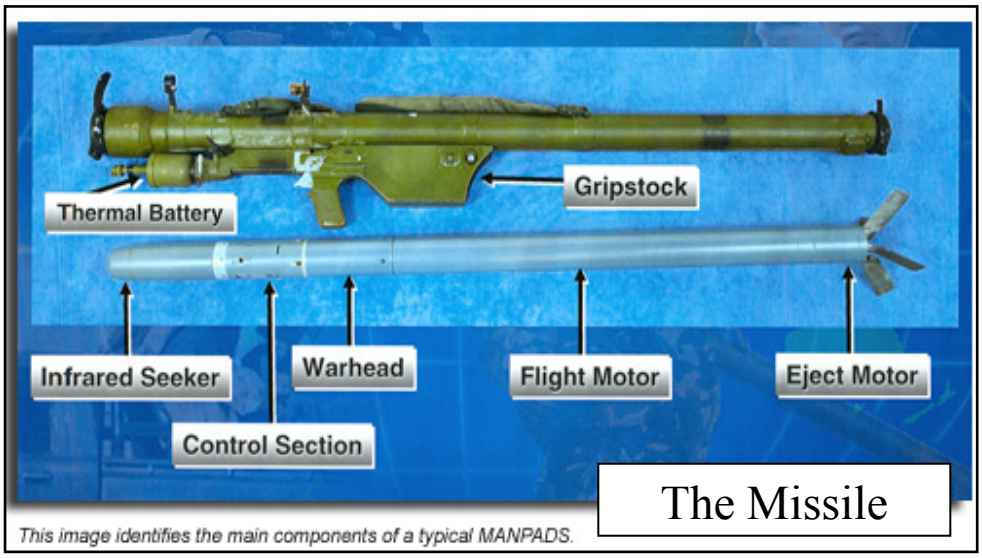


**Figure 1. Typical MANPADS Components**[69]

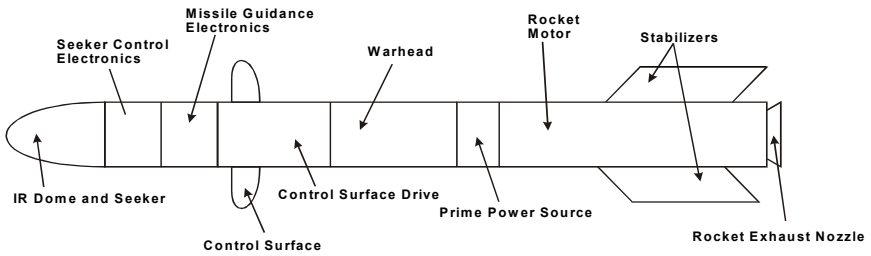


**Figure 2. Typical MANPADS Missile**[70]

IR missiles use passive guidance, meaning they emit no signals until they are fired, which makes them extremely difficult to detect during their short, five to six second flight path.[71] As an aircraft flies through the sky, it naturally emits energy as IR, visible, and ultraviolet (UV) parts of the electromagnetic spectrum.[72] Just as humans see visible light, the IR seeker head sees IR energy and attempts to guide its payload to the given target.[73] With technological and computing speed advances over the years, IR seeker technology varies tremendously in terms of capability. With this, IR missiles are classified according to sophistication and denoted as first, second, third, and fourth generations.[74] Russian SA series MANPADS increase in sophistication as their nomenclature increases with the first generation SA-7 being the least sophisticated.[75]

First generation IR missiles are tail chase weapons that must pursue their targets from behind.[76] They essentially chase the hottest item in the sky such as the thermal signature from the exhaust and hot sections of the aircraft. Because of this, they are highly susceptible to interference from background sources such as the sun, flares, and various directed energy countermeasures which will be discussed later. [77] First generation IR MANPADS include the American Redeye, Soviet SA-7, and the Chinese HN-5.[78] The SA-7 Strela-2 (NATO: Grail) and its variants are the most widely deployed first generation MANPADS with thousands in existence today.[79]

Second generation IR variants include the American Stinger, the Soviet SA-14 Strela-3 (NATO: Gremlin), SA-16 Igla-1 (NATO: Gimlet), and the Chinese FN-6.[80] All of these use coolants to cool the conical scanning seeker head and in turn filter out most interfering background IR

sources as well as permitting head-on and side engagement profiles.[81] These second generation missiles are effective against traditional flares and use a cross-scan or rosette-scan "two-color" targeting capability.[82] This enables the seeker to use IR as a primary and UV as a secondary emissions source for target acquisition.[83]

Third generation IR systems include the French Matra Mistral, the Russian SA-18 Igla (NATO: Grouse), the Pakistani Anza Mk II, and the American Stinger B.[84] These scan multiple color bands and produce a quasi-image of the target and are essentially flare-proof (traditional and advanced).[85] Finally, fourth generation IR missiles include the Stinger Block 2 and others in development in Russia, Japan, France, and Israel that use focal plane array guidance for greater engagement range.[86] Table 3 shows some of the more widely proliferated IR systems.

| Name | Origin | Weight | Max Range | Max Altitude | Guidance |
|---|---|---|---|---|---|
| Stinger | U.S. | 35 lbs | 5 miles | 2 miles | Passive IR/UV |
| SA-7B (Strela-2)/ (Grail) | Russia, China, Egypt | 33 lbs | 2.6 miles | 1.4 miles | Passive IR |
| SA-14 (Strela-3)/ (Gremlin) | Russia | ~30 lbs | 3.7 miles | >2 miles | Passive IR |
| SA-16 (Igla-1)/ (Gimlet) | Russia | ~30 lbs | 3.1 miles | 2.2 miles | Passive IR/UV |
| SA-18 (Igla)/ (Grouse) | Russia | ~30 lbs | 3.2 miles | 2.2 miles | Passive IR/UV |
| Qianwei/ QW-1 Advanced Guard | China, Pakistan | 36 lbs | 3.1 miles | 2.5 miles | Passive IR |

**Table 3. Widely Proliferated IR MANPADS**[87]

CLOS missiles are guided to the target by a human operator who flies the missile into the victim aircraft using radio controls.[88] Standard aircraft mounted countermeasure systems are not effective against this type of missile.[89] Unlike IR guided systems which are essentially fire-and-forget weapons, CLOS require highly trained operators, thus making them less

appealing to terrorist organizations.[90] Afghan Mujahedin were reportedly disappointed with British Blowpipe CLOS missiles because they could not master them, especially against fast moving jet aircraft.[91]

Laser beam riding MANPADS follow a laser beam aimed by a human operator to its intended target.[92] Like CLOS systems, laser beam riders are resistant to current aircraft mounted countermeasure systems and cannot be jammed after they are launched.[93] Existing systems include the Swedish RBS-70 and the British Starstreak.[94] While this system does require extensive training, it is more user-friendly and particularly menacing in the hands of a well-trained adversary.[95]

Regardless of which kind of guidance system directs the missile to its target, once it arrives it packs a powerful punch. Warheads are blast-fragmentation by design and range in size from three to seven pounds.[96] Some systems explode on impact while others use proximity detonators to better strike softer areas of the aircraft such as fuel-rich wings and fuselage sections. Regarding blast capability, consider the following lethality statistics.

## Lethality

"Since 1973, 49 percent of all aircraft losses in combat worldwide have been attributed to IR-seeking surface-to-air missiles…"[97] Furthermore, "by some estimates, 90 percent of all the aircraft lost in combat in the last 15 years have fallen to MANPADS missiles."[98] According to CIA estimates, Mujahideen fired MANPADS achieved a 70 percent kill probability against helicopters and aircraft during the Soviet–Afghan war.[99] RAND Corporation reports 35 attacks against civilian aircraft with 24 planes shot down.[100] This includes non-jet-powered aircraft such as helicopters, turboprop, and piston-driven ones, but also includes large jet-powered airliners.[101] The Congressional Research Service reports six attacks on large civilian turbojet aircraft since 1978 with all but one resulting in substantial if not catastrophic damage.[102] Table 4 summarizes MANPADS attacks on civilian aircraft from several well respected sources and includes fatalities.

| Organization | Period Covered | Number of Attacks | Number of Deaths |
|---|---|---|---|
| TSA | 1979-present | 35 | 640 |
| CIA | 1977-1996 | 27 | 400 |
| FBI | 1970s-present | 29 | 550 |
| RAND | 1975-1992 | 40 | 760 |
| Janes | 1996-2000 | 16 | 186 |

**Table 4. MANPADS Attacks on Civilian Aircraft**[103]

With these statistics, it is worth mentioning that attacks resulting from anti-aircraft artillery (AAA) and rocket propelled grenades (RPG) are often confused with and misreported as MANPADS attacks.[104] While both AAA and RPGs are a definite concern, combating them is much simpler than countering high-tech, self-guided, fire-and-forget MANPADS. Generally speaking, AAA and RPGs are less threatening to aircraft and only effective below 1,000 feet.[105]

Another clarification regarding MANPADS lethality is that some debate whether or not a missile hit will actually "kill" a large turbine powered passenger aircraft or merely "damage" it. The aforementioned statistics are quite clear upon initial observation; however, one can argue that many of the data points include kills of smaller, slower aircraft. While this is true, no one cherishes the idea of being targeted whether the result is a miss, a survivable hit, or an all out catastrophic destruction. The Mombassa miss and the DHL crash landing in which no one was killed probably scared more people and hurt the aviation industry more than the other incidents combined.[106] Regardless, the U.S. Air Force 46th Test Wing *Large Aircraft Survivability Initiative (LASI)* is currently researching and testing such fundamental questions as:

- What is the vulnerability of large aircraft to a MANPADS attack?
- What components are likely to be hit?
- How much damage will be sustained?
- What is the expected effect of damage on aircraft safety-of-flight?
- Will a hit result in an aircraft kill?[107]

All in all, these issues are important, especially to military essential missions, but in the commercial aviation business negative publicity and mere perception are the key drivers and can cost billions overnight.

## Proliferation

Ultimately, MANPADS are lethal to aviation and thousands are available to guerrilla and terrorist groups worldwide as illustrated in Figure 3.[108] While Al Qaeda represents the obvious threat to the United States, other groups are worthy of concern. Hezbollah possesses SA-7s, Stingers, and Chinese-made Qianwei-1 Advanced Guard (QW-1) systems while the Palestinian Authority possesses SA-7s.[109] This complicates the airspace of Israel tremendously and probably explains rumors of countermeasure systems on Israeli carriers. As far as success goes among terrorist groups, the Liberation Tigers of Tamil Eelam (LTTE) have enjoyed tremendous success with former Soviet and China-made MANPADS.[110] Closer to home in the Western Hemisphere, two insurgent Colombian groups, the Revolutionary Armed Forces of Colombia (Fuerzas Armadas Revolucionarieas de Colombia—FARC) and the National Liberation Army (Ejercito de Liberacion Nacional—ELN) possess MANPADS.[111] With American air carriers visiting numerous destinations on a daily basis in Central and South America influenced by these two groups, the potential for an "encounter" is certainly plausible. This is especially true when one considers the United States' continuing efforts to aid the Colombian government in its fight to control these two groups. Tables 5 and 6 provide further specifics and insight into all the groups worldwide believed or confirmed to possess MANPADS.

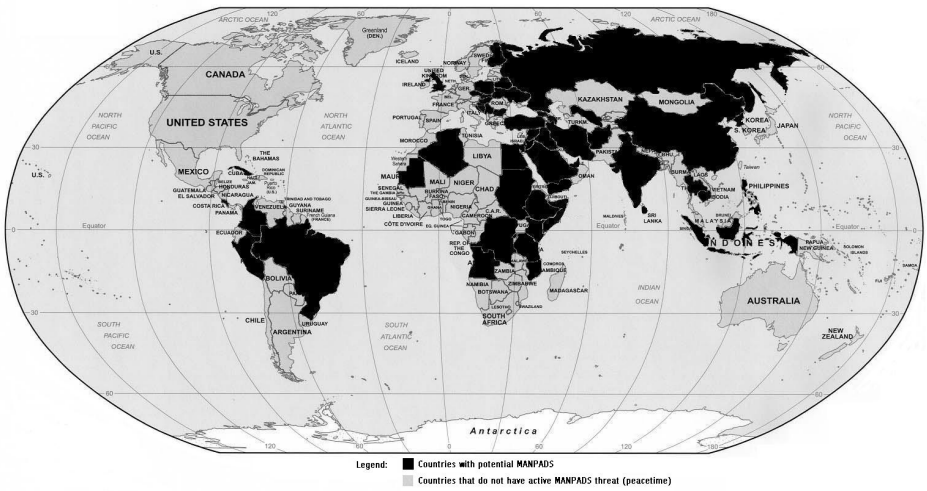


**Figure 3. Nations with MANPADS Potentially in the Hands of Terrorists**[112]

## Non-State Groups with MANPADS: 1996-2001

Note: Groups reported but not confirmed to have MANPADS are included. The following disclaimer applies to all entries for purposes of clarification: confirmed (c), reported (r).

