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School of Business and Public Management

Aircraft and Passenger Flight Security Improvements

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Submitted by:

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I. Introduction and Overview

This research project is intended to be both timely and appropriate considering the recent national tragedies of the 11th of September 2001. These disastrous events involved the separate crashes of four large commercial aircraft (e.g., Boeing 757 and 767), of which three flights found intended targets in major landmark buildings (i.e., World Trade Center [WTC] Towers and the Pentagon). The fourth hijacked aircraft tragically came to a final resting spot in the fields of rural western Pennsylvania.

These unprecedented and unparalleled acts of air piracy and terrorism were without comparison in the annals of American aviation. The primary deviation between these acts of barbarism and previous acts of aircraft hijackings was the ferocity of the outcome. Years ago, numerous aircraft were hijacked and diverted to José Marti International Airport in Havana, Cuba. Generally, these hijackings were ideologically or politically motivated and usually ended without the loss of life. As a rule, these diverted aircraft were quickly refueled and returned to the United States without further delay or incident. Other episodes of terrorism (e.g., TWA hijacking in the Mediterranean, et al) were in philosophical alignment with one political cause or another and did result in some loss of life or the severe damage or loss of the aircraft itself. Finally in 1988, the appalling loss of Pan Am Flight 103 over Lockerbie, Scotland was due to a bomb placed on-board by Libyan terrorists who premeditatedly killed innocent people all the while protecting themselves in a remote location far from harm's way.

The deliberate attacks on the two World Trade Center Towers in New York, the direct hit on the Pentagon in Virginia and the remote crash in Pennsylvania have heralded a new age of barbarism and an unprecedented level of fanaticism by terrorists. For the first time in modern aviation history, terrorists used themselves to commandeer commercial aircraft for use solely as massive guided missiles.

The domestic flights selected were all transcontinental flights ensuring these aircraft would be carrying full or nearly full amounts of jet fuel. The hijackings took place from three major airports (two from Boston's Logan, one from Newark International in New Jersey and the last from Washington's Dulles International in Virginia). The two aircraft from Boston's Logan International Airport, destined for California, carried nearly 200,000 lbs of jet fuel each. While the flash point for aviation fuel is not as low as gasoline, the mixture of jet fuel with priss (an additive to prevent freezing at high altitudes) remains highly explosive. By commandeering these aircraft, the terrorists had, in effect, successfully created powerful missiles capable of delivering nearly 200,000 lbs of highly volatile aviation fuel into the sides of the WTC Twin Towers and the Pentagon. Only aggressive action on the part of heroic passengers over the passing landscape of Pennsylvania prevented the fourth commercial aircraft from achieving its' suicidal mission. By the end of the infamous day of September 11th, American Airlines and United Air Lines each had lost two commercial aircraft plus the many hundreds of lives of passengers and crewmembers.

II. Framing the Project Objective and Identifying the Sub-Goals

The slightly long introduction was meant to emphasize the difference between an occasional aircraft hijacking and a deliberate suicide mission. Not since the defiant kamikaze pilots of Imperial Japan attempted to reverse the inevitable conclusion of the Second World War has the world witnessed such deliberate acts of suicidal aggression. The immediate reactions were those of disbelief and what can we do to preclude a recurrence. Naturally, an emphasis has been on developing a comprehensive approach to both integrated physical security and preventative counter-terrorist measures. Simply stated, our goal or objective for this project is "to improve aircraft and passenger flight security within commercial aviation."

Project management clearly defines the triple constraint as including the elements of cost, time, and specifications and we translate these elements into useful tools to include budgets, schedules, and quality or customer considerations. The same project management approach is incorporated and reiterated throughout this project by alignment of the major goals or considerations with the triple constraints.

