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Finding the Balance Between Price and Protection: Establishing a Surface-to-Air Fire Risk-Reduction Training Policy for Air-Carrier Pilots

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Overview[1]

The U.S. air carrier industry, in conjunction with regulating bodies and industry partners, has not formally addressed the need to determine if there is a necessity to provide air-carrier pilots with training to mitigate the risk associated with surface-to-air fire (SAFIRE) threats. Currently, no formal examination (by industry or the federal government) has been made to determine if there is a justifiable requirement for this type of training. Before a policy decision can be implemented, industry and government stakeholders should conduct a cost-benefit analysis (CBA) to determine if the cost of training is justified by the risk posed by the potential loss of life and property associated with a SAFIRE attack against a U.S. air carrier. This effort presents background on the types of SAFIRE threats and attacks, potential training methods, and examines two cost-benefit analysis methodologies that could be used when performing the CBA required to drive federal policy. The research contained is intended to serve as a catalyst for discussion and to highlight the need for a formal policy decision regarding the requirement and implementation of SAFIRE risk-reduction training programs for U.S. air carriers.

U.S. air-carrier pilots do not receive formal training to mitigate the risks associated with surface-to-air fire threats. Additionally, U.S. air-carrier aircraft are not fitted with defensive systems capable of countering the worldwide SAFIRE threat (J. Denton, personal communication, July 12, 2011). Over the last decade, the bulk of SAFIRE related research, policy discussion, and materiel development has focused on defeating Man-Portable Air Defense Systems (MANPADS), which are, primarily, shoulder-fired infrared (IR) missiles. The three pillars of the Counter-MANPADS National Strategy consist of non-proliferation, technical counter-measures, and tactical operations by the Department of Homeland Security (DHS), and

[1] The views expressed here are solely those of the author and do not, in any way, represent the views of the Department of Defense, U.S. Air Force, or any other entity of the U.S. government.

Transportation Security Administration (TSA) (Wilson, 2010). To date, this and other similar documents have failed to seriously consider training as a leading risk mitigation option.

Technological efforts have proven to be feasible, but have two drawbacks. First, counter-MANPADS systems (which use aircraft mounted lasers to blind the missile's IR sensor) are too expensive for U.S. air carriers, costing over $1 million U.S. dollars per aircraft (Elias, 2010). Second, counter-MANPADS systems are only effective against IR guided missiles and do not mitigate the danger posed by manually-aimed threats (Ahmad, 2014) and lasers (Bunker, 2008). SAFIRE risk-reduction training is a low-cost alternative that prepares air-carrier pilots to avoid, detect, defeat, and report SAFIRE attacks by employing counter-tactics (contained within Tactics, Techniques, and Procedures (TTP) documentation) that are safe and easy to understand. Military transports, comparable in size and configuration to U.S. air-carrier aircraft, have used counter-tactics to defeat missiles, small arms fire, and laser attacks in Iraq and Afghanistan for over a decade (Erwin, 2003). Many of the counter-tactics have unclassified equivalents, as disclosed by the Congressional Research Service in a report titled *Homeland security: Protecting airliners from terrorist missiles*, which would be suitable for incorporation into civilian SAFIRE risk-reduction TTP and training programs without compromising military secrets (Bolkcom & Elias, 2006). Air-carrier counter-tactics of this type could be used as a stand-alone risk mitigation method or in conjunction with any technological countermeasures adopted by U.S. air carriers in the future.

Research conducted in 2014, contained within *A Comparative Study Analyzing the Value of Air-Carrier Pilot Surface-to-Air Fire Risk-Reduction Training,* has shown the majority of air-carrier pilots (70.5% of 112 pilots surveyed, which included 63 pilots who had received military flying training and 49 who had only received civilian pilot training) agreed or strongly agreed with the statement "I believe that SAFIRE risk-reduction training is necessary and should be included as part of my formal training as an air-carrier pilot," (Burress, 2014). The results, combined with the lack of additional academic effort in this area of study, highlight the importance of the topic and emphasize the need for future research.