| Group | Location | Type |
|---|---|---|
| Armed Islamic Group (GIA) | Algeria | Stinger (c) |
| Chechen rebels | Chechnya, Russia | SA-7 (c), Stinger (c), Blowpipe (r) |
| Democratic Republic of the Congo (DRC) rebel forces | Received in Kinshasa | SA-16 (r) |
| Harkat ul-Ansar (HUA) | Kashmir | SA-7 (c) |
| Hezbollah | Lebanon | SA-7 (c), QW-1 (r), Stinger (r) |
| Hizbul Mujahideen (HM) | Kashmir | Stinger (r) |
| Hutu militiamen | Rwanda | Unspecified MANPADS (r) |
| Jamaat e Islami | Afghanistan | SA-7 (c), SA-14 (c) |
| Jumbish-i-Milli | Afghanistan | SA-7 (c) |
| Khmer Rouge | Thailand/Cambodia | Unspecified MANPADS (r) |
| Kosovo Liberation Army (KLA) | Kosovo | SA-7 (r) |
| Kurdistan Workers Party (PKK) | Turkey | SA-7 (c), Stinger (c) |
| Liberation Tigers of Tamil Eelam | Sri Lanka | SA-7 (r), SA-14 (r), Stinger (c), Hongying-5 (c) |
| Oromo Liberation Front (OLF) | Ethiopia | Unspecified MANPADS (r) |
| Palestinian Authority (PA) | Palestinian autonomous areas and Lebanon | SA-7 (r), Stinger (r) |
| Popular Front for the Liberation of Palestine-General Command (PFLP-GC) | Palestinian autonomous areas and Lebanon | Unspecified MANPADS (r) |
| Provisional Irish Republican Army (PIRA) | Northern Ireland | SA-7 (c) |
| Revolutionary Armed Forces of Colombia (FARC) | Colombia | SA-7 (r), SA-14 (r), SA-16 (r), Redeye (r), Stinger (r) |
| Rwanda Patriotic Front (RPF) | Rwanda | SA-7 (r), SA-16 (r) |
| Somali National Alliance (SNA) | Somalia | Unspecified MANPADS (r) |
| Taliban | Afghanistan | SA-7 (r), Stinger (c) |
| National Liberation Army (ELN) | Colombia | Stinger (r), various MANPADS (r) |
| National Liberation Army (UCK) | Macedonia | SA-18 (c) |
| National Union for the Total Independence of Angola (UNITA) | Angola | SA-7 (c), SA-14 (r), SA-16 (r), Stinger (c) |
| United State Wa Army | Myanmar | SA-7 (c), HN-5N (c) |
| United Somalia Congress-Somali Salvation Alliance | Somalia | Unspecified MANPADS (r) |
| Osama bin Laden ('Al Qaeda') | Afghanistan | SA-series missiles (c), Stinger (c) |

**Table 5. Non-State Groups with MANPADS**[113]

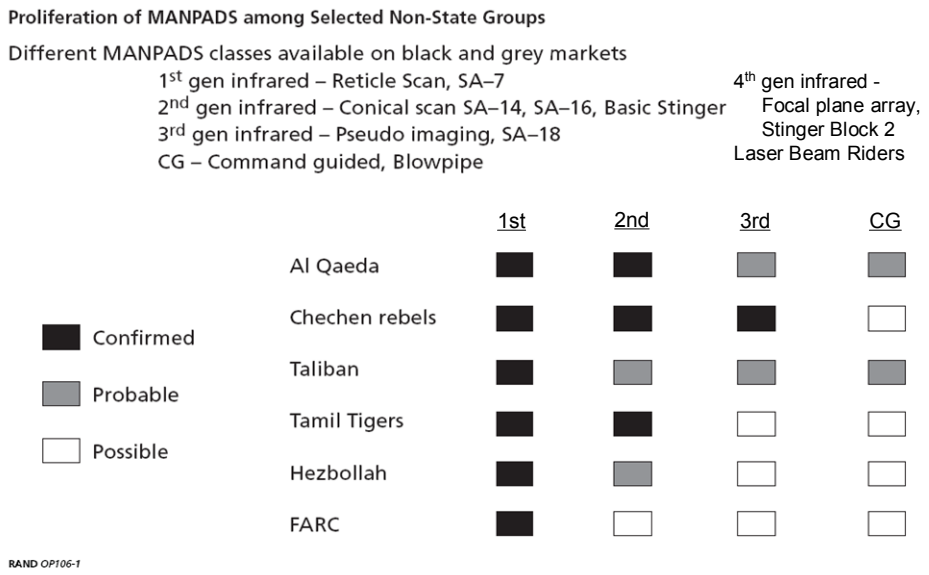


**Table 6. Selected Non-State Groups with MANPADS**[114]

With over one million MANPADS produced since they were first introduced in the late 1960s, numerous sources are to blame for their availability to non-state groups today. During the Soviet-Afghan War, the CIA provided Mujahideen fighters in Afghanistan approximately 1,000 Stingers in the mid-1980s.[115] Again, in the late 1980s, the CIA covertly provided FIM-92A Stingers to UNITA rebels in an effort to overthrow Angola's pro-communist government.[116] During the collapse of the Soviet Union, the availability of SA-series MANPADS drastically increased.[117] In November 2002, Russia acknowledged that "tens of thousands" had been stolen from its arsenal during the 1990s.[118] This event flooded the black market and in-turn drove the price of first generation systems down as low as $5,000.[119] This also introduced an unknown number of more sophisticated second and potentially third generation MANPADS further complicating the entire scenario.

With terrorist organizations actively seeking to increase their MANPADS arsenals with greater quantities and more capable systems, one can assume the black market will strive to fulfill the demand. Whether the source is from left-over caches of first generation missiles or innovative suppliers such as the Russian mafias which have demonstrated the ability to obtain virtually any type of weapon system, the cash value of MANPADS certainly motivates the process.[120] Following the adage that "the enemy of my enemy is my friend," common objectives produce some strange bed-fellows. With conservative estimates of 6,000 MANPADS unaccounted for, Al Qaeda, its multiple affiliates, and a host of other adversaries have suppliers standing by to satisfy their demands.[121]

Evidence supports this with numerous examples. Excess Mujahideen Stingers ended up in guerrilla arsenals from Chechnya to Sri Lanka.[122] Given their overwhelming success against the Soviets during the Afghan war with over 270 kills, Stingers have brought as high as $80,000 to $250,000, depending on demand and sophistication.[123] Osama bin Laden's bodyguards are believed to be equipped with Stingers and he reportedly supplied Chechen rebels with 50.[124] Additionally, the Chechens seem to have other sources of Stingers and SA-7s with delivery methods ranging from smuggling to airdrops.[125] They have procured SA-7s for as little as $10,000 apiece and actively pursue more to use against the Russians.[126] As of April 2001, Chechen rebels had destroyed 38 Russian aircraft with 66 percent attributed to MANPADS.[127]

Whether the MANPADS threat strikes commercial aviation sooner or later, it is certainly clear that they are more than capable of destroying unprotected airliners. Furthermore, multiple groups possess them or could readily procure them given their widespread availability and low cost. Given their compact size and the multiple seams in the globalized shipping world, it is only a matter of time before sufficient numbers are smuggled into place to effect an attack, or a more foreboding simultaneous assault. To further motivate attention to the MANPADS threat, economic and psycho-social repercussions are discussed next.

# IV. Economic and Psycho-Social Repercussions

The consequences of a MANPADS attack on United States' carriers span many levels of consideration. Such a potential scenario could range in scope from only a single attempt to an extended series of simultaneous attacks across the country and abroad. Obviously, the range of possibilities makes specific analysis challenging, but general outcomes and expected trends are quite conceivable. This section will first discuss economic ramifications and then turn to psycho-social considerations. Throughout, please recall the United States' strength is based on its economy and the well-being of its citizenry is absolutely critical.

## Economic

The repercussions of 9/11 serve as a valuable baseline for quantifying the potential effects of a MANPADS attack. The quarter immediately following 9/11 yielded 35 to 40 percent declines in airline revenues, the sharpest in history.[128] While industry performance was declining prior to the 9/11 terrorist attacks, most of the losses were a direct result of corporate travel freezes and leisure trip cancellations prompted by the attacks.[129] The ripple effects extended far beyond the airline industry. The Mikken Institute estimates the U.S. Stock Market lost $1.7 trillion in wealth by the end of the first week of trading after the attacks and approximately 145,000 jobs disappeared in 34 states by the end of 2002.[130] While history is still accounting for the long-term losses caused by 9/11, many economists including Robert Keleher, Chief Macroeconomist for the Joint Economic Committee, say that the actual losses may be even worse.[131]

In early 2005 the RAND Corporation, a nonprofit, nonpartisan research organization, released an extensive study entitled *Protecting Commercial Aviation Against the Shoulder-Fired Missile Threat.* This federally funded study was designed to inform decision-makers and the American public of the utility of protection measures, costs, and policy considerations regarding commercial aircraft and attacks from shoulder-fired missiles.[132] From this study and other points of reference, one gains valuable insight into the vital importance of the commercial aviation sector to the United States' economy and the need to protect it.

Given a simultaneous MANPADS attack on United States' soil against passenger aircraft, the terror, the profound loss of security and well-being, and economic impact could exceed that of 9/11.[133] A prolonged, multi-phased attack with follow-on assaults would certainly surpass the losses of 9/11. Economically, the RAND report considers three categories: immediate tangible losses, subsequent air travel shutdown direct losses, and long term reduced air travel demand indirect losses.[134] The statistics that follow are extrapolated from 9/11 when air travel stopped for three days and was severely disrupted for several weeks. A MANPADS attack, isolated or widespread, would almost certainly prompt another airspace system shutdown.[135]

As mentioned earlier, each 300 passenger aircraft shot down approximates an immediate $1 billion tangible loss.[136] The economic impact from the direct losses associated with the subsequent air travel shutdown would be directly dependent on the duration. RAND, using an economic welfare model, assigns direct consumer and producer combined losses at $0.5 billion for a single day shutdown, $3.4 billion for a one week shutdown, and $14.1 billion for a one month shutdown.[137] Additionally, indirect losses associated with long term reduced air travel demand would climb well into the multi-billions.[138] Fear of flying, increased security hassles, and changes in airline schedules are some of the many factors responsible for this expected reduction in long term demand.[139] RAND postulates the longer the system shutdown, the greater the reduction in future travel, and hence, the greater the overall combined consumer and producer economic loss.[140] Based on extrapolation from 9/11, RAND assigns long term indirect losses at $0.9 billion for a one day shutdown, $12.4 billion for a one week shutdown, and $56.6 billion for a one month shutdown.[141] These extrapolations are summarized in Table 7.

While RAND's extrapolations are speculative, especially the long term "future loss factors," they do provide a quantitative illustration of the economic magnitude of a MANPADS attack. Regarding long term effects, public perception definitely plays a tremendous role. Ultimately, the sooner federal officials credibly assure the American public that law enforcement officials have apprehended the MANPADS operatives and air travel is once again safe, then the less the economic impact and fear factor.[142] A prolonged shutdown would significantly increase the economic losses as noted in Table 7. Furthermore, the longer a shutdown,

then the greater the degree of social amplification of fear made readily available via multiple media sources with up close and personal, real-time coverage.[143] All in all, the longer fear permeates the American populace, then the greater the level of flying paranoia and the less people return to the skies.[144] Also, a premature resumption of service coupled with a follow-on attack would certainly prove catastrophic. Economic losses would accrue at disproportionate rates and Americans would further doubt the federal government's ability to protect them.

| **Immediate Tangible Loss per Downed Aircraft*=$1.0 (All $ in Billions)** | | | |
|---|---|---|---|
| **Total Welfare Losses from a System-Wide Shutdown=Direct+Indirect Losses** | | | |
| **Subsequent Air Travel Shutdown Direct Losses** | | | |
| | **One Day** | **One Week** | **One Month** |
| Consumer Surplus Loss** | $0.3 | $2.0 | $8.4 |
| Producer Surplus Loss*** | $0.2 | $1.4 | $5.7 |
| Subtotal—Direct Loss | $0.5 | $3.4 | $14.1 |
| **Long-Term Reduced Air Travel Demand Indirect Losses** | | | |
| Future Loss Factor | 10% Reduction (next 2 weeks) | 15% Reduction (next 6 months) | 25% Reduction (next 18 months) |
| Indirect Loss Subtotal | $0.9 | $12.4 | $56.6 |
| | | | |
| **Total Welfare Losses** | **$1.4** | **$15.8** | **$70.7** |
| **Total Extrapolated Losses=Total Downed Aircraft x $1.0+Total Welfare Losses** | | | |

**A "Downed Aircraft" is defined as one carrying approximately 300 passengers. While this may appear grossly generalized, the author's intent is to provide a numerical appreciation of the extreme cost involved with an aircraft loss. Larger Boeing, Airbus, and other "Large," "Heavy," and "Jumbo" category passenger carriers approximate this number after averaging passenger capacity and load factor.*[145]

*** "Consumer Surplus" relates to the additional value that consumers are willing to pay above current market value if that particular good or service is taken away.*[146] *With air travel, it is not readily replaceable in many situations because of time and convenience.*

**** "Producer Surplus is defined as the difference between revenue and costs" and accounts for contractual and fixed costs.*[147]

**Table 7. Extrapolated Economic Impact from a MANPADS Attack on Commercial Aviation**[148]

## Psycho-Social

Regarding follow-on attacks, this falls in line with Al Qaeda's modus operandi to execute such. Unlike 9/11 when federal officials were able to quickly implement security measures to prevent future attacks, a MANPADS scenario would prove more challenging.[149] While many of the security measures initiated following 9/11 are still criticized as minimally effective, they did provide assurance to the American people that the skies were again safe to fly, thus prompting a return to the ticket counters.[150] A shoulder-fired missile attack would not be as simple given the scope of the threat and the vulnerability of the commercial fleet.