A. *Financial Impact Consideration or Perspective*

Clearly, financial considerations emanating from any prescribed solution or alternative may have an enormous impact on the affected airlines required to make identified physical changes to their aircraft, or tangible revisions to their security policies, procedures and methods by which the airlines conduct their daily businesses. These pre-eminent concerns have been entitled the "Financial Perspective" within the EC 2000 Software application and associated Analytical Hierarchy Process for this project. Among the major financial impact perspective sub-goal considerations (i.e., expenses or costs to be incurred and the type of financial transaction) are the following:

1. Research and Development Costs (Indirect, Nonrecurring)
2. Implementation or Deployment Costs
    - 2.1 Training (Indirect, Nonrecurring or Recurring)
        - 2.1.1 Comprehensive Training Program Development (Indirect, Nonrecurring)
        - 2.1.2 Administration of Initial Training (Indirect, Nonrecurring)
        - 2.1.3 Periodic Retraining and Updates of Training Program (Indirect, Recurring)
    - 2.2 Equipment and Systems Installations (Direct, Nonrecurring or Recurring)
        - 2.2.1 Initial Installation Costs (Direct, Nonrecurring)
        - 2.2.2 System Replacement Costs (Direct, Recurring)
    - 2.3 Aircraft Structural Modifications (Direct, Nonrecurring)
    - 2.4 Re-engineering Costs For Existing Aircraft (Direct, Nonrecurring)
3. Maintenance Costs (Direct, Recurring)

The hierarchy reflects those financial impacts with a one-time charge (known as nonrecurring costs) and those elements that generate a repetitive cost (i.e., recurring) over the lifetime of a program or aircraft lifecycles. Further, the sub-objectives are identified as direct or indirect charges as prescribed by Cost/Schedule Control System (CS^2) utilized by most aerospace contractors, airlines, and project management systems. Primarily, the OBS and WBS act as collectors to segregate and consolidate costs.[1]

B. *Implementation Consideration or Perspective*

The schedule impact has been assessed as the "Implementation Perspective" or the timeframe in which probable solutions or viable alternatives may be incorporated and this element addresses the urgency of the implementation schedule. Scheduling may entail the grounding of aircraft at airline depot maintenance facilities to incorporate certain modifications or changes to reduce potential risk. Certainly, the grounding of aircraft adversely affects the air carriers' ability to generate revenue and to sustain positive cash flows. Moreover, the terms under which the modifications are mandated (e.g., Airworthiness Directives, Service Bulletins, et al) will dictate the implementation schedule and the impact on both the airline depot maintenance facility and the carrier's continuing ability to generate revenue on a consistent basis. The identified "Implementation Considerations" include the following sub-goals:

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[1] C/SCS uses Organization Breakdown Structure to segregate costs and the Work Breakdown Structure to track and accumulate all costs including direct and indirect costs – both recurring and nonrecurring.

1. Implementation Time Schedule Impact - (includes the impact of grounded aircraft on the maintenance depot and the negative effect on Programmed Depot Maintenance [PDM] schedules).[2]

2. Implementation – Degree Of Difficulty - (i.e., complexity of prescribed installations or modifications above general maintenance) – Includes technical and logistical support from OEM and any re-engineering associated with disassembly and the remanufacturing of detail parts or assemblies.

3. Urgency Requirements - (i.e., legal, financial or logistical mandates and demands on airline maintenance depot manpower and the established PDM schedule). These major urgency requirements are segregated into:

   3.1 Airworthiness Directives – Issued by the United States Department of Transportation, Airworthiness Directives (commonly known as "ADs") have the full intent of U.S. Federal Law and must be complied with in strict accordance with their issuance including the possible immediate grounding of all affected aircraft, as directed, and incorporation of all revisions prior to next flight[3]. Compliance is mandatory and is strictly enforced. All inspections, changes or retrofits must be incorporated as specified in the timeframe delineated within the Airworthiness Directive including the continued grounding of affected aircraft.

   3.2 Service Bulletins – Issued by Original Equipment Manufacturers (OEM) such as Airbus Industrie, Boeing[4], Bombardier Aéronautique, Embrarer, Fairchild Dornier, Gulfstream and other manufacturers in concurrence with and subject to the approval of the United States DOT. Service Bulletins are recommended actions to be taken by the depot maintenance facility at the frequency interval specified. While not mandated by law, Service Bulletins are usually incorporated at the next "C" or "D" Programmed Depot Maintenance or service rotation at the airlines' depot maintenance facilities. These FAA requirements, in addition to technical difficulty and general scheduling problems, will dictate the implementation schedule for alternatives as devised within this project.[5]

Programmed Depot Maintenance scheduling is a huge impact to air carriers and these implementation considerations address the overall PDM schedule, the degree of technical difficulty to implement an alternative or viable solution coupled with the urgency requiring the retro-fits, modifications and corrective actions. To put the global impact of timely implementation in perspective, American Airlines, for example, has over 800 commercial aircraft not counting the smaller aircraft owned by the regional feeder carriers using the American Airlines insignia.