The next step in the policy development process is to determine if the risk associated with the threat is sufficient to justify the air-carrier training expense. Notably, several of the survey respondents commented that the cost of training would prevent air-carriers from implementing this type of training (Burress, 2014). This cost consideration, coupled with the narrow profit margins and the cyclic economic nature of the air-carrier industry, makes it difficult to expect that air-carriers would voluntarily develop and implement proactive SAFIRE risk-reduction training programs. Therefore, the responsibility for a policy of this type would have to fall within the realm of U.S. federal regulation. The inclusion or exclusion of SAFIRE risk-reduction training for U.S. air-carrier pilots should be decided after reviewing the facts, analyzing the risk, and conducting a formal Cost-Benefit Analysis (CBA) of air-carrier expense with a panel of stakeholders. In this case, we define stakeholders as representatives from industry and government who have a direct interest and expertise on specific areas of the topic.

To conduct the CBA, stakeholders from the air-carrier industry and the federal government must examine the issue to determine if SAFIRE poses a threat significant enough to justify the cost of implementing SAFIRE risk-reduction training across all U.S. flagged air-carriers (Kaufman, 2012). This project presents two CBA methodologies, a Direct Comparison model and an Expected Value model, to show that various methodologies can produce opposing results. The two example CBAs show that the panel of stakeholders will need to consider and select an appropriate model to avoid predetermined or misleading results. To conduct the CBA, it is necessary to populate the formulas with historical data, performance estimates, and cost estimates provided by the stakeholders.

Historically, the SAFIRE threat has consisted primarily of self-guided threats (portable surface-to-air missiles), manually-aimed threats (small arms, Ruchnoi Protivotankoviyi Granatomyot [RPG] recoilless grenade launchers, rockets, and light anti-aircraft artillery), and laser illuminators (both visual and infrared) capable of inducing disorientation and permanent eye damage (Burress, 2014). The risk of these threats can be mitigated using unclassified techniques available in the public domain and contained within Congressional Research Service (CRS) and Federal Aviation Administration (FAA) publications (Bolkcom & Elias, 2006). It should be noted that the use of evasive maneuvering (like the maneuvers used in threat evasion by fighter aircraft) is not under consideration as a threat mitigation procedure. The CRS document *Homeland Security: Protecting Airliners from Terrorist Missiles* states that (a) "…large transport category airplanes are generally not maneuverable enough to evade a shoulder-fired SAM", (b) "There is also concern that defensive maneuvering of large transport aircraft could result in loss of control or structural failure," and (c) "most observers concur that evasive maneuvering is not a viable option for mitigating the risk of missile attacks" (Bolkcom & Elias, 2006, p. 14-15). Existing TTP, which contain options other than evasive maneuvering, will be discussed in detail later in this document.

The research contained within this effort, the recommended notional training programs, and sample CBAs are intended to serve as the catalyst for discussion and to highlight the need for a formal policy decision regarding the requirement and implementation of SAFIRE risk-reduction training programs for U.S. air carriers. This research does not advocate the implementation of a federally mandated SAFIRE risk-reduction training program. Instead, it

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highlights the necessity for the creation of a formal policy, based on a CBA, to be completed by a panel of industry and government stakeholders.

Problem Statement and Resolution Criteria

The FAA, in conjunction with other federal and military agencies, has not provided air carriers with a formal or informal policy position regarding the requirements for the implementation of a mandatory SAFIRE risk-reduction training program or the recommendation of any standardized operating procedures. Problem resolution will occur when a federal policy decision is made which either states that (a) U.S. air-carriers are required to ensure all pilots have completed the FAA SAFIRE risk-reduction training syllabus, which will be supported by company standardized operating procedures, or (b) U.S. air carriers are not required to implement SAFIRE risk-reduction training programs or develop any standardized operating procedures required to support SAFIRE risk-reduction training. It should be noted that this effort is intended to address the lack of existing policy and to use notional examples to demonstrate how this goal can be achieved. If a formal FAA policy identifies the need for training, additional research would be necessary to address specific training and policy requirements.

Methodology

To address the lack of a federal policy defining the requirement for SAFIRE risk-reduction training, this project will (a) use historical data to highlight the importance of the subject, (b) identify TTP to counter the SAFIRE threat, (c) outline potential elements of a SAFIRE risk-reduction training program, (d) identify potential stakeholders, and (e) provide examples of two distinct CBA approaches, which will demonstrate the availability of suitable analysis tools. The example CBAs are intended to show that it is possible for stakeholders to conduct a CBA capable of quantifying the expense associated with implementation of a training policy, which is necessary prior to establishing a formal policy.