Given an attack scenario, whether large or small, conventional wisdom based on the events of 9/11 and subsequent Al Qaeda endeavors show that the media coverage would be tremendous. With this, all government security agencies would work feverishly to curtail the assault while the American public anxiously awaited a solution. During this time, just the attempt of another attack would spike more media attention and public concern. Ultimately, Al Qaeda could find itself in a position to manipulate and frustrate the United States government and its people with random follow-ons and mere threats. Ultimately, successive attacks spread over a short period of time would likely be viewed as an indicator of more to come and have an extreme psychological impact on the flying public.[151]

Such a situation would be quite similar to the "D.C. Sniper Attacks" that occurred in the National Capital Region in October 2002. During the sniper attacks, John Allen Muhammed and John Lee Malvo kept the entire nation on pins and needles.[152] These two criminals eluded authorities for 23 days as they indiscriminately shot 13 victims, killing 10, ranging from 13 to 72 years of age as they took part in normal day-to-day activities.[153] During this time, people operated in fear, especially while visiting gas stations, parks, and parking lots where most of the attacks occurred.[154] Schools and youth groups in the area curtailed outdoor activities and trips after a specific threat against children appeared.[155] The White House described the shootings as "traumatic" and "scary" and the greater Washington D.C. area remained "on edge" until the perpetrators were caught.[156] With Al Qaeda and its ability to pervert American civil liberties into protection for its sleeper cells secretly stationed around the United

States waiting to strike, assurance by the federal government that such a MANPADS attack were over would be quite difficult to achieve.[157]

While the "D.C. Sniper Attacks" only involved two aggressors and is not a direct comparison with an Al Qaeda style operation, it does illustrate how fear can impact a society. Another situation which occurred in March 2004 in Spain provides another perspective. During rush-hour on March 11, 2004, Al Qaeda operatives set off 10 explosives within 15 minutes along a busy nine-mile stretch of commuter train line in Madrid, Spain, killing 191 persons and wounding over 1,800 others.[158] Perceived mishandling of the crisis quickly mushroomed and detrimentally impacted the government's credibility.[159] With national elections only three days away on the 14th, the opposition party won and Spain's political power basis changed overnight.[160]

Since Al Qaeda determines its time and place of choosing for an attack, the United States could find itself extremely vulnerable going into the next election given the low opinion polls of the current administration. President Bush currently has an all-time low job satisfaction rating and continues to receive criticism for the war in Iraq and his handling of Hurricane Katrina.[161] Hurricane Katrina, which left over 1,300 dead and caused tens of billions of dollars in damage in the Gulf Coast region, has especially tarnished the Commander-in-Chief's image.[162] Public opinion now sees the President's ability to handle a crisis or provide leadership as diminished along with the government's ability to protect the country.[163]

Given the staggering economic impact that a MANPADS attack could impart and the psycho-social intangibles that shape the reality of all involved, one should also consider the perceptions of the major players on the world stage. On one side are the terrorists led by Al Qaeda with a desire to dictate perception and boost their cause against the evil Western World. On the other side are the United States and its allies in the Global War on Terrorism. As these two sides carry on their various battles, "the audience is global and the primary stakes are psychological."[164] This said, should a successful attack on commercial aviation occur, then Al Qaeda and others like them would not only inflict serious loss of life and economic damage, but they would also reap profound strategic psychological gains.[165] The terrorists would likely spread propaganda embellishing their cause while imparting serious doubts about the safety of commercial air travel. Furthermore, as evidenced by past bin Laden tapes

and audios, Al Qaeda would certainly attempt to cast doubt on the viability of American counterterrorism efforts.[166] With the severity of the repercussions understood, this discussion will now explore existing and proposed solution strategies to the problem.

# V. Solution Strategies and the Way Ahead

No single solution exists for the MANPADS threat. Instead, multiple layers of defenses working in concert are the answer. Geopolitical, economic, and technological limitations serve as the primary constraints, while the seriousness of the threat and the associated repercussions motivate the sense of urgency. Figure 4 provides an overall strategy template starting with offensive operations, counterproliferation, and interdiction activities abroad while simultaneously increasing security, countermeasures, vulnerability reduction, and risk management measures at home. While no solution strategy can guarantee the desired outcomes, these measures, if pursued in earnest, collectively provide a high assurance of damage limitation and casualty reduction. Furthermore, this strategy will hopefully "buy time" by dissuading terrorists from choosing MANPADS as the United States seeks to better protect its commercial fleet.

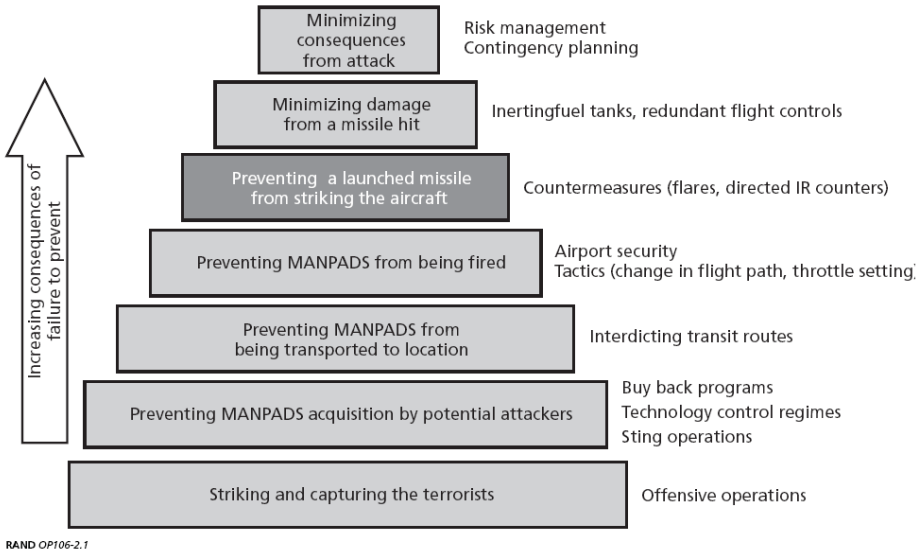


**Figure 4. MANPADS Layers of Defenses**[167]

## Striking and Capturing Terrorists

The strategy begins overseas with offensive operations on the terrorists' home turf to seize the initiative. The Global War on Terrorism has made great strides in this regard, but the timetable is continual and will take many years to complete.[168] Operation Enduring Freedom in Afghanistan has taken a tremendous toll on Al Qaeda and continuing efforts in Iraq enable U.S. forces to capture terrorists and weapon caches at the root of the problem.[169]

## Preventing MANPADS Proliferation

The next layer of defense involves nonproliferation and counterproliferation initiatives that focus on the MANPADS supply. As technology progresses with ever and ever faster computer capabilities, MANPADS become more and more lethal.[170] The international community recognizes this and is taking a concerted effort to protect the critical role of aviation in their free market economies. This includes both their economic interests and their security interests.[171] The United States has taken the lead and brokered several multilateral and bilateral agreements involving over 95 countries.[172] The U.S. Department of State (DOS) has the primary responsibility in facilitating these agreements with the U.S. Department of Defense (DoD) serving a key support role.[173]

DOS's Bureau of Political-Military Affairs leads United States diplomatic efforts to eliminate obsolete MANPADS and to improve the security of stockpiles that could wind up in terrorists' hands.[174] This includes facilitating the destruction of older hardware that is ineffective against modern military aircraft, but still a lethal threat to civilian aircraft.[175] DoD supports these efforts with expertise entailing management, control, physical security, and accountability.[176]

Another DOS entity, the Bureau for International Security and Nonproliferation focuses on preventing the transfer of MANPADS and the technology to produce them to undesirable end-users.[177] Diplomatic efforts to secure bilateral and multilateral agreements are the primary means with an emphasis on responsible export controls.[178] DoD's Golden Sentry program supports these efforts by monitoring United States' Foreign Military Sales of MANPADS to ensure that they do not fall into

the hands of criminals or terrorists.[179] The Defense Threat Reduction Agency, Defense Security and Cooperation Agency, and the U.S. Army play a vital role in this effort.[180]

The key basis of most MANPADS multilateral agreements is the Wassenaar Arrangement (WA). The WA *Elements for Export Controls of Man-Portable Air Defense Systems (MANPADS)* was agreed to in December 2000 by 33 countries.[181,182] It includes all major arms suppliers except China.[183] It recognizes the threats posed by MANPADS to civil aviation, peace-keeping, crisis management, and anti-terrorist operations.[184]

> 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.[185]

These guidelines seek to prevent MANPADS from being stolen or illicitly transferred.[186] The basic intent of the WA serves as the foundation for the multilateral agreements that follow.

The United States has obtained several multilateral agreements involving over 95 countries to adopt MANPADS export and stockpile security measures.[187] Some of the more notable multilateral agreements include the June 2003 G-8 Evian Summit in which leaders agreed to the following measures:

- Provide assistance and technical expertise for the destruction of excess MANPADS.
- Adopt stringent national export controls on MANPADS and their essential components.
- Ban transfers of MANPADS to non-state end-users.
- Exchange information on uncooperative countries and entities.

- Examine for new MANPADS the feasibility of adding specific technical performance or launch control features that preclude their unauthorized use.
- Encourage action in the International Civil Aviation Organization's Aviation Security Working Group on MANPADS.[188]

In 2005 the G-8 continued to implement these measures.[189]

Cooperation among G-8 members includes a joint United States-Russian-United Kingdom sting operation. This effort lasted 18 months and netted three arms dealers attempting to sell 200 Russian SA-18 MANPADS and import them into the United States.[190] This operation illustrated collaboration and information sharing among three of the world's most capable intelligence services that would have been unheard of just a few years prior.[191] Hopefully, continued sting operations such as this one will help to deter the supply and demand cycle of the illicit MANPADS market.

The Organization for Security and Cooperation in Europe (OSCE) followed the G-8 and adopted similar guidelines by applying the WA's *Elements for Export Controls of Man-Portable Air Defense Systems* on May 26, 2004.[192] Other organizations agreeing to multilateral MANPADS control agreements include the Asia Pacific Economic Cooperation Forum in November 2004 and the Organization of American States in June 2005.[193] Also, NATO with its Partnership for Peace Trust Fund Project is assisting the Ukraine with destruction of its excess MANPADS along with munitions, small arms, and light weapons.[194]

As far as bilateral cooperation, the United States has focused on geographic locations where there is a combination of excess MANPADS, poor control, and a risk of proliferation to terrorist groups or other undesirables.[195] In these areas, the United States works with vulnerable countries to develop nonproliferation strategies to reduce stockpiles, secure remaining weapons, and facilitate policies and procedures to control exports.[196] The United States and Russia agreed in February 2005 to destroy obsolete or excess MANPADS; exchange information regarding control and physical security; and to share sales and transfer information to third parties.[197]

Since 2003, the United States has facilitated the destruction of over 17,000 MANPADS in Africa, Central America, Eastern Europe, and

Southeast Asia.[198] This includes almost 6,000 in Bosnia and Herzegovina; 45 in Liberia; 233 in Cambodia; and nearly 1,000 in Nicaragua.[199] Also, the United States has commitments for the destruction of 6,000 more as it continues this initiative.[200] In addition to this voluntary cooperation, the United States also pursues buyback programs in such places as Afghanistan, Iraq, and other prime zones where it pays a bounty for weapons turned in for ransom.

In addition to United States efforts, the United Nations contributed a significant measure in 2003 by adding MANPADS to Category 7 of the United Nations Register of Conventional Arms.[201] This action distinguishes MANPADS separately from other missiles and missile launchers.[202] Although this is not an arms control measure, it focuses attention on MANPADS and highlights their significant threat.

While these efforts show success, the multilateral agreements are often criticized for lacking enforcement. This is because most provisions are predicated on voluntary compliance. According to the U.S. General Accounting Office, the ability to assess progress is limited by "the lack of mechanisms to monitor countries' implementation of their commitments."[203] The General Accounting Office report goes on to criticize the Department of Defense for its lack of reliable control records of Stinger missiles sold since 1982.[204] Thus, without accurate records, calculating the number of U.S. Stingers outside of responsible nation-state arsenals is an estimate at best.

Other critics note the "catch-22" of the globalized nature of the problem. With many voluntary signatories subscribing to the various agreements, members do not always agree on specifics of the threat and hence consensual decision-making is slow at best.[205] Furthermore, signatories are extremely slow to implement international policies into their national legislations or may not do so at all.[206]

Ultimately, with the vast, unknown number of MANPADS from all origins already in non-state hands or available on the black market, no one will ever know a precise count. With more than 20 countries producing MANPADS and over one million produced since they were first introduced, nonproliferation and counterproliferation efforts must aggressively continue.[207] Ideally, the various ones in existence will continue to improve and become more efficient in countering the supply.

## Interdiction

To the extent that offensive operations, nonproliferation initiatives, and counterproliferation efforts fail to keep MANPADS out of the hands of terrorists, interdiction and border security efforts must endeavor to protect the homeland and its valuable infrastructure. Interdiction efforts depend heavily on information sharing and cooperation with the 95+ nations that participate in the various nonproliferation agreements. The Central Intelligence Agency, the Federal Bureau of Investigation, the Department of Defense, and the Department of Homeland Security along with the Terrorist Threat Integration Center and the Terrorist Screening Center among others are all crucial to this process.[208]

## Border Security

As the threat gets closer to the United States, border security initiatives spearheaded by the Department of Homeland Security (DHS) enter into the equation. With over 95,000 miles of coastline and 7,514 miles of land border along with the ease of global travel, the nation's air, land, and sea borders offer many avenues for illegal entry.[209] In light of America's dependence on global trade and travel, the United States cannot isolate itself and close its borders. The efficient flow of lawful traffic and commerce is essential to a healthy economy while prevention of terrorist entry is paramount. This includes 11.2 million trucks and 2.2 million rail cars that enter the United States annually along with 7,500 foreign flagships that make 51,000 calls to American ports.[210] DHS continues to install a series of initiatives that "smarten," layer, and extend America's borders with advanced detection devices, biometrics, fused data processing, and improved policies and procedures.

DHS agencies and initiatives critical to securing the border and preventing the entry of terrorists and terrorist weapons into the country include U.S. Customs and Border Protection agencies, the Transportation Security Administration, the U.S. Coast Guard, the National Targeting Center, the Customs-Trade Partnership Against Terrorism (C-TPAT), and the Container Security Initiative (CSI) among many others.[211] These originated with the creation of DHS in March 2003 and continue to mature. Several of these endeavors involve international cooperation and

extend the United States' borders outward. The CSI enables the United States to station inspectors at 42, soon to be 50, of the world busiest shipping ports and inspect cargo before it starts its final voyage to American soil.[212] This equates to spot-inspection opportunities thousands of miles away from the homeland for nearly 90 percent of the trans-Pacific maritime cargo entering the United States.[213]

Despite the tremendous progress made in a relatively short time, defeating MANPADS and other illicit threats at the border is a gargantuan task. The borders continue to have exploitable seams which require precious time and billions of dollars to secure. This is another reason the overall solution strategy requires a series of congruent defenses. Ultimately, time and politics will determine the success or failure of these efforts. Hopefully, the legislative and executive branches can keep these essential processes on track and not let special interest haggling over illegal immigration and trade leave the backdoor to the homeland wide open to terrorist attack.