C. Technology Consideration or Perspective

The "Technology Perspective" addresses the engineering specifications and degree of technical difficulty or feasibility of the plausible solutions. Naturally, some alternatives may be somewhat simplistic in nature and may provide for a "quick-fix" approach. Other technological solutions, while far more difficult and complex, may provide for long-term solutions to preclude any chance of recurrence. Our Technology Perspective includes the following sub-objective considerations and criteria:

1. Technology Feasibility (i.e., probability it can be achieved from a technological standpoint?).

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[2] Programmed Depot Maintenance includes established "C" and "D" Checks at the frequency intervals specified by the OEM.

[3] Ferry flights may be exempted from the DOT grounding order provided no passengers or cabin crewmembers are flown to airport base of maintenance depot operations. All ferry flights must be direct to maintenance facility with no stops and no deviation from established flight plan.

[4] The Boeing Company includes the former McDonnell Douglas and North American Aviation division of Rockwell.

[5] Federal Aviation Administration provides oversight for the U.S. Department of Transportation and only an approved FAA Certified Chief Inspector may sign off Airworthiness Directives or Service Bulletins as incorporated and issue a Flight Release.

  - 1.1 Research and Knowledge Availability (i.e., are the research components, data resources and knowledge-bases for these new technologies available?).
  - 1.2 Developmental Time-Line (i.e., can it be developed for commercial use in timely manner?).
2. Technological Applicability and Practicality
   - 2.1 Ability To Apply Technology To Commercial Aviation (i.e., can it be applied commercially?).
   - 2.2 Practical Commercial Use Of Technology Application (i.e., are the technologies viable, realistic, and can these be pragmatically applied in a commercial environment?).
3. Technological Reliability and Dependability (i.e., technical engineering considerations).
   - 3.1 Systems Reliability and Repeatability (i.e., consistency and ability to predict same results?).
   - 3.2 Systems Availability and Dependability (i.e., ease-of-use and frequency on sustained basis?).
4. Technological Accuracy (i.e., is technology accurate and precise on a sustainable basis?).

The objectives pertaining to the Technology Perspective tend to be more complex than the other major objectives or considerations within our model due to the fact that the proposed alternatives may be of differing degrees of complexity. Some engineering concepts work well in a static environment, but fail to work well in a commercial atmosphere where repetitive use may in result in unsatisfactory performance. Some engineering concepts or alternatives may be unreliable, financially cost-prohibitive or developmentally unfeasible. Further, some engineering concepts may take an inordinate amount of time to research and develop to the point of practical commercial applications.