Background

This effort will define SAFIRE threats as either a self-guided threat (a shoulder-fired surface-to-air missile), a manually-aimed threat (a hand-held rifle, pistol, RPG, rocket, or light anti-aircraft artillery), or a laser threat used to blind pilots in flight. The self-guided threat portion has been scoped to focus on IR MANPADS. It does not include radar, visual, or laser-guided surface-to-air missile systems (SAMs), such as the SA-11 radar-guided mobile missile system (which was likely responsible for downing Malaysia Airlines Flight 17 over the Ukraine on July 17, 2014). This specific incident will be addressed independently. Self-guided threats have garnered the greatest amount of attention from the federal government and the air-carrier industry since the al-Qaeda attacks of September 11, 2001 (Elias, 2010).

Self-Guided Threats and Risk Mitigation Options

IR MANPADS are shoulder-fired missiles specifically designed to destroy rotary and fixed wing aircraft in flight. IR MANPADS, to include the American FIM-92 Stinger and Russian SA-16 Gimlet, are equipped with a "fire-and-forget" seeker and have a range of several miles. IR MANPADS can be successfully operated with little training and can be purchased on the black market for the non-prohibitive price of between $5,000 and $30,000 per unit (Elias, 2010). Additionally, MANPADS are small enough to conceal in common civilian vehicles and are armed with a warhead that is specifically designed to destroy aircraft.

Air-carriers have not faced a valid MANPADS threat within the continental United States (Aero-News Network, 2013). The following passage is a transcript of the Houston Intercontinental Airport Automated Terminal Information Service (ATIS) broadcast from

020710Z, provided via email from a pilot flying in the area at the time, which serves as evidence of a recent reported MANPADS incident:

> The Houston Intercontinental Departure ATIS Golf at 0153Z Winds 060/03 Visibility 10 SM Few at 25,000 Temp 26/Dewpoint 16 Altimeter 29.99 Arrivals Expect ILS Runway 26 Right, ILS Runway 26 Left, ILS Runway 27, Simultaneous Approaches in Use, Departing Runway 15 Left, Runway 15 Right, Runway 26 Left, NOTAMS Continental Airlines ramp control in effect, bird activity in vicinity of the airport, SBI out of servce (sic), ALT readbacks, transponders on, attentional (sic) all aircraft MANPAD alert attack, reported 20 miles east of intercontinental airport, at 13,000 feet, at 0130Z, advise you have information Golf (T. Shackouls, personal communication, May 30, 2009).

This recorded transmission includes a message identifier (Golf), date/time group, weather and airfield conditions, and bird hazard information. It also contains a general MANPADS warning, but offers no guidance to help pilots mitigate the risk associated with this threat.

The Bonn International Center for Conversion research indicates that there have been 50 IR MANPADS attacks against non-military aircraft worldwide, causing 30 civilian shoot downs and resulting in the loss of over 920 lives between 1973 and 2013 (Ashkenazi, Grebe, Kögler, & Kösling, 2013). International participants (nations, law enforcement agencies, militaries, and non-governmental agencies) have made efforts to quell the proliferation of IR MANPADS, but estimates indicate between 5,000 and 150,000 units could be under criminal, terrorist, or insurgent control (Elias, 2010). It is estimated, for example, that between 10,000 and 15,000 Russian IR MANPADS may have been stolen from the Libyan military during the 2011 Libyan civil war (Stewart, 2012). Additionally, an April 2016 New York Times article quoted a Central Intelligence Agency (CIA) source in regard to the conflict in Syria, which stated that,

> The CIA believes that rebels have obtained a small number of Manpads (sic) through illicit channels. Fearing these systems could fall into civilian hands for use against civilian aircraft, the spy agency's goal now is to prevent more of them from slipping uncontrollably into the war zone (Klein, 2016).