Should all efforts to counter MANPADS outside of America's borders fail and terrorist operatives smuggle MANPADS into the United States or into close proximity to foreign airports frequented by American carriers, then the top four layers of defense illustrated in Figure 4 must provide protection. These layers are:

1. Prevent MANPADS from being fired,
2. Prevent them from hitting an aircraft,
3. Minimize their damage, and
4. Minimize their consequences.[214]

These areas are the most challenging and lag the farthest behind. On the international scene, commercial aviation assets are considerably more vulnerable. With numerous scheduled passenger and cargo flights transiting destinations with a known terrorist presence such as Central and South America and other points depicted in Figure 3, these top four defenses are extremely important.

## Airport Security

Airport perimeter security within the United States and some of America's allies is one of the most expedient measures available to help prevent a MANPADS from being fired. Heightened security, surveillance, and patrols of the immediate vicinity of the airport and the approach and landing corridors can deter and/or defeat the MANPADS threat significantly when effectively coordinated. This layer of defense incorporates threat and vulnerability assessments so airport and airspace managers can work with law enforcement officials to determine locations on and beyond the airfield with the greatest threat potential.[215] Using this logic, security measures are focused on high risk areas where arriving and departing aircraft are most vulnerable. This approach in military lexicon is known as reverse intelligence preparation of the battlefield (reverse IPB). While this layer of defense is readily available, its effectiveness varies tremendously based on location. In densely populated areas perimeter security measures require tremendous manpower and are intelligence intensive. In more rural settings with low density traffic, perimeter security measures are much more effective.

In terms of scope, the MANPADS threat envelope extends approximately three miles in range and up to 15,000 feet in altitude. The approach and departure paths place a typical aircraft in this threat envelope for approximately 10 to 15 minutes and generally encompass approximately 300 square miles in geography for a single runway.[216] In some high density airspace environments the vulnerability envelope greatly exceeds this estimate because of numerous complexities and constraints associated with air traffic saturation and urban areas. The New York City corridors vulnerable to shoulder launched missiles for the area's various airports exceed 1,000 square miles and include upwards of 10,000,000 people.[217] Los Angeles International includes 870 square miles of MANPADS vulnerable area with 6,800,000 people and 2,500,000 housing units.[218] When one ponders these statistics along with the cover provided by urban structures and the availability of many major freeways for easy access and escape, the challenges associated with perimeter security are quite obvious.[219]

For illustration purposes, consider the crowded airspace surrounding LaGuardia International in New York City illustrated in Figure 5.

LaGuardia shares some of the busiest airspace in the world with Newark International and JFK International along with several other smaller airports in close proximity. The vast volume of air traffic along with multiple national symbols such as the Statue of Liberty, Wall Street, Broadway, Central Park, the United Nations, numerous sky scrapers, and millions of people make New York incredibly complex.[220] With numerous over-flight and noise abatement restrictions integrated into hundreds of arrival and departure procedures designed to de-conflict thousands of aircraft, operational constraints further increase the time aircraft are in the MANPADS envelope.[221]

**Figure 5. LaGuardia and Lower Manhattan**[222]

With Figure 5 in mind, try to imagine how an organized force could reliably patrol such an area on a continuous basis and not infringe upon civil liberties. For example, consider a high-rise apartment complex with

multiple ethnicities looking out on the approach path of one of the nation's busiest airports and occupied by an Al Qaeda sleeper cell. If such a situation were to develop with operatives and armament in place, how likely would perimeter security measures prevent an attack? The answer is unknown and speculative at best. Civil liberty protection, fought for and protected by American citizens, certainly complicates the surveillance of such individuals. While this is merely a hypothetical scenario, it is just one of a multitude of examples that illustrates the many challenges complicating the task of effective perimeter security. Furthermore, with nearly 400 primary airports in the United States and each possessing unique security considerations, the surveillance and patrol staffing requirements are tremendous.

Information sharing, intelligence, and interagency coordination are essential to the success of perimeter security. While it is impractical and arguably illegal to survey high rise apartment complexes and other potential launching points under the approach and departure paths of the nation's airports without probable cause, successful perimeter security requires integration of all threat intelligence so that limited resources and manpower can be efficiently and effectively employed. Multiple private, local, state, and federal security and law enforcement players figure into the equation with the Federal Bureau of Investigation (FBI) leading the way. All of these entities are generally flexed to the maximum extent to handle their current taskings and can ill afford to be used in an ineffective manner.

Ultimately, given the scope of the geography and the various complexities, the perimeter security layer of defense is helpful since it is readily available, but certainly limited. Given the potential of Al Qaeda's sleeper cells to attack without warning, perimeter security is certainly a useful deterrent if needed short-notice or to calm public fear should an attack occur. Hopefully, as technology advances, some countermeasure systems currently under development will greatly enhance perimeter security effectiveness.

## Tactics

Two other measures that contribute to preventing a MANPADS launch involve air traffic control (ATC) procedures and pilot technique.[223] Both of these are location-limited as just discussed regarding high density

traffic areas. Theoretically, when airspace congestion permits, ATC departure and arrival routings can minimize aircraft time in the MANPADS threat envelope below 15,000 feet altitude and randomize the routes of aircraft under vectored control. In low density traffic areas these concepts are feasible. Departing aircraft can climb immediately to higher altitudes without being held lower for traffic considerations. Similarly, arriving aircraft can remain at higher altitudes until flight characteristics, vice routing considerations, dictate descent for landing. In such environments as New York and Los Angeles, among many others, the sheer volume of conflicting traffic simply does not permit such options because the airspace is just too saturated.[224] However, many relatively isolated aerodromes ranging in size from small to large do lend themselves to further study by the Federal Aviation Administration (FAA) to employ these tactics.

Hand-in-hand with ATC procedures is pilot technique which also offers viable options to minimize the potential of a MANPADS hit. When ATC descent and routing limitations allow, pilots can use minimum power settings during arrival and approach and lower infrared emissions tremendously. This significantly minimizes an older generation missile's chances of success. While many factors such as strong tailwinds, turbulence, thunderstorm avoidance, pilot workload, and a whole host of other challenges must be accounted for during arrival and approach procedure design, lower power setting profiles, if properly employed, can definitely reduce a MANPADS effectiveness.

In the context of pilot technique, many assume evasive maneuvering is also a viable option to defeat a shoulder launched missile. Simply put, this is not true. Large transport aircraft are minimally maneuverable and are far more likely to suffer structural failure and/or a loss of control than evade a MANPADS.[225] Furthermore, passenger injuries in such an event would be extensive.

## Technical Countermeasures

As the ominous MANPADS threat is addressed, all viable solutions must be incorporated into the overall solution strategy. Next, countermeasures (CMs) to defeat MANPADS will be explored. Generally, these are reactive in nature and may be aircraft mounted or

ground-based. Current CMs and ones in development will be addressed including prototypes presently being tested by the Department of Homeland Security.

Currently, many military aircraft employ various onboard CM systems depending on mission, threat environment, and operational risk. Commercial aircraft, in contrast, are defenseless with Israeli airline El Al and its 34 aircraft being the primary exception.[226] Critics, led by key figures in airline industry, cite several arguments against fielding CMs on commercial aircraft. Acquisition and life cycle costs are the primary concerns along with logistics, operating costs, safety, environmental, and reliability issues.[227] Perception is another serious concern with the airline industry afraid that CMs might amplify the fear of flying.[228] John Meenan, Executive Vice President and Chief Operating Officer for the Air Transport Association, said outfitting commercial aircraft with CMs would be a "multi-billion [dollar] mistake…"[229] All in all, given the financial state of the industry with several major legacy carriers in Chapter 11 bankruptcy, much of the opposition boils down to financial fear. The airlines simply are not in a position to support CMs regardless of how essential they might be because they will have to shoulder part of the expense.

As far as actual CM systems, those onboard which require little or no flight crew intervention are preferred.[230] Onboard protection allows aircraft to go into a threat environment without relying on pre-positioned security measures. In many countries frequented by U.S. carriers, ground security measures are often inadequate, and depending on foreign relations or other host nation constraints, ground-based CMs would not be feasible.

In terms of CM performance, missiles hold the advantage over the various defenses. Throughout the history of MANPADS, current and emerging technology has kept the missiles even or ahead of the respective CMs. The seemingly endless cycle of missile, CM, counter-CM has methodically progressed with no leaps in defensive technology.[231]

Rotor and fixed-wing military losses by the Soviets/Russians and the United States illustrate this fact. The Soviets suffered tremendous losses in Afghanistan during the 1980s, while the Russians frequently lose aircraft in Chechnya today.[232] The United States suffered losses over Yugoslavia and subsequently had to change its low-level tactics.[233] Most recently in Iraq, the limited ability to counter MANPADS drastically

affects which air mobility assets are allowed into Baghdad and other similar threat level locations.[234] This limitation impacts forward basing options and drives inefficiencies in the U.S. air logistics system.[235] All in all, every time a countermeasure evens the score, then a more advanced missile enters the fray. Ultimately, in the context of commercial aircraft, almost any missile is potentially lethal since there are no countermeasures installed for protection and proposed defensive measures must account for all MANPADS variants, old and new.

Recall from the earlier section, *MANPADS—Defined and Quantified,* that countermeasure systems include two critical subsystems, the missile warning system (MWS) and the actual countermeasure. The MWS must first detect an incoming MANPADS and then inform the countermeasures system to fool, blind, spoof, or degrade the incoming missile.[236] Today's CM systems are predicated on a reactive strategy in which the MWS is only capable of detecting an attack after the missile is launched.[237] This makes the MWS's ability to detect the launch and command an active defense extremely time critical since the duration between launch and impact is only five seconds. Technology drives this situation and will remain a constraint until a leap in technology occurs that allows proactive measures to detect and disable the MANPADS before launch.[238]

Within the limitations of existing technology, CM systems must distinguish between ground clutter, solar effects, various atmospheric phenomena, and a host of other distracters while attempting to reliably detect a missile using passive, reactive means.[239] With this, MWS sensitivity is a fine balance between detection capability and false-alarms. In the confined urban environment of most commercial airports, false alarms cause safety, expense, and perception problems. Pandora's box of challenges is over-running but solutions are achievable.

MWSs mounted on tethered aerostats and strategically positioned around a given airfield could enhance detection capability and minimize false alarms.[240] Such warning systems could be data-linked to each arriving and departing aircraft's onboard MWS. These statically mounted MWSs could better distinguish actual MANPADS launches from ground clutter, solar glint, and other local effects, thus drastically reducing false alarms.[241]

In the context of detection, MWSs' accuracy can be enhanced with multi-spectral imaging in which several parts of the electromagnetic

spectrum are used.[242] In newer MWSs, false alarms are minimized by use of filters. Multi-spectral IR launch signatures for all know MANPADS as programmed into the MWS and serve as "clutter-rejection" filters and decrease false alarms. Thanks to increased computing capability, multi-spectral imaging, and clutter rejection filters, later generation MWSs enjoy much better speed and accuracy.[243]

Another measure to enhance detection capability integrates pulse-doppler radar into the search logic.[244] Radar emissions in a military combat environment can compromise the presence of an aircraft and do more harm than good. In a civilian setting this is not a concern since the given aircraft is obvious.[245] All in all, the capabilities of current CM systems lag the counter-CMs of many of today's more modern MANPADS, but solutions are achievable. Next, CM systems currently fielded or ones approaching production will be discussed.

The military is the primary proving ground for CMs. For several decades, flares have served as the primary means of defense for military aircraft against MANPADS. By concept, they emit intense IR energy in an attempt to fool the MANPADS seeker head into breaking lock from the targeted aircraft and chasing the flare itself.[246] They can be released preemptively or in response to an actual MANPADS attack detected by an aircraft's MWS.[247] Today, conventional, advanced, and covert flares exist with varying degrees of effectiveness against IR-guided missiles and have absolutely no effect against laser beam riders and radio controlled, command line of sight (CLOS), MANPADS.[248]

Conventional flares are effective against first and some second-generation MANPADS which use IR energy as their sole emission source for target acquisition.[249] More advanced seeker heads distinguish between flare bursts that emit a single band IR signature and travel away from the trajectory of the originally intended target.[250] Advanced flares, in contrast, include a cocktail of different intensities and wavebands, also referred to as colors, that burn at different temperatures and attempt to mimic the spectral signature of an entire aircraft.[251] This enables advanced flares to defeat second and some third-generation missiles that discriminate intensity and spectral properties in addition to simply chasing IR signatures.[252] While advanced flares are much more capable than conventional flares, they are more expensive and essentially useless against seekers that incorporate pseudo-imaging.[253] Furthermore,

conventional and advanced flares pose a significant fire-risk, especially in urban settings where most major airports are located.[254]

The third type of flare, the covert flare, has very little visible signature and poses a significantly reduced fire risk. [255] Instead of burning, these flares self-ignite when exposed to oxygen and yield very little visible effect. Also, they provide better signature matching than pyrotechnic flares. For these reasons, covert flares offer promise in the perception-conscious airline industry in terms of fear factor and ground-fire hazard and overcome some of the counter-CMs of later generation IR-guided MANPADS. Despite these advantages, their overall effectiveness against mid and later generation MANPADS is lacking and requires further advances.

All in all, while flares are readily available today and effective against the widely proliferated first generation MANPADS, they do not offer a reliable solution to the entire MANPADS threat dilemma. With costs projected into the $40 billion range to outfit and maintain the entire United States' commercial fleet, the CM system chosen must be more reliable against a greater spectrum of threats.