Over the last decade, the DHS had addressed this threat by leading a campaign to develop technological countermeasure systems to defeat IR MANPADS attacks in flight. Although the concept proved to be technically effective, the estimated cost of $1-4 million per aircraft (which equals $40 billion when multiplied across the entire U.S. air-carrier industry) made the solution unaffordable to the air carriers (Kimball, 2013). As a probable alternative, it may be possible to mitigate the risk using training and a number of tactics that would not require costly technological solutions. These open-source threat-mitigation tactics, contained in the Congressional Research Service report (Bolkcom & Elias, 2006) include:

- reducing aircraft heat signature by minimizing the use of auxiliary power units and other heat sources;
- minimizing engine power settings and reducing engine power if a missile launch is detected;
- altering air traffic procedures to minimize vulnerability and making flight patterns less predictable;
- using spiral descents, when appropriate and feasible;
- varying approach and departure patterns;
- maximizing the use of over water approach and departure procedures;
- increasing use of nighttime flights; and
- minimizing the use of aircraft lighting.

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Although many of these counter-tactics seem intuitive, actual air-carrier pilot training and air-carrier policy changes to permit the use of these tactics is required prior to employment. It should be noted that the above list does not include evasive maneuvering as a viable counter-tactic.

Additional unclassified counter-tactics may be made available through an interagency partnership between Department of Defense (DOD), DHS, FAA, and Federal Bureau of Investigation (FBI). Pilots could effectively execute these tactics, once validated, if they were given formal training and the air-carrier authorized them to employ these procedures when directed by the company or deemed necessary. Surprisingly, the best-known recent SAM shoot down, which occurred in 2014, was not conducted using an IR MANPADS, but instead by a radar-guided SA-11 mobile SAM system.

The SA-11 Attack on Malaysia Airlines Flight 17

The Malaysia Airlines Flight 17 shoot down occurred near Torez, Ukraine, on July 17, 2014 and resulted in the deaths of 298 individuals (Dutch Safety Board, 2014). Pro-Russian military-trained individuals operating a captured SA-11 SAM system, which typically consists of multiple tank-sized vehicles, most likely conducted this attack (Gregory, 2015). This type of weapon is difficult to conceal, maintain, and employ and is not well-suited for criminals, terrorists, or insurgents. Although the radar-guided missiles could not have been defeated by MH 17 in flight, training may have emphasized the importance of avoiding the intentional overflight of nations involved in open war and prevented the incident. In addition to this effort's specific focus on air-carrier training and tactics, there is room for additional research in the areas of threat analysis and threat information dissemination by air-carrier management and dispatch personnel. The size and complexity of a radar-guided surface-to-air missile system makes it a poorly suited weapon for use in a covert attack. This incident was not included as a data point within the historical data used when conducting the two sample CBAs.

Manually-Aimed Threats and Risk Mitigation Options

Manually-aimed threats include small-arms weapons, rockets, RPGs, and light anti-aircraft artillery. To employ these weapons, the weapons operator must visually acquire the target, aim the weapon, track the target, and fire the weapon. Manually-aimed weapons are more widely proliferated than IR MANPADS but are considered to be less lethal by many (Elias, 2010). The AK47 rifle is the prime example of a manually-aimed threat. It is believed to be the most widely proliferated weapon in history, with an estimated 10 million rifles in production, and is known to be in the hands of state and non-state actors around the world (Chivers, 2010).

A manually-aimed weapon was used in an attack against Pakistan International Airlines Flight 756 in June 2014. In this incident, the aircraft was hit with six rifle rounds while on approach to Bacha Khan International Airport, killing one passenger and injuring two others. When faced with unexpected real-time threats, air-carrier pilots can mitigate the risk of manually-aimed weapons by avoiding overflight of higher risk areas and making their aircraft more difficult to acquire visually. There is a lack of technology to mitigate the risk posed by manually-aimed threats, so effective mitigation hinges on SAFIRE risk-reduction training.

Laser Threats and Risk Mitigation Options

Handheld laser devices have the ability to disorient, flash blind, and cause permanent eye damage to air-carrier pilots. In a study that focused on U.S. incidents that occurred between 2004 and 2008, over 2,492 laser illumination incidents were reported against U.S. aircraft, with 73% of these attacks being prosecuted against air-carrier aircraft in U.S. airspace (Nakagawara, Montgomery, & Wood, 2011). This equates to a 37-fold increase in incidents over a four-year period. In 2015, the FAA reported that the number of laser attacks has increased to an average of approximately 200 incidents per day (Elser, 2016). Additionally, handheld lasers that exceed the 5 milliwatt (mW) Food and Drug Administration limit are readily available for purchase online (Nakagawara et al., 2011). For example, there is a 2000 mW unit, which can be purchased online for $150 (Houston, 2011). Although there have been no documented incidents resulting in the loss of an aircraft from laser attack, it is possible that criminals, terrorists, and insurgents could use lasers to increase the risk of flying into a specific airport to the point that air carriers may choose to not fly into that location. This tactic could be used to deny operations within a specific area without destroying an aircraft.

The counter-tactics to defeat a laser attack are simple but counter-intuitive. After the crew becomes aware that they are being targeted by a laser, it is not uncommon for a pilot to look outside the aircraft to identify the source of the attack. This action puts pilots at risk because this response increases the exposure of their eyes to the laser energy (N. Bollum, personal communication, June, 2015). The counter-tactic for a laser attack should be to look away to protect the eyes, position the body to limit exposure, and land the aircraft (Nakagawara et al., 2011). If it becomes impossible for the aircrew members to protect their eyes, they should change course to exit the area and choose an alternate route. Counter-tactics provided within *Federal Aviation Administration Advisory Circular 70-2A: Reporting of Laser Illumination of Aircraft* include:

- avoiding direct eye contact with the beam and shielding eyes to the maximum extent possible;
- regarding the event as an in-flight emergency;
- taking evasive action to avoid further exposure to the laser illumination; and

- reporting incidents of unauthorized laser illumination by radio to the appropriate controlling facility (Federal Aviation Administration [FAA], 2013).

Although other SAFIRE threats exist (to include aerial improvised explosive devices, anti-aircraft mines, unmanned aerial systems), the three categories previously addressed cover the preponderance of threats that air-carriers are likely to encounter. This examination of threat systems has provided a foundation for the subsequent examination of the elements of the CBA. To understand the process for conducting a CBA it is first necessary to identify the stakeholders.

Stakeholders

Organizations that will expend resources or be significantly economically impacted by a SAFIRE risk-reduction training policy can be included as stakeholders. Potential stakeholders and their areas of interest:

- Federal Aviation Administration: Regulatory body responsible for aircrew training policies.
- Department of Homeland Security: Government body tasked to address domestic SAFIRE threats.
- Federal Bureau of Investigation: Lead U.S. anti-terrorism law enforcement organization.
- Office of the Director of Central Intelligence: Oversight from the federal and military intelligence community.
- Office of the Secretary of Defense: Directs utilization of DOD funds and test resources.
- U.S. Transportation Command: Military Combatant Command responsible for the Civil Reserve Air Fleet, which moves 90% of all deploying U.S. service members and 40% of the military's cargo during time of war, emergency, or other military conflict (Imbriani, 2012).

- U.S. Air Force Air Mobility Command: Air Force Major Command capable of developing and executing applicable counter-tactics.
- Individual air-carriers: Air-carriers that would be responsible for paying the hourly wages associated with "train-the-trainer" training for instructors and for the training of each air-carrier pilot employed by their company.
- Air-carrier pilot unions: Ensures that the training is reasonable and complies with necessary employee contracts.
- Air-carrier pilot training companies: Simulator and aircraft companies that would be required to train their instructor staff to instruct in accordance with FAA guidelines.
- Insurance companies that cater to air-carriers: These companies may factor SAFIRE risk-reduction training into policy pricing (M. Reishus, personal communication, June 6, 2016).
- Aircraft manufacturers: These companies have the ability to influence design and procedures that directly impact the air carriers using their products.
- International Air Carrier Organizations and Governing bodies: Organizations to include International Civil Aviation Organization (ICAO) and International Air Transportation Association (IATA) have the ability to influence international policy.

Because a policy of this sort could potentially affect dozens of organizations, it would be necessary to identify a panel of individuals to represent various categories of participants. This panel would be involved in the decision-making process and would have to be balanced to ensure that neither the government representatives, nor the industry representatives, had a disproportionate amount of influence within the process.

A Notional SAFIRE Risk-Reduction Training Program

Common air-carrier pilot training options include computer-based training (CBT), classroom training, and simulator training. Flying SAFIRE risk-reduction training aboard actual aircraft would not be desirable due to cost, limited aircraft availability, and the relative availability of high fidelity of existing full-motion simulators. The 2014 study *A Comparative Study Analyzing the Value of Surface-to-Air Fire Risk-Reduction Training* showed that 85.7% of air-carrier pilots surveyed would prefer that a SAFIRE risk-reduction training program consist of a blended approach to training through the combination of CBT, classroom training, and simulator training (Burress, 2014).