Another, more capable class of CMs is infrared countermeasures (IRCM). IRCMs use IR energy to confuse IR-guided MANPADS with either lamp-based or laser energy.[256] The lamp-based systems are "area in nature" and emit a broad radiation pattern that jams the guidance system of many IR-guided missiles. They require an up-to-date library of threat-seeker codes to ensure optimum performance.[257] They can be employed preemptively on a continuous basis or upon attack.[258] While these can protect a C-130 size transport aircraft, one shortcoming is their jammer-to-signal ratio is too small to protect larger aircraft such as the C-17, C-5, Boeing 757/767/777/747, and other similar large aircraft.[259]

Newer IRCM systems use directed IR energy in the form of laser beams to increase the power concentration and overcome the jammer-to-signal ratio limitation of the lamp-based systems.[260] These are known as directed IRCMs (DIRCM) and employ a slewable turret to precisely aim a laser beam at an incoming missile.[261] Northrop Grumman's Large Aircraft Infrared Countermeasures (LAIRCM) program includes systems capable of protecting larger aircraft including C-17s.[262]

LAIRCM systems operate by directing concentrated laser energy into the missile seeker head with the necessary accuracy, concentration, and at

the correct wavelength to drive the missile off course.[263] Like the lamp-based systems, DIRCM systems also require an up-to-date library of threat-seeker codes to ensure optimum performance.[264] Some of the more advanced ones are "threat adaptive" meaning they analyze a particular MANPADS' reflective signature in flight and adapt to the threat's specific codes.[265] All in all, DIRCM systems are extremely complex; much more so than the lamp-based IRCMs and flares. After initial detection by the MWS, DIRCMs must constantly maintain precise contact with the targeted seeker head. Onboard tracking sensors enable such and continuously slew the turret so the concentrated laser beam is properly aimed.[266] According to RAND, "A single-turreted laser-based countermeasure system would have good effectiveness against single shots by the majority of current MANPADS threat types and some dual coordinated firings, but would not fully protect against all possible attacks."[267]

Today, DIRCM systems are the most advanced CMs available and deployed on over 300 United States military aircraft including C-17s and C-130s.[268] Northrop Grumman and BAE Systems are leading the way with DIRCM technology.[269] However, they do have their limitations in terms of cost and are ineffective against laser beam riders, CLOS missiles, and focal plane imaging IR seekers.[270] Since these MANPADS categories are the least proliferated and DIRCMs protect against virtually every other kind of missile, DIRCMs offer the best protection of any CM system currently available.[271]

All of these CM systems represent billions of dollars and years of research by industry and the United States government.[272] While the current systems offer excellent defenses against most MANPADS, all are reactive in nature and none are comprehensive against all threats.

The Defense Advanced Research Projects Agency (DARPA) hopes to develop capabilities predicated on a proactive posture. It is leading the Multifunction Electro-optics for Defense of U.S. Aircraft (MEDUSA) program which seeks to develop a future generation aircraft-mounted, laser-based, multi-spectral system that is capable of both proactive and reactive CMs against IR and electro-optical threats.[273] In the proactive sense, MEDUSA would eliminate the threat before it is launched. In the reactive sense, it would counter the threat in much the same way as current DIRCM systems, but would be capable of jamming several different

frequency bands at once.[274] The lofty goals of MEDUSA will need to develop a multifunctional laser or system of lasers capable of 30 watts in a small, affordable package that currently does not exist.[275] If DARPA is successful with MEDUSA, then MANPADS defenses will be lighter, less expensive, and effective against IR, laser beam, and CLOS-guided missiles.[276]

While MEDUSA is midterm in regard to availability timeline, a future concept seeks hard-kill lasers.[277] This proposal would bypass the complexities associated with multiple, constantly changing signatures associated with today's reactive jamming approach. Instead, hard-kill lasers would detect, track, and then destroy hostile threats targeting an aircraft instead of just misdirecting them.[278] Such a system would effectively counter all types of MANPADS and potentially rocket propelled grenades and other similar threats.[279] Mature laser technology is the greatest hurdle stopping such a system at this point. Cost, capability, weight, volume, and performance of such a system all require significant improvements.[280] For MANPADS defense, two general categories exist, solid-state and chemical.

Solid-state lasers offer the most promise for a compact, durable weapon, but fielding a system is 20 years away. Solid-state lasers have technological and engineering shortcomings at this time, but offer a continuous flow of ammunition limited only by electrical power. Eventually this laser concept will be more suitable to airborne application because of its smaller size and greater firepower.[281]

Compared to solid-state lasers, chemical laser technology is further along and has enjoyed a steady stream of success. Northrop Grumman and Boeing have systems well underway in their design pipeline. Chemical lasers greatest drawbacks include their large size and limited "magazine" of shots, requiring chemical reload. Chemical storage, mixing and waste along with thermal waste are other challenges associated with chemical lasers.[282] Despite the shortcomings associated with both solid-state and chemical lasers, these systems offer promise for the future.

A hard-kill laser concept that is not so far away is a ground-based system. Northrop Grumman has a chemical, ground-based, mobile, tactical, high-energy laser (MTHEL) test-bed that has successfully destroyed missiles and rockets in flight and could potentially be ready for production in three years.[283] A palletized version of MTHEL known as

Hornet could greatly augment airport security.[284] It includes a radar air picture, tracking system, and megawatt chemical laser.[285] With aircraft corridor adjustments to minimize exposure, an airport such as Reagan National would require a minimum of three Hornet-like systems to properly secure it against MANPADS.[286]

The advantages of a ground-based hard-kill system are significant. The capability to counter every current and foreseeable future seeker technology with an actual kill instead of depending on guidance jamming is significant and simpler in the long run.[287] This includes not only MANPADS, but also artillery, rockets, and unmanned vehicles, along with other missile threats.[288] Cost could be significantly less with a ground-based system than with an aircraft mounted system depending how it was employed. For example, CONUS based aircraft flying domestic routes could potentially forego onboard CMs and rely solely on MTHEL-like CMs. This would drastically reduce logistical complications, fuel burn, and both short and long term airline specific operating expenses.

On the negative side, foreign airports would not be conducive to such a system in many countries. Such a system would require intense security to protect the hardware, operators, and secretive technology. Potential fratricide would also be a concern. Such a system would certainly have to be perfected to prevent a passenger jet from inadvertently taking a laser strike or someone losing their eyesight to a laser beam.[289]

Another future MANPADS defense involves high power radio frequency weapons or high power microwaves. These microwave systems can produce either narrowband beams in long pulses or wideband beams in very short pulses, also called ultra-wideband. Narrowband beams are concentrated and wideband beams are "area in nature."[290] In sufficient concentrations, microwave weapons can severely impact guidance systems of all missile types. Such a system can also cause collateral damage to "friendly" airborne assets, especially wideband types, but Raytheon seems to be well on its way to finding a solution.[291]

Raytheon has a microwave system in development known as Vigilant Eagle that offers great potential. It is ground-based and could be deployed within 12 to 18 months from an official government tasking.[292] Furthermore, the waveform used is a generic modulation that is a focused, precisely steered beam of electromagnetic energy designed to disrupt a MANPADS' internal electronics and divert it off course.[293] Vigilant

Eagle could handle multi-round engagements.[294] Also, the proposed waveform reportedly would not interfere with aircraft avionics.[295] In conceptual terms, the system would consist of detection and tracking devices mounted on various tall structures around a given airfield which would command a ground-based, directed energy, high-power-microwave amplifier transmitter (HAT) in the event of an attack. [296] This would effectively provide a protective dome around an airport and scramble an incoming missile's electronics and drive it away from its intended target.[297] Such a system, if installed at 53 of the busiest U.S. airports, would protect 84 percent of the total stateside air traffic for a fraction of the cost of an aircraft-mounted DIRCM system.[298]

The biggest problem with a ground-based system is the vulnerability of international flights flying into foreign destinations without any protection. While many locations would welcome a protective system, security, maintenance, and funding issues require resolution. The civilian reserve air fleet (CRAF) is another reason that ground-based systems are criticized. Many key decision-makers see aircraft mounted CM systems as a portable, last line of defense. This is especially true regarding the CRAF which provides irreplaceable troop and cargo transport during time of war. Many feel the CRAF is a primary MANPADS target and needs an onboard CM system.

Ideally, within the realistic constraints of present and near-term technology, an onboard DIRCM system augmented by a ground-based system that coupled MTHEL-like hard kill laser capability with a Vigilant Eagle-like microwave CM would offer the best defense. Considering the colossal financial requirements and unknown timelines involved with fielding such an "ideal" system, one has to weigh many competing factors. Ultimately, good stewardship balanced against risk and a timely response is critical.

In light of the viable options currently available or in the near term, the threat demands attention now and not later. While several military CM systems are operational with varying degrees of capability, all have their shortcomings. MANPADS performance trends of increased seeker sensitivity, increased CM resistance, earlier target detection, increased lethality, longer range, faster speed, and smaller launch signature are disturbing to defensive system engineers and demand continued research and development diligence.[299] Steadfast pursuit of improved DIRCM

systems along with further development of hard-kill and microwave CM systems is an absolute necessity. Ultimately, as time passes, the window of opportunity opens wider for Al Qaeda and other terrorist adversaries to strike undefended commercial aircraft. Given the urgency of the situation and CM systems available, steps must be taken immediately to defend the civilian fleet.

## The Department of Homeland Security

The Department of Homeland Security (DHS) is currently overseeing measures to fulfill this void with its Homeland Security Counter-MANPADS Program. It is tasked by Congress to manage the development of a commercially compatible CM system for the nation's passenger fleet. DHS's intent is to re-engineer existing military technology consistent with airport operations and commercial air carrier logistics, safety, maintenance, support, training, and operational tempo constraints[300] This program stems from legislation first introduced in 2003 directing DHS "to prepare a plan for the development and demonstration of a counter-MANPADS device suitable for equipping commercial aircraft."[301] The general requirement of the counter-MANPADS system is to "protect airliners the size of a Boeing 737 or larger during take-off and landing (for 10 minutes on each occasion) against threats ranging from the SA-7 to the SA-18, Stinger and equivalent designs."[302] Performance standards call for the following:

- Minimum of 90 percent success against multiple launches.
- Minimal of 80 percent success against two missiles with simultaneous impact times.
- False alarms not to exceed one per every 100 take-offs or landings, or 17 hours of operation, whichever is the lower.
- Maximum weight of 1,000 pounds.
- Total drag increase less than 1 percent at cruise speed and altitude.[303]

DHS originally started a 24-month program in January 2004 to fulfill this tasking. Initially, 24 applicants submitted concepts and three were

chosen for phase I. Following the first phase, BAE Systems and Northrop Grumman Corporation emerged as the remaining finalists.[304] Each company was awarded $45 million to complete phase II and develop a commercially viable prototype that applies existing military DIRCM technology. Northrop Grumman unveiled its prototype called Guardian, pictured in Figure 6, in November, 2005. Guardian is pod-mounted and draws from Northrop Grumman's Nemesis system installed on several hundred military aircraft.[305]

**Figure 6. Northrop Grumman's Guardian**[306]

BAE Systems also unveiled its prototype called JETEYE, pictured in Figure 7, in November 2005. Like Guardian, it leverages DIRCM technology but it differs in that it is primarily internally mounted.[307] This will likely make it more involved to install; however, its aerodynamic drag component is less than Guardian thus saving significant amounts of fuel over time due to less aerodynamic drag. JETEYE is based on BAE's Advanced Threat Infrared CM (ATIRCM) system developed to protect military aircraft. All total, BAE has delivered more than 14,000 IRCM systems worldwide.[308]

Both the Guardian and JETEYE prototypes are undergoing flight testing and integration validation to ensure they meet program criteria. Originally, the program was set to end after the completion of phase II, but $110 million of additional funding was recently approved for continued prototype vetting and expanded research and development.[309] Phase III will continue testing Guardian and JETEYE to further assess performance, reliability, logistics, cost, potential liability issues, and technology protection considerations.[310] This testing is set to conclude in 18 months

with results due to Congress in 2008. Phase III will also explore the potential of three other CM systems. L-3 Communications AVISYS Corporation ($1.4 million), Northrop Grumman Space Technology ($1.9 million), and Raytheon Company ($4.1 million) were awarded contracts in October 2006 to demonstrate their counter-MANPADS systems over the same period.[311]

**Figure 7. BAE JETEYE**[312]

The L-3 Communications AVISYS Corporation will perform interoperability and allocation analyses of its off-the-shelf, pulse Doppler, Civil Aircraft Protection System (CAPS2) warning subsystem technology.[313] Northrop Grumman will develop an operational concept for using its MTHEL ground-based, high-energy laser, hard-kill system in a civilian aviation environment. It will also perform component testing and assess life-cycle costs. This civilian version, known as Skyguard, is projected by company officials to be one-fourth the size and one-half the cost of MTHEL while also being more powerful and more efficient.[314] Raytheon will demonstrate the suitability of its Vigilant Eagle Airport Protection System to function in a civilian environment and protect aircraft of all types from MANPADS. Vigilant Eagle is a ground-based system that uses steered electromagnetic (microwave) energy to drive its intended target off course and offers significant savings in terms of installation, operation, and support costs when compared to aircraft-borne systems.[315] In summary, these three new entrants into the DHS Counter

MANPADS Program offer nearer term capability and potential cost relief given more competitors in a high-stakes market.

With more than 6,800 aircraft and 400 airports, cost, logistics, security, and system capability constraints will continue to offer formidable challenges.[316] Although existing CM systems have only limited or no capability against laser beam riders, CLOS systems, and third and fourth generation IR systems as previously discussed, the proliferation of such MANPADS is minimal thus making the DIRCM based Guardian and JETEYE prototypes close to acceptable in terms of aircraft-mounted capability. In other words, these two systems boast the ability to defeat almost all of the most advanced IR MANPADS that are known to be in non-state hands.[317]

Cost on the other hand is the most limiting concern at this point with DHS capping the installed price per aircraft at $1 million.[318] BAE and Northrop Grumman both project their respective systems will be well under the limit with BAE advertising $650,000 per system installed and ready for flight.[319] Furthermore, in terms of cost, life-cycle expense is even more critical. Traditionally, this is three times greater than the initial acquisition cost of an IRCM system.[320]

Reliability is key to keeping life-cycle cost down. Additionally, in an airline environment, the ripple effect of an aircraft taken out of service for flight essential equipment wreaks havoc on passenger connections and costs exponentially in lost revenue.[321] DHS is calling for a mean time between failure (MTBF) rate of 3,000 hours as a threshold goal with the program's objective set at 4,500 hours.[322] The current military systems on which Guardian and JETEYE are based have a MTBF rate of 200-300 hours.[323] Obviously, to fence long-term cost overruns, reliability is a DHS emphasis item.

With cost and system capability still under the microscope, it is no surprise that the CM program was extended with phase III. This will allow further research, development, and testing of the two aircraft-mounted DIRCM systems plus better exploration of the new phase III entrants.

As far as system costs comparisons which are predictive at best, a ground-based Vigilant Eagle-like system could protect 84 percent of the stateside traffic if installed at 53 of the nation's busiest airports.[324] Raytheon projects a cost of $25 million per airport which would total

$1.325 billion if their initial estimate is accurate.[325] While conventional wisdom warns that such estimates are often optimistic, if remotely close, the savings would be tremendous when compared with the airborne option.

The RAND Corporation study cited earlier provides a cost projection for the airborne DIRCM option. The installation cost is estimated at $11 billion if all 6,800 passenger aircraft are outfitted.[326] Also, more than another $2 billion per year for maintenance over the projected 10-year life cycle of the system along with other expenses would be required to field and maintain such a system.[327] Table 8 summarizes and further details RAND's cost expectations for an airborne DIRCM system.

**Total Airborne DIRCM System LCC Estimates (FY 2003 Dollars, Billions)**

| Cost Element | Estimate (FY-2003 Dollars) |
|---|---|
| Installation | $11.2 |
| RDT&E | $0.45 |
| Production Start-Up | $0.17 |
| Initial Spares and Test Benches | $0.90 |
| A & B-Kit Procurement & Aircraft Retrofit (Based on Qty of 6,800) | $9.75 |
| O&S (Phase-In and Ten-Year Service Life After FOC)* | $27.0 |
| A & B-Kit Maintenance | $12.5 |
| Added Fuel** | $4.2 |
| Cost Growth/Uncertainty (25 Percent) | $4.2 |
| Tech Upgrade Sustainment Cost | $4.1 |
| Net Revenue Loss of Delayed Passengers | $2.0 |
| **Total LCC Estimate** | **$38.2** |

**If an RDT&E phase begins in FY 2004, the first year of procuring DIRCM-modification kits for retrofitting commercial aircraft is assumed to begin in the FY 2007 timeframe. Phase-in of O&S costs for the first configured aircraft begins in this fiscal year and continues until the last commercial aircraft is retrofitted in FY 2013. O&S cost continues once full operational capability (FOC) of all aircraft is completed in FY 2014, and costs are estimated annually for a ten-year service life through FY 2023.*

***Author's Note: With fuel cost based on FY 2003 dollars, this figure is considerably low.*

**Table 8. Total Airborne DIRCM System Life Cycle Cost (LCC) Estimates (FY 2003 Dollars, Billions)[328]**

Industry proponents of airborne DIRCM systems from BAE and Northrop-Grumman dispute RAND's cost data saying that they can produce their respective system for far less and that RAND's data is a year and a half out-of-date.[329] While these individuals are salesmen for their respective companies, it is quite obvious that the critical CM piece of the overall solution strategy requires further study. Regarding cost, when one considers the immediate tangible loss per downed aircraft approaches $1 billion, then the cost of an effective MANPADS CM system for less than $1 million seems small.[330] When this matures, DHS officials will present the Administration and Congress with viable aircraft mounted and ground-based aircraft protection options for consideration.[331] Also included in this debate will be the question the airlines fear almost worse than the threat, "who pays?"[332] In the mean time, the final two layers of defense in the overall solution strategy – vulnerability reduction and minimizing consequences – are next.

## Vulnerability Reduction—Minimizing Damage from a Missile Hit

Vulnerability reduction measures primarily focus on minimizing the level of damage that a MANPADS can inflict on an aircraft.[333] Also included in this context are passive means to reduce a MANPADS' ability to strike. In general, most of the vulnerability reduction, also known as survivability, measures are cost prohibitive in terms of retrofitting existing aircraft.[334] However, if incorporated into the initial design of a new airplane, then such measures as are quite plausible. Examples include:

- Redundancy and separation of flight controls and hydraulic systems.
- Hydraulic fusing (self-sealing hydraulic lines and isolation measures).
- Improved fire suppression and containment capabilities.
- Inerting fuel systems so the fuel within is not a secondary explosion threat.
- Installation of fuel shut-off valves and self-sealing fuel lines.

- Hardening of vital areas within close proximity to the MANPADS-targeted, high IR signature components of the aircraft such as the engine pods and immediately adjacent wing or fuselage areas.
- Reducing the exhaust temperature of the engines for less IR signature.[335]

The new Airbus 380 incorporates several of these self-protective measures and will likely be required to carry a missile defense system within the next two years.[336]

As far as passive means, one inexpensive protective measure is painting airliners with a non-reflective, flat paint. This would reduce the aircraft's IR reflectivity and visual profile.[337] While an aircraft cannot be entirely "camouflaged" in the IR spectrum, such a measure would mitigate the IR missile threat to some degree.[338] Furthermore, since MANPADS involve a human operator, a reduced visual profile would hinder visual acquisition and essentially shrink the threat envelope in varying degrees.[339] Granted, flat paint only provides a small level of protection against MANPADS, but it is the sum of all the defenses that tips the odds in favor of the aircraft instead of the missile. All in all, while flat, camouflaging paint is simple and readily available, the airlines abhor the idea.[340] According to the Congressional Research Service, flat paint would acknowledge the threat and upset passengers.[341] As noted before, perception management can cost an airline billions. This lack of acknowledgement of the problem is poor and leads into the final layer of defense.

## Minimizing Consequences

If and when an attack ever occurs, which certainly seems likely, contingency planning and risk management measures need to be established, funded, trained, and ready to execute.[342] National security, the economy, and the American way demand such. As discussed in the *Economic and Psycho-Social Repercussions* chapter, the extent of indirect losses from an attack is directly proportional to the length of a system shutdown. The ability to reopen the skies and avert economic disaster depends on reestablishing security and providing credible and well coordinated information in a timely manner. Otherwise, passengers and

air cargo sit while the economy and public confidence spirals downward. In such an event, strong leadership founded on substantive and accurate information is essential to allay the psycho-social impact and restore confidence in day-to-day life. Failure to have pre-established plans would result in utter chaos with exponential repercussions.

Some of the key stakeholders and their respective roles include:

- Department of Homeland Security (DHS)—Proactively facilitate contingency planning and ensure a national communication system is in place to ensure and simplify interagency communication during a crisis.
- Transportation Security Administration (TSA)—Conduct vulnerability assessments at all primary airports with priority given to those with the highest traffic count and greatest risk.
- Federal Bureau of Investigation (FBI)—Coordinate TSA vulnerability and risk assessments with all applicable federal, state, local, and private law enforcement and security agencies. With this effort develop integrated plans for each airport to ensure prompt apprehension of any MANPADS attack perpetrators.
- Federal Aviation Administration (FAA)—Develop and then stand ready to enact altered air traffic procedures to mitigate the MANPADS risk. In the event of an actual attack, facilitate the orderly shutdown of the nation's airspace as dictated and the subsequent reopening when conditions allow.
- Department of Defense (DoD)—Organize, train, and equip personnel and resources to protect the nation's air transportation system. These forces would be directed by U.S. NORTHERN Command and integrated with assets and agencies from the other key stakeholders. Furthermore, DoD should identify efficient and effective uses of its vast air, land, and sea transportation assets to sustain the nation's economy in the event of a MANPADS attack prompting a prolonged air system shutdown.
- Congress—Study and debate the feasibility of a government aircraft hull and liability insurance program.[343] In light of the staggering costs and subsequent legislative liability debate

> regarding the four lost aircraft from 9/11, a MANPADS scenario could exceed those losses and plague the system for an indefinite time with subsequent attacks. In such an event, commercial insurance rates would likely sky-rocket and exacerbate the economic side of the disaster thus potentially forcing carriers to ground their fleets. Such a program, if preemptively pursued and ready for execution, could actually serve as a deterrent to would-be terrorists targeting the United States economy.[344]

While these are only a few suggestions regarding MANPADS consequence and risk management measures, they should provide ideas for consideration. Ultimately, if proactive planning and interagency coordination are not fully in place when a MANPADS event occurs, then effective solutions will not be available when needed most.

In summary, no single solution to the MANPADS threat exists. Instead, a layered solution strategy ranging from global to local efforts must be continuously pursued in parallel. Internationally, counter and non-proliferation programs must endeavor to keep MANPADS and other terrorists' enablers out of the hands of rogue, non-state organizations. For those MANPADS already in adversarial hands, offensive and interdiction operations along with border security measures must continue to pursue the threat and protect the home front. Where those efforts fall short, airport security, tactics, technical countermeasures, vulnerability reduction measures, and consequence mitigation provisions must bridge the gap. Ground-based and airborne technical countermeasures offer the most focused defense against MANPADS, but the defense perpetually lags the capability of the offense. In the overall Global War on Terrorism, any terrorist means removed is a score for the free world. Specifically, in the context of MANPADS, this layered solution strategy buys time as CM technology matures and hopefully allows the defense to defeat the offense.

# VI. Conclusion and Recommendations

Terrorists with MANPADS represent one of the greatest threats to the United States today. With the added security measures installed since 9/11 to better screen passengers, cargo, and flightline personnel, MANPADS are even more attractive to terrorists than before. These are now the weapons of choice for threatening the nation's air system, the system which symbolizes America's global influence and sustains its economy with over $1.0 trillion in annual economic activity.[345] Today, at least 27 non-state groups possess MANPADS and the capability to target any of the nation's undefended 6,800 aircraft comprising the commercial fleet.

Since 2002, the frequency of terrorist attacks using MANPADS has greatly increased with Al Qaeda affiliates directly involved in most. Terrorists find MANPADS attractive because of their lethality, widely proliferated availability, ease of operation, and asymmetric cost advantage. Furthermore, countermeasures (CM) are extremely expensive and even the most advanced ones have their shortcomings. Given all this coupled with the economic and psycho-social repercussions expected from an attack, one must conclude that MANPADS in the hands of terrorists represent a clear and present danger to the nation.

Terrorist groups such as Al Qaeda certainly have the means and motive to inflict catastrophic harm on the American people and bring the economy to a screeching halt. All they are lacking is opportunity and commercial aviation offers a target-rich environment. Recent events continue to sound the alarm that the aviation industry is a primary target. As recently as January 2006, an SA-18, one of the most sophisticated MANPADS in non-state hands, attacked a Congressional delegation. The message is clear! American adversaries possess the means and motive to attack and will eventually seize the opportunity if not stopped.

Since these groups are highly dynamic and resourceful, they will find an opportunity sooner or later.[346] Eventually, at the time and place of their choosing, they will exploit a breach and strike the soft and unprotected aviation sector with MANPADS unless it is aggressively protected.[347] Worst of all, many of these groups are fueled by radical Islamic fundamentalist hatred of Western ideals and are capable of bringing the fight inside America's borders with sleeper cells hidden behind the guise

of civil liberties. They are often irresponsible, unpredictable, and frequently have no "return address."[348] Furthermore, these groups have global reach, an expansive financial network, intellect, and imagination.[349] Al Qaeda, especially with its modus operandi favoring mass casualty, high visibility operations aimed at killing Americans and inflicting maximum harm, must surely be looking for an opportunity to strike.

Currently no single solution exists, but an overall solution strategy that incorporates multiple layers of defense provides protection. Ideally, these layers of defense work simultaneously in parallel abroad and at home to deter or defeat MANPADS in one way or another. As attention focuses on the glaring vulnerability of the nation's unprotected commercial aviation assets, this orchestrated solution strategy will hopefully buy enough time for Congress to decide how much to spend and how to protect this critical link. Ultimately, commercially compatible air or ground-based technical CMs are the key layer of defense and these are the most lacking. Further research and development to achieve greater system performance capability, reliability, and affordability is an absolute.

The most limiting factor is time. While good stewardship of limited dollars and resources calls for the best system for the best price, Americans are frequently reminded that the enemy is ever present with terrorist events in Mombassa, Bali, London, and Madrid. Creative and adaptive solutions cannot wait indefinitely, but they must comply with technological, legal, funding, personnel, and resource limitations. While politicians determine the outcome of these complex issues, the clock continually ticks giving Al Qaeda and other terrorist adversaries more and more opportunities to strike.

As this decision process continues, one must keep in mind that a perfect defense against MANPADS is a goal but never fully achievable. To study the problem indefinitely in search of an infallible system with an affordable cost is an immense risk. Delay invites attack and allows greater opportunity for would-be attackers to pre-position armament and operators.

Should a simultaneous, prolonged attack take place forcing an airspace shutdown for a prolonged time, then the cost would be staggering. According to John Pike, Head of GlobalSecurity.Org, before reopening the skies, not only would the economy suffer the losses conservatively projected in Table 7, but improvised, ad hoc emergency

measures to secure the airways and unclog the aerial ports would run into the trillions.[350] All in all, according to Charles Peña, "We may be living on borrowed time."[351]

So what must be done at this point in time? As the Federal government steadfastly endeavors to "provide for the common defense" as set forth in the Constitution, the following recommendations should be considered:

- First and foremost, the DHS Counter-MANPADS Program must continue to receive top priority from both the administration and Congress. Time is of the essence and funding is critical. This is a problem that simply will not go away and failure is not an option. Terrorists have the weapons and can bring them into the country in a matter of days. Effective solutions as addressed in the *Solution Strategies and the Way Ahead* chapter take months and years to develop. Technical CMs are the lynchpin to the entire solution strategy and while expensive, their cost is low when compared to the cost of an attack. Furthermore, once fully developed, they will serve at home and abroad and in war and peace.