Survey results contained six specific comments, which indicated that a training program would be of little value if the information was only presented using CBT. Seven comments specifically cited the need for simulator training in the comments section of the survey (Burress, 2014).

- Under this notional training construct, classroom training would only be required for the initial qualification and would be conducted in a two-hour block with a student-to-instructor ratio of 10 students per instructor. A team of federally funded “train-the-trainer” instructors could be utilized to qualify a cadre of instructors with each air carrier.
- CBT could be used for recurrent training. The training would be provided in sessions of less than two hours every five years.
- Simulator training would not require any significant hardware or software changes, with threat indications being provided verbally to the aircrew. Simulator training would focus on decision making, threat awareness, and post-incident management.

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These events would be integrated into existing simulator profiles and debriefed after the event in a format similar to those used during existing "Upset Training" profiles, wherein aircrews practice recovering from unusual attitudes. Simulator instructor inputs may include a verbal, air traffic control report of a manually aimed SAFIRE incident against a preceding aircraft, the introduction of a complex emergency that could represent a MANPADS strike, or a prompt that would require the aircrew to respond properly to a laser attack. A simulator SAFIRE event would be required every two years.

TTP and Training Syllabus Development Cost

The SAFIRE risk-reduction training program would be developed with a goal of providing air-carrier pilots with suitable training and SAFIRE counter-tactics TTP capable of reducing the risk associated with SAFIRE attacks. In a partnership between government and industry, it is likely that the federal government could be tasked to develop the TTP, training standards, and guidance for the instructor teams required to qualify the air-carrier instructor pilot cadre within each company. It is likely that an interagency partnership could conduct TTP development, validation, publication, and develop a training standards within three years and for under $10 million. As an example of TTP development cost, similar TTP development initiatives conducted by the DOD Joint Test and Evaluation "Joint Test" program have achieved results for amounts less than $10 million (Ramirez, 2012).

It is important to develop and train TTP that give air-carrier pilots safe and effective counter-tactics that can be used for SAFIRE risk-reduction. A failure to do so may put an air-carrier pilot in a time-critical situation perceived as "life or death" without formal guidance. In this situation, the air-carrier pilot may attempt to "make up their own TTP on the spot" in an effort to take immediate action. These ad hoc TTP may be unnecessary and could actually prove to be more dangerous than the threat. Fortunately, there are unclassified counter-tactics which can be safely employed if pilots have received effective training and if authorized by that company's standard operating procedures for pilots. Before training these TTP, it is necessary to evaluate them to ensure that they are executable, appropriate, and effective.

The U.S. military airlift community has developed and tested a significant number of threat counter-tactics that could influence the development of a SAFIRE risk-reduction TTP. The most cost effective method to develop and validate counter-tactics would be to leverage DOD and DHS expertise and assets. The DOD, for instance, has demonstrated the ability to develop and test counter-tactics, TTP, and training programs for under $10 million on a two-year timeline (Thompson, 2015). This program could use U.S. Air Force airlift pilots and U.S. mobility aircraft as platforms for live-fly missions against simulated threats. This type of program would be very similar to the efforts currently being executed under the Office of the Secretary of Defense Joint Test and Evaluation Program, which successfully executed the Joint Exploitation of Modern Surface-to-Air Missile Quick Reaction Test in 2011 (Gilmore, 2011). In this scenario, the federal government could shoulder the bulk of the cost for the development of the counter-tactics, TTP, and training syllabus. This expense would be a one-time government cost and will be omitted from the air-carrier CBA. The TTP, training syllabus, and "train-the-trainer" portion of the effort could be executed for approximately $10 million if federally funded and supported. *Cost to federal government: $10 million. Cost to air-carrier: None.*

Air-Carrier Pilot Training Cost

Air-carrier pilot training costs are likely to be the biggest point of contention between the air-carriers and policy makers. For the purpose of the following sample CBA, air-carrier training costs have been assigned the value of $1,000 for initial training per pilot (for either pilots

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fulfilling line duties or for those performing as instructor pilots). This value is based on a cost estimate of three hours of paid training at $200 per hour with an additional $400 in overhead and additional costs ($600 + $400=$1,000). Recurrent training would consist of CBT and would update the initial classroom training every five years at a cost of $500 per student. Simulator training would consist of occasional instructor verbal injects to frame suitable emergency-procedure training or to trigger Cockpit Resource Management training scenarios. The air-carrier may also have minor incidental program-maintenance costs, which have been set at $500 per year (J. Denton, personal communication, May 26, 2016). Using these values, the air-carrier cost for training averages $117 per year and $3,490 for the duration of a 30-year career per pilot.