- The DHS Counter-MANPADS Program was extended into a third phase for extremely valid reasons. As ground-based and airborne CM technology matures, it should be fielded without delay. Again, time, technology, and funding are the crucibles. Spiral-up development provisions that accommodate science and engineering advances into subsequent versions are a means to assist with overcoming the hurdles of time, technology and cost. Technological progression will determine whether an airborne CM system or a ground-based system is fielded first. Ideally, the airborne version will appear first since it is viewed as a last line of defense, especially at overseas locations. Regardless, once a deployable system is available it should be fielded without delay. Ground-based systems should be placed where they can protect airfields with the greatest traffic count first. Airborne systems should be installed on the 1,100[352] (approximate) aircraft comprising the civil reserve air fleet (CRAF) first. Passenger and cargo aircraft registered for CRAF stage one (approximately 80 aircraft)[353] would receive a pre-installation kit first and an actual

system as soon as available. CRAF stage two (approximately 120 aircraft)[354] aircraft would follow suit followed by CRAF stage three aircraft. This deployment strategy would justify greater federal funding since the installed CM systems would be available for national defense plus these aircraft fit the highest operational risk management (ORM) category given their overseas flight schedules. Inevitably, many aircraft such as long-haul, wide-bodies not registered in the CRAF would need CMs sooner than later based on ORM. These would receive the next priority balanced against funding and this is where the airlines would be expected to carry a greater portion of the financial burden. Beyond this, ORM, time, funding, and production would dictate the installation schedule. In summary, actual fielding of either a ground-based or an airborne system is close but still in the future. Once these are deployable they should be deployed as soon as possible. Ultimately, fielding these systems provides for the common defense, protects the citizenry, and ensures the vitality of the American economy.

- Deception—as CM systems become deployable, install decoys. For ground-based CMs, much of the setup extends beyond the critical high-tech hardware. Therefore, proceed with the overall setup and use decoys for the prioritized components on backorder. The same logic follows for the airborne CMs. While fake turrets cause aerodynamic drag which equates to fuel expense, go ahead and fly with decoys. This amounts to deception and deterrence. While the modus operandi of the adversary often strives for high yield effects, it also dislikes failure. This may be one of the key reasons that Al Qaeda operatives have not attempted another aviation strike in the United States. They constantly morph to the path of least resistance as they attempt to gain an asymmetrical advantage. While the commercial aviation industry is a lucrative target, any and all means of discouragement to the adversary is progress in the overall defense strategy.
- Highly consider ground-based CMs as the primary system within the borders of the United States if technology matures to an acceptable level. If this becomes the case, then the Federal

Aviation Administration (FAA) would need to address onboard CM criteria for domestic flights that land outside the United States in such places as Mexican, Caribbean, and Canadian destinations. This would potentially save billions if regional and most narrow-body aircraft did not require onboard CMs.

- Continue to pursue the layers of defense addressed in the *Solution Strategies and the Way Ahead* chapter. These are not only valuable in countering MANPADS, but essential to defending the U.S. homeland in the Global War on Terrorism. Offensive operations, counter and nonproliferation efforts, interdiction, and border security initiatives essentially allow the fight to be fought somewhere other than home soil. This is the case when an "away game" is preferred. While politics and geo-political considerations drive each situation, border security efforts are probably the most lacking. America's borders are an invitation to disaster and need securing. As far as the other measures outlined in this chapter, the recommendations for airport security, tactics, vulnerability reduction, and minimizing consequences are previously spelled out.
- Finally, the 9/11 Commission cited "Failure of Imagination" as the "most important failure" leading to the events of 9/11.[355] With MANPADS, the evidence that they pose a clear and present danger to the United States is obvious. While imagination and innovation are keys to problem solving, this time around initiative is most important. Technical CMs must be pursued with the highest of priority.

In closing, this discussion has attempted to consolidate the most pertinent sources available on the topic into one comprehensive work. It combines expertise from both the private sector and various departments of government along with passion and experience on the topic from the author. While the intent has not been alarmist in nature, the outcome may seem so given the seriousness of the situation. Ultimately, Al Qaeda-like adversaries with the means and motive to attack will steadfastly endeavor to seize the opportunity if not stopped. America must defend its commercial aviation fleet.

# Notes

1. Richard A. Clarke et al., *Defeating the Jihadists, A Blueprint for Action*, (New York: The Century Foundation Press, 2004), 1. Al Qaeda is the phrase used to describe the global network of jihadist terrorist groups threatening the United States and the Western World.

2. John R. Bartak, *Mitigating the MANPADS Threat: International Agency, U.S., and Russian Efforts*, Naval Postgraduate School Thesis, (Monterey, California: March 2005), 8.

3. Robert Sherman, "The Real Terrorist Missile Threat, and What Can Be Done About It," *The Journal of the Federation of American Scientists,* Autumn 2003, Volume 56, Number 3, n.p. [no pagination], On-line, Internet, 10 March 2006, available from http://www.fas.org/faspir/2003/v56n3/missile.htm.

4. Al Qaeda is a conglomerate of groups throughout the world that operates as a network. It is led by Osama bin Laden who advocates pan-Islam. Bin Laden's ideology cuts across divisions and appeals to West Asian and non-West Asian groups. The Al Qaeda network has tremendous financial backing and global reach along with a vast arsenal of combat proven experts, trainers, and fighters. Its mode of operation includes the following: (1) economic targets are high priority, (2) leadership targets (assassinations) sought, (3) icon and symbolic targets are high priority, (4) embassies, trains, aircraft, airports, and hotels are key targets, (5) one/two punches—multiple simultaneous strikes, (6) mass effect—pursuing WMD, (7) careful and long-term planning typical, (8) rigorous training and practice runs first, (9) persistence, 10) suicide bombers, 11) favors conventional explosives, 12) mass casualties are a bonus, 13) later public claims by leadership, 14) central leaders inspire, fund, approve, appoint, 15) Allah is the audience and receives the glory Rohan Gunaratna, "Terror Unlimited," *Frontline*, Volume 18 – Issue 20, 20 September – 12 October 2001, n.p., On-line, Internet, 24 January 2006, available from http://www.frontline onnet.com/fl1820/18200280.htm. Mode of operation listing augmented by Dr. Barry R. Schneider, "State and Non-State Terrorism Threats—A World View," lecture, Air War College, Maxwell Air Force Base, AL, October 31, 2005.

5. Sarah Chankin-Gould and Matt Schroeder, "MANPADS Proliferation: Understanding the Problem," *The Journal of the Federation of American Scientists*, January 2004, n.p., On-line, Internet, 16 November 2005, available from http://www.fas.org/asmp/campaigns/MANPADS/MANPADS.html.

6. Fatwa issued February 1998 entitled, "Declaration of the World Islamic Front for Jihad against the Jews and Crusaders," Jerrold M. Post, M.D., "Killing in the Name of God," Counterproliferation Papers, Future Warfare Series, No. 18, November 2002, USAF Counterproliferation Center, Maxwell AFB, Alabama, 8.

7. James Chow et al., "Protecting Commercial Aviation Against the Shoulder-Fired Missile Threat," RAND Corporation Occasional Paper, January 2005, 1.

8. Ibid.

9. Ibid.

10. "The Economic Impact of Civil Aviation on the U.S. Economy," Wilbur Smith Associates, 1 May 2002, 1, On-line, Internet, 9 March 2006, available from http://www.wilbursmith.com/Economic_Impact_of_Civil_Aviation_on_the_US_Economy.pdf.

11. Chow, 1.

12. "Bin Laden's Message: A Call to Bleed the U.S. Economically," *USA Today*, November 2, 2004, n.p., On-line, Internet, 9 March 2006, available from http://www.usatoday.com/news/world/2004-11-02-bin-laden-economy_x.htm.

13. Charles V. Peña, "Flying the Unfriendly Skies Defending Against the Threat of Shoulder-Fired Missiles," Policy Analysis No. 541, April 2005, 10.

14. Ibid., 4. Authors note: MANPADS range in cost tremendously depending on sophistication, time period, and source. Most importantly, they are widely available at a minuscule cost compared to the damage and repercussions they can cause.

15. Mark Hewish and Joris Janssen Lok, "David Versus Goliath," *Jane's International Defence Review,* 1 April 2004, n.p., On-line, Internet, 24 January 2006, available from http://www.au.af.mil/au/aul/lane.htm via library limited access database subscription http://jtic.janes.com/subscribe/jtic/doc_view_print.jsp. MANPADS attack and kill probability statistics vary widely, but nonetheless are considerably lethal.

16. Thomas B. Hunter, "The Proliferation of MANPADS," *Jane's International Defence Review*, 1 September 2001, 43.

17. Chow, 3, 7. RAND estimates initial monetary damages for the crash of a large passenger aircraft carrying approximately 300 passengers to approach one billion dollars with two to two and a half million dollars placed on each life lost and the aircraft valued at 200 to 250 million dollars. This estimate does not does not extrapolate potential air travel shutdown losses or reduced demand once the industry resumes operations.

18. Ibid., 4; Hunter, 43; and Peña, 4. Authors note: Costs range between $5,000 and $250,000 with newer, more capable systems demanding a greater price.

19. Peña, 2 and Bruce Lawrence, ed., *Messages to the World—The Statements of Osama Bin Laden*, (New York: Verso, 2005), 242 which states that Al Qaeda spent only $500,000 on the 9/11 attacks.

20. David A. Kuhn, "Mombassa Attack Highlights Increasing MANPADS Threat," *Jane's Intelligence Review,* 1 February 2003, n.p., On-line, Internet, 15 December 2005, available from http://www.au.af.mil/au/aul/lane.htm via library limited access database subscription http://www8.janes.com/search.

21. Jacqueline D. Von Ovost, Lt Col, USAF, "Global Mobility: Anywhere, Anytime, Any Threat? Countering the MANPADS Challenge," Occasional Paper Number 38, December 2005, USAF Center for Strategy and Technology, Maxwell AFB, Alabama, 10.

22. Paul J. Caffera, "A Proposal to Protect Troops On Civilian Planes," *San Francisco Chronicle,* 30 September 2003, 7, On-line, Internet, 24 February 2006, available from http://sfgate.com/cgi-bin/article.cgi?file=/c/a/2003/09/30/MN306842.DTL.

23. Paul J. Caffera, "Plane with U.S. Officials was Fired at; House Members say C-130's Defenses Repelled Missile; Boxer Argues for Similar Equipment on Commercial Jets," *San Francisco Chronicle,* 8 April 2006, n.p., On-line, Internet, 22 April 2006, available from http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2006/04/08/MNGESI60LE1.DTL.

24. Ibid.

25. Ibid.

26. Kuhn, n.p.

27. Ibid.

28. Ibid.

29. Ibid.

30. Von Ovost, 9.

31. Ibid.

32. Quoted in Christopher Bolkcom et al., Homeland Security: *Protecting Airliners from Terrorist Missiles,* Congressional Research Service (CRS) Report for Congress Order Code RL31741 (The Library of Congress, October 22, 2004), 7.

33. Von Ovost, 9.

34. Hewish, n.p.

35. Ibid.

36. Von Ovost, 18.

37. Ibid., 9.

38. Ibid., 45.

39. Ibid.

40. Ibid.

41. Copied from Hunter, 44.

42. Al J. Venter, "Special Report – SAMs – the Ultimate Terror Threat," *Jane's Terrorism and Security Monitor*, 1 October 2003, 1, On-line, Internet, 25 January 2006, available from http://www.au.af.mil/au/aul/lane.htm via library limited access database subscription http://www8.janes.com/search.

43. U.S. Department of Justice Federal Bureau of Investigation National Press Office, *Immediate Release August 13, 2003*, 1.

44. Ibid., 2.

45. Copied from Hunter, 45.

46. Kuhn, n.p.

47. Ibid.

48. Ibid.

49. Ibid.

50. Ibid.

51. Peña, 3.

52. U.S. Department of State, Bureau of Political-Military Affairs and Bureau of International Security and Nonproliferation, *Fact Sheet—The MANPADS Menace: Combating the Threat to Global Aviation from Man-Portable Air Defense Systems*, 20 September 2005, n.p., On-line, Internet, 16 November 2005, available from http://www.state.gov/t/pm/rls/fs/53558.htm.

53. Bolkcom, 1.

54. Michael Puttre, "Facing the Shoulder-Fired Threat," *The Journal of Electronic Defense 24*, no. 4, April, 2001, 39.

55. Hunter, 42.

56. Chow, 5.

57. Bartak, 6.

58. Peña, 4.

59. Von Ovost, 19.

60. Ibid.

61. Ibid.

62. Hunter, 42.

63. Ibid.

64. Kuhn, n.p.

65. Hunter, 42.

66. Ibid.

67. Von Ovost, 19, and Kuhn, n.p.

68. Von Ovost, 19.

69. Copied from *Fact Sheet—The MANPADS Menace, n.p.*

70. Copied from Von Ovost, 21.

71. Bolkcom, 2.

72. Loren B. Thompson, Ph.D. "MANPADS—Scale & Nature of the Threat," (briefing slides), Lexington Institute, 12 November 2003, n.p., On-line, Internet, 22 January 2006, available from http://www.lexingtoninstitute.org/docs/614.pdf.

73. Thompson, n.p.

74. Bolkcom, 2.

75. Bartak, 6.

76. Bolkcom, 2.

77. Ibid.

78. Ibid.

79. Puttre, 41.

80. Bolkcom, 2.

81. Ibid.

82. Puttre, 42.

83. Ibid.

84. Puttre, 42 and Bolkcom, 2.

85. Ibid.

86. Bolkcom, 2.

87. Taken from Thompson, n.p., Kuhn, n.p., and Hewish, n.p.

88. Bolkcom, 2.

89. Ibid.

90. Ibid.

91. Ibid.

92. Ibid., 3.

93. Ibid.

94. Ibid.

95. Ibid.

96. Von Ovost, 19.

97. Puttre, 39.

98. Ibid.

99. Venter, 2.

100. Chow, 5.

101. Ibid.

102. Bolkcom, 9.

103. Taken from Thompson, n.p.

104. *Fact Sheet—The MANPADS Menace, n.p.*

105. Hunter, 42.

106. Kuhn n.p. and Hewish, n.p.

107. Gregory Czamecki, Robert Yelverton, and Carter (Ben) Brooks, "Large Aircraft Vulnerability to Man-Portable Air Defense Systems," *Aircraft Survivability*, Summer, 2005, 10.

108. Hunter, 42.

109. Ibid., 45.

110. Ibid.

111. Ibid., 43.

112. Copied from Von Ovost, 16.

113. Taken from Hunter, 43.

114. Copied from Chow, 5.

115. Dr. J. C. K. Daly, "Middle East—MANPADS 'blowback' for Al-Qaeda," *Jane's Terrorism and Security Monitor*, 1 November 2003, 1, On-line, Internet, 25 January 2006, available from http://www.au.af.mil/au/aul/lane.htm via library limited access database subscription http://www8.janes.com/search.

116. Hunter, 42.

117. Bartak, 14 & 15.

118. Bartak, 42.

119. Chow, 4.

120. Hunter, 44.

121. Peña, 4.

122. Hunter, 43.

123. Hunter, 43; Puttre 39; and Peña, 3.

124. Hunter, 43.

125. Ibid.

126. Ibid.

127. Puttre, 39.

128. Peña, 2.

129. Ibid.

130. Ibid.

131. Ibid.

132. Chow, iii.

133. Ibid., 3.

134. Ibid., 7.

135. Ibid.

136. Ibid.

137. Ibid., 10.

138. Ibid., 9.

139. Ibid.

140. Ibid.

141. Ibid., 10.

142. Ibid.

143. Tanja M. Korpi and Christopher Hemmer, "Avoiding Panic and Keeping the Ports Open in a Chemical and Biological Threat Environment," Counterproliferation

Papers, Future Warfare Series, No. 30, June, 2005. USAF Counterproliferation Center, Maxwell AFB, Alabama, 4.

144. Chow, 10.

145. James C. "Chris" Whitmire, the author, Lifelong United States Military and American Airlines Airline Transport Pilot, 24 February 2006.

146. Chow, 8.

147. Ibid.

148. Taken from Chow, 10, with author clarifications.

149. Peña, 3.

150. Ibid.

151. Sherman, 2.

152. "Beltway Sniper Attacks," Wikipedia.org, n.p., On-line, Internet, 8 March 2006, available from http://en.wikipedia.org/wiki/Beltway_sniper_attacks.

153. Ibid.

154. Ibid.

155. Ibid.

156. "Sniper Keeps D.C. Area on Alert," CNN.Com/U.S., 9 October 2002, n.p., On-line, Internet, 8 March 2006, available from http://archives.cnn.com/2002/US/South/10/08/shootings.maryland/index.html.

157. Post, 19.

158. Steven Woehrel, *March 11 Terrorist Attacks in Madrid and Spain's Elections: Implications for U.S. Policy,* Congressional Research Service (CRS) Report for Congress Order Code RS21812 (The Library of Congress, October 5, 2004), 1.

159. Ibid., 2-4.

160. Ibid.

161. "Poll: Katrina Response Inadequate," CBS News, 8 September 2005, n.p., On-line, Internet, 24 February 2006, available from http://www.cbsnews.com/stories/2005/09/08/opinion/polls/main824591.shtml.

162. Mimi Hall, "Homeland Security Chief Takes Blame for 'Many Lapses' in Katrina Aftermath," *USA Today*, 16 February 2006, 3a.

163. "Poll," n.p.

164. Chow, 11.

165. Ibid.

166. Ibid.

167. Copied from Chow, 14.

168. Chow, 13.

169. Ibid.

170. Chankin-Gould, n.p.

171. Bartak, 44.

172. *Fact Sheet—The MANPADS Menace, n.p.*

173. Ibid.

174. Ibid.

175. Ibid.

176. Ibid.

177. Ibid.

178. Ibid.

179. Ibid.

180. Ibid.

181. Bartak, 20 names the following nations as participants in the WA: Argentina, Austria, Australia, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, and the United States.

182. Wassenaar Plenary, *Elements for Export Controls of Man-Portable Air Defense Systems (MANPADS),* 1 December 2000, 1-2, On-line, Internet, 15 March 2006, available from http://www.wassenaar.org/docs/oth_manpads.pdf.

183. Bartak, xi.

184. Wassenaar Plenary, 1.

185. Chankin-Gould, n.p.

186. U.S. Department of State, *Department of State's MANPADS Threat Reduction Efforts*, n.p., On-line, Internet, 13 December 2005, available from http://www.state.gov/t/np/acw/cl2759.htm.

187. *Fact Sheet—The MANPADS Menace, n.p.*

188. Ibid., and also note, Evian Summit 2003, *MANPADS—A G8 Action Plan,* n.p., On-line, Internet, 4 October 2005, available from http://www.g8.fr/evian/extras/502.html.

189. *Fact Sheet—The MANPADS Menace, n.p.*

190. Bartak, 49. Note—FYI: Some sources state 50 MANPADS instead of 200 and place the duration of the sting at two years verses 18 months. Reference "Recent Events" chapter.

191. Ibid., 50.

192. Organization for Security and Co-operation in Europe Forum for Security Co-operation, *Decision No. 3/04 OSCE Principles for Export Controls of Man-Portable Air Defence Systems (MANPADS),* 26 May 2004, 1-5.

193. *Fact Sheet—The MANPADS Menace, n.p.*

194. Ibid.

195. Ibid.

196. Ibid.

197. Ibid.

198. Ibid.

199. Ibid.

200. Ibid.

201. Bartak, 18.

202. Ibid.

203. U.S. General Accounting Office, *Nonproliferation: Further Improvements Needed in U.S. Efforts to Counter Threats from Man-Portable Air Defense Systems,* 14 May 2004, 14.

204. Ibid., 19-28.

205. Bartak, 28.

206. Ibid.

207. *Fact Sheet—The MANPADS Menace, n.p.*

208. James C. "Chris" Whitmire, the author, Air War College Homeland Security Course architect and instructor, 15 March 2006.

209. Department of Homeland Security website, 12 May 2004, On-line, Internet, 13 May 2004, available from http://www.dhs.gov/dhspublic/display?theme=50&content=875.

210. Ibid.

211. Ibid.

212. Department of Homeland Security website, 22 February 2006, On-line, Internet, 15 March 2006, available from http://www.dhs.gov/dhspublic/interapp/press_release/press_release_0865.xml.

213. Ibid.

214. Chow, 13.

215. Bolkcom, 17.

216. Von Ovost, 19 and Thompson, n.p.

217. Peña, 4.

218. Ibid.

219. Ibid., 6.

220. Whitmire personal experience—major airline pilot formerly based in Miami, Chicago, New York, and St. Louis with frequent routes in and out of the nation's largest airports.

221. Ibid.

222. LaGuardia International Airport New York, NY and surroundings, On-line, Internet, 27 November 2006, available from http://www.terraserver.com/posters/poster_details.asp?posterid=417; http://www.mustseenewyork.com/maps/laguardia-airport-hotels.html; and http://www.inetours.com/New_York/Images/H-cptr/Lower_9547.jpg.

223. Bolkcom, 15.

224. Whitmire personal experience.

225. Bolkcom, 15.

226. Ibid, 12. El Al is reportedly in the process of equipping its 34 aircraft with CM systems.

227. Ibid.

228. Ibid.

229. Greta Wodele, "Groups Differ on Countering Shoulder-Fired Missile Threat," *GOVEXEC.COM,* 9 December 2005, n.p., On-line, Internet, 16 December 2005, available from http://www.govexec.com/story_page.cfm?articleid=32992.

230. Ron Laurenzo, "Antimissile Systems for Airliners," *Aerospace America,* March, 2005, 33.

231. Chow, 24.

232. Puttre, 40.

233. Ibid.

234. Von Ovost, 17.

235. Ibid., 18.

236. Ibid., 24.

237. Ibid.

238. Ibid.

239. Ibid.

240. Ibid., 38.

241. Ibid.

242. Ibid., 25.

243. Ibid.

244. Ibid.

245. Ibid.

246. Bolkcom, 12.

247. Ibid., 13.

248. Chow, 17.

249. Ibid.

250. Von Ovost, 25.

251. Chow, 17.

252. Ibid.

253. Ibid.

254. Ibid.

255. Ibid.

256. Von Ovost, 26.

257. Ibid.

258. Ibid.

259. Ibid.

260. Ibid.

261. Chow, 19.

262. David Snodgrass, "Laser-Based Infrared Countermeasures for Both Large Aircraft and Helicopters," *Aircraft Survivability,* Summer 2003, 8-9.

263. Von Ovost, 26 and Chow, 19.

264. Von Ovost, 26.

265. Ibid., 27.

266. Chow, 19.

267. Ibid., 20.

268. Peña, 6.

269. Ibid.

270. Chow, 20.

271. Ibid., 19.

272. Von Ovost, 27.

273. Ibid.

274. Ibid.

275. Ibid.

276. Ibid., 28.

277. Ibid.

278. Ibid.

279. Ibid.

280. Ibid.

281. Ibid., 29-31.

282. Ibid.

283. Chow, 21.

284. Ibid.

285. Ibid.

286. Ibid.

287. Ibid.

288. Ibid.

289. Ibid.

290. Von Ovost, 31.

291. Ramon Lopez, "U.S. Extends Counter-MANPADS Competition for Another Year," *Professional Pilot,* April, 2006, n.p., On-line, Internet, 2 May 2006, available from http://www.propilot.com/april/article4_april.htm.

292. Doug Venter, "High-powered Microwave Counters MANPADS Threat," *Jane's Missiles and Rockets*, 1 August 2005, n.p., On-line, Internet, 24 January 2006, available from http://www.au.af.mil/au/aul/lane.htm via library limited access database subscription http://www8.janes.com/search.

293. Venter, n.p. and "Vigilant Eagle – A Revolution in Airport Protection," *Raytheon Company News Release*, 2006, n.p., On-line, Internet, 28 November 2006, available from http://www.raytheon.com/fetaure/vig_eagle07061.

294. Ibid.

295. Ibid.

296. Lopez, n.p.

297. Lopez, n.p.

298. Ibid.

299. Von Ovost, 32.

300. U.S. Department of Homeland Security, *Fact Sheet: U.S. Department of Homeland Security Programs Countering Missile Threats to Commercial Aircraft*, August, 2004, n.p., On-line, Internet, 13 December 2005, available from http://www.fas.org/asmp/campaigns/MANPADS/DHSfactsheet25aug04.htm.

301. Hewish, n.p.

302. Ibid.

303. Ibid.

304. Ibid.

305. Jim Skeen, "Laser Device May Protect Jets from Attack," Dailynews.com, 10 November 2005, n.p., On-line, Internet, 14 November 2005, available from http://www.dailynews.com/antelopevalley/ci_3199123.

306. Lopez, n.p.

307. Keith Lewis, "BAE Systems Counter-MANPADS JETEYE System Takes Flight on Commercial Airliner for DHS," *BAE Systems Company News Release,* 10 November 2005, n.p., On-line, Internet, 16 November 2005, available from http://www.na.baesystems.com/featuredDetail.cfm?a=50 and Lopez, n.p.

308. Ibid.

309. Ibid.

310. Charlotte Adams, "Q&A: James Tuttle Counter-MANPADS Moves Forward," Avionics Magazine, 1 May 2006, n.p., On-line, Internet, 1 December 2006, available from http://www.avionicsmagazine.com/cgi/av/show_mag.cgi?pub=av&mon=0506&file=qa.htm.

311. Department of Homeland Security, *DHS Awards $7.4 Million in Combined Contracts to Three Firms to Support Emerging Counter-MANPADS Technologies*, n.p., On-line, Internet, 28 November 2006, available from http://www.dhs.gov/xnews/release/pr_1161601469252.shtm.

312. Lopez, n.p.

313. "L-3 AVISYS Extends Its Civil Aircraft Self-Protection Systems Offerings," Spacemart, 20 September 2006, n.p., On-line, Internet, 29 November 2006, available from http://www.spacemart.com/reports/L_3_AVISYS_Extends_Its_Civil_Aircraft_Self_Protection_Systems_Offerings_999.html.

314. "Photo Release—Homeland Security Department to Evaluate Skyguard High-Energy Laser From Northrop Grumman to Defeat MANPADS Threat to Commercial Aviation," Northrop Grumman News Release, 20 October 2006, n.p., On-line, Internet, 28 November 2006, available from http://www.irconnect.com/noc/press/pages/news_releases.mhtml?d=107278.

315. Venter, n.p and "Vigilant Eagle—A Revolution in Airport Protection," n.p.

316. Chow, 23.

317. Laurenzo, 36.

318. Ibid., 34.

319. Ibid., 36.

320. Ibid., 34.

321. Ibid.

322. Ibid.

323. Ibid., 33.

324. Lopez, n.p.

325. Ibid.

326. Chow, 24.

327. Ibid., 27.

328. Copied from Ibid., 24.

329. David Mulholland, "Civil Market for Missile Jammers Nearing Reality," *Jane's Defence Weekly,* 2 February 2005, 1.

330. Caffera, "Plane with U.S. Officials was Fired at; House Members say C-130's Defenses Repelled Missile; Boxer Argues for Similar Equipment on Commercial Jets," n.p. and Chow, 10.

331. Laurenzo, 33.

332. Lopez, n.p.

333. Chow, 15.

334. Ibid.

335. Ibid., and Chankin-Gould, n.p.

336. Lopez, n.p.

337. Bolkcom, 14.

338. Ibid.

339. Ibid.

340. Sherman, 7.

341. Ibid.

342. Chow, 15.

343. Sherman, 7.

344. Ibid.

345. Laurenzo, 34.

346. Dr. Barry R. Schneider, "State and Non-State Terrorism Threats—A World View," lecture, Air War College, Maxwell Air Force Base, AL., 31 October 2005.

347. Ibid.

348. Ibid.

349. Ibid.

350. Mulholland, 1.

351. Peña, 11.

352. Chow, 25.

353. Von Ovost, 35.

354. Ibid.

355. National Commission on Terrorist Attacks upon the United States, *The 9/11 Commission Report, Executive Summary,* 21 August 2004, 9, On-line, Internet, 12 May 2006, available from http://www.gpoaccess.gov/911/pdf/execsummary.pdf.