Expense Associated with an Aircraft Loss Due to Terrorist Attack

It is also necessary to determine the economic expense associated with a successful SAFIRE attack for the CBA. The RAND Corporation addressed this issue in its 2005 study, *Protecting Commercial Aviation Against the Shoulder-Fired Missile Threat.* This study stated that, "Initial damages from such an attack would likely approach $1 billion per aircraft destroyed. These estimates are straight-forward. Larger aircraft typically cost $200–250 million (depending on the exact model) and carry around 300 passengers each" (Chow et al., 2005, p. 7). In an effort to provide a conservative CBA, a single aircraft loss to a SAFIRE event will be assigned a value of $2 billion for this analysis, which was based on the $250 million for the aircraft, $750 million for the loss of 300 lives, and the conservative estimate of $1 billion associated with the a week long aviation shutdown (Chow et al., 2005). Additionally, the report indicated that additional cost would hinge on the amount of time the National Airspace System was shut down, but that a week-long grounding of air-carrier aircraft would cause an immediate loss of $3 billion ($1 billion more than the conservative $2 billion value selected for the CBA) with further losses equaling $12-15 billion (Chow et al., 2005). *Cost to air carrier: $2 billion per aircraft lost due to SAFIRE attack.*

Assumptions for the Cost-Benefit Analysis

The following assumptions are being used when conducting the CBA of air-carrier expense. The values below are notional and do not represent a specific air-carrier. Some of these factors are explained in detail in subsequent paragraphs:

- Only air-carrier expenses are factored into the CBA.
- Government expenses are the responsibility of the federal government.
- The training is presumed to increase survivability by 50%. The survivability increase of 50% was a notional value selected because it provided a desired minimum effectiveness value that would be both conservative but impactful. A more accurate estimate for this value could be determined through testing during TTP development.
- MANPADS-attack data contains incidents from 1973-2013 (Ashkenazi et al., 2013).
- Notional air-carrier employs 12,000 total pilots (with an 8.33% turnover rate and a career of 30 years).
- Notional air-carrier conducts 2,000 flights a day.
- Rate of non-military aircraft lost to MANPADS globally = 1.22 per year based on an analysis of the aircraft losses contained in *Brief 47: MANPADS. A terrorist threat to civilian aviation?* (Ashkenazi et al., 2013).
- Initial qualification cost = $1,000 per pilot or instructor pilot.
- Recurrent qualification cost = $500 per pilot or instructor pilot every 5 years.
- Program maintenance = $500 per year.
- Expense associated with the loss of an aircraft = $2 billion.

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- Inflation rate = 1.1%.

Cost-Benefit Analysis of Air-Carrier Expense

Two CBA methodologies were included in this project, to demonstrate the availability of multiple CBA tools and to illustrate the wide differences in results that the tools can provide. The stakeholders will be required to identify a specific CBA methodology to justify the policy recommendation advocated by this paper. The CBAs are notional exercises intended to demonstrate the viability of the tool and were calculated using common and well known industry formulas. The results are not representative of any actual U.S. air carrier.

Case One: Direct Comparison

The first method of CBA was conducted using a simple Direct Comparison. To conduct the Direct Comparison, the estimated financial impact of the loss an air-carrier aircraft due to SAFIRE attack ($2 billion per aircraft lost) was compared to the present worth of the training expenses using the Net Present Value formula (Newnan, Eschenbach, & Lavelle, 2012).

This formula (1) will provide a dollar value for the cost of training for an air-carrier that employs 12,000 pilots over a 30-year period (which equates to a notional 30-year air-carrier pilot career).

$$NPV(t,N) = \sum_{t=0}^{N} \frac{FV_t}{(1+i)^t} \qquad (1)$$

The Net Present Value calculation will then be compared to the damages associated with a single SAFIRE attack.

Values and Assumptions:

- Total number of pilots and instructor pilots = 12,000

- Turnover rate = 8.33%
- i = Inflation rate = 1.1%
- Sorties per day = 2,000
- Initial qualification cost = $1,000 per pilot or instructor pilot
- Recurrent qualification cost = $500 per pilot or instructor pilot every 5 years
- Program maintenance = $500 per year
- N = total years = 30 years
- FV = future value: The current asset value at a specified date in the future based on an assumed growth
- Expense associated with the loss of an aircraft = $2 billion

These values and assumptions resulted in a Net Present Value of $59.96 million. In this case, results indicate the cost of the training over 30 years ($59.96 million) is significantly less (1.73%) than the cost of the loss of the aircraft ($2 billion). *In this case, the training is a cost effective measure.* Direct comparison, however, does not account for the likelihood of an attack, effectiveness of the training, and cost of the aircraft loss corrected for inflation. Case two incorporates these factors and presents a different result.

Case Two: Expected Value Formula

The second method of CBA was conducted using the Expected Value Formula. The Expected Value Formula compares the estimated financial impact of the loss of an air-carrier aircraft due to SAFIRE attack ($2 billion per aircraft lost) against the worth of an aircraft lost with likelihood of attack and inflation taken into account.

$$E[X] = \sum x_i p_i \qquad (2)$$

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This formula (2), which is often used in the insurance industry, includes the likelihood of an attack, effectiveness of training, expense of aircraft loss, and inflation corrections within its calculations (Newnan et al., 2012).

Values and Assumptions:

- Total number of pilots and instructor pilots = 12,000
- Turnover rate = 8.33%
- i = Inflation rate = 1.1%
- Sorties per day = 2,000
- Initial qualification cost = $1,000 per pilot and instructor pilot
- Recurrent qualification cost = $500 per pilot and instructor pilot every 5 years
- Program maintenance = $500 per year
- N = total years = 30 years
- x = outcome
- p = probability of outcome
- Rate of aircraft lost to MANPADS globally = 1.22 per year (Ashkenazi et al., 2013)
- TTP impact = 50%
- FV = future value: The current asset value at a specified date in the future based on an assumed growth
- Expense associated with the loss of an aircraft = $2 billion

These values and assumptions resulted in an expected value of $88,321 for the loss of slightly more than one aircraft per year (globally) over a 30-year period. With the addition of training, the expected value is halved to $44,160 due to the 50% predicted effectiveness of the TTP. Combined with the training cost, the total present worth of the expected value for training is

$59.96 million. When the training cost of over *$59 million* per individual air carrier is compared to the expected savings of slightly over *$44 thousand* per air carrier the comparison shows that *in this case, the training is not cost effective.* Ultimately, the results from case one and case two show that the stakeholder's methodology selection can significantly impact the outcome of the CBA effort and that the stakeholders must not select a CBA that will result in a predetermined policy decision.

Recommendations

The historical data (based on the annual rate of MANPADS attacks against air-carriers and the rapid increase in laser attacks against air-carriers) justifies a proactive examination of policy, which should use a formal CBA of air-carrier expenses and could be executed by a panel of qualified stakeholders. The panel of stakeholders from the federal government and industry should conduct a formal CBA to codify the status quo (no training required) or to identify the requirement for a mandatory training program. It is necessary to identify a lead agency with the authority to select and implement policy after considering inputs from the other stakeholders. When conducting the CBA, the lead agency should select a methodology that accurately evaluates the problem and does not result in a predetermined solution. If a training program is deemed necessary, the stakeholders should provide input to identify methods to distribute expenses between industry and the federal government. If training is required, federal agencies could consider subsidizing the training or offering other financial incentives to reduce the cost associated with the training program.

Conclusion

This research shows that it is possible to conduct a CBA to determine if the expense of a SAFIRE risk-reduction training program outweighs the risk associated with the SAFIRE threat.

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By using this methodology to develop a formal policy, U.S. policy makers will be able to evaluate risk and make a decision using a rational and defendable process. The resulting policy, achieved through informed decision, will enhance national security and make it possible for the federal government and air-carrier industry to fulfill the moral obligations to preserve lives and the public trust.

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