D. Safety and Risk Impact Consideration or Perspective

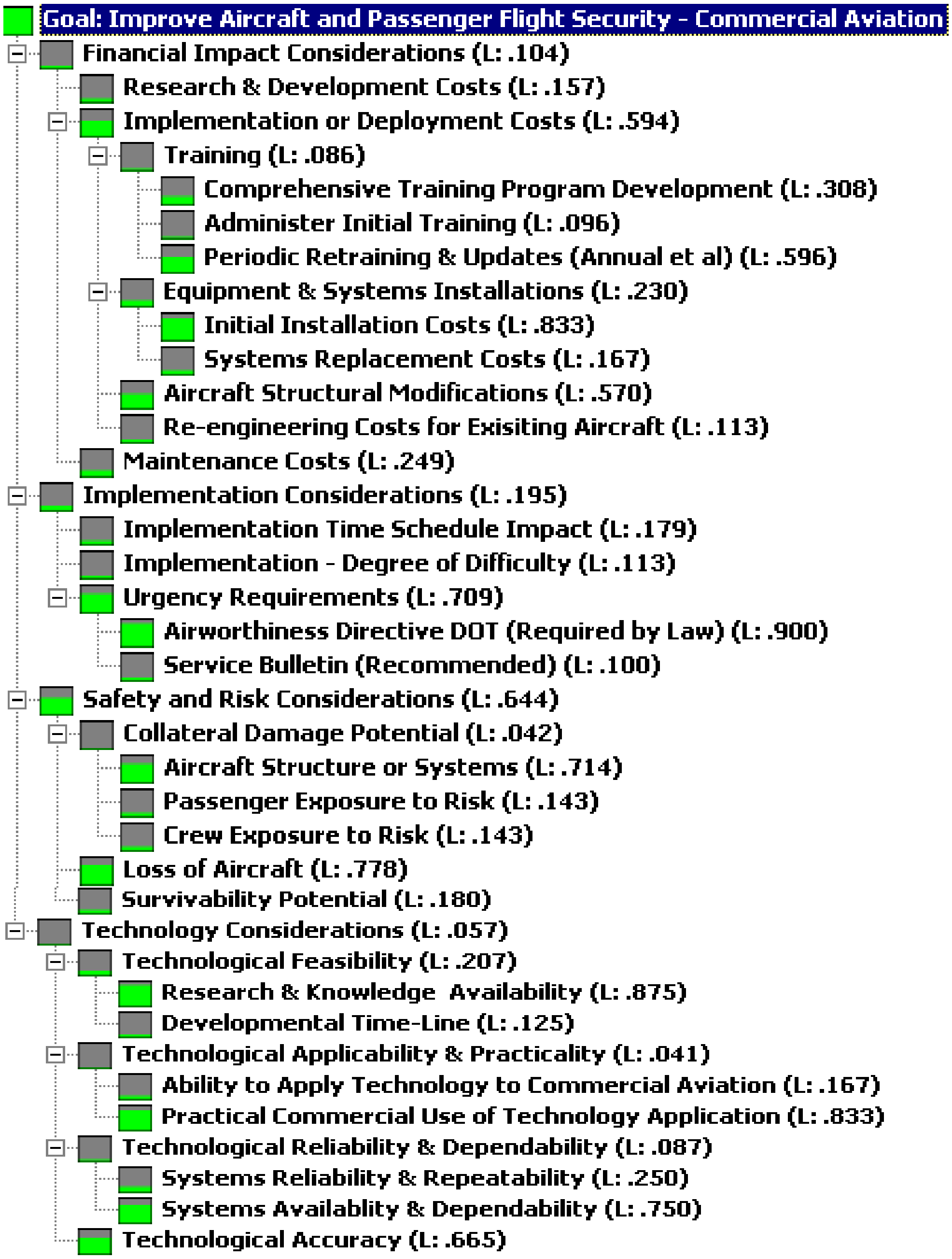
Finally, methodical project management necessitates an overall risk assessment. Since any alternative selected as a feasible solution to the problem may have a degree of risk associated with that element, it appears quite appropriate for the combined “Safety and Risk Assessment Perspective” to be considered as a major deliberation for aircraft security and flight integrity. Within this perspective, we have elected to address risk as an assessment of each individual alternative as if this proposed solution was chosen for across the board incorporation. Under the aegis of Safety and Risk Considerations, the following sub-objectives or criteria have been identified:

1. Collateral Damage Potential (e.g., armed pilots, crews and air marshals).
   - 1.1 Aircraft Structure or System (e.g., aircraft systems survivability, airframe integrity, cabin depressurization, et al).
   - 1.2 Passenger Exposure To Risk (e.g., death, injury, etc.).
   - 1.3 Crew Exposure To Risk (e.g., death, injury, etc.).
2. Loss Of Aircraft (i.e., crash probability from shots, electrical, hydraulic and fuel systems failures, loss of cabin pressure, evasive in-flight maneuvers, etc.).
3. Survivability Potential (i.e., survival potential from pilots’ evasive actions, depressurization, et al).

The safety and risk considerations evaluate the trade-offs encountered between introducing one alternative as a type of security deterrent and potentially compounding the original problem with secondary ramifications emanating from the proposed alternative (e.g., guns on an aircraft). As we address the identified alternatives within this project, the risks associated with each were evaluated to determine the cause and effect relationship, if any, and whether the potential benefits of the cure was offset by unacceptable risk or collateral damage (i.e., cause and effect relationships).

Safety and security considerations may be divided into physical security, which includes the physical barriers and impediments impervious to terrorist actions and those security methods that are considered to be predominately preventative in nature. This project addresses alternatives from both aspects of security.

The fully expanded objectives, as extracted from the EC 2000 Software, are reflected in Exhibit 1. These objectives include the stated overall goal, the four major perspectives or major nodes, as highlighted in this research paper and their respective sub-objectives and third or fourth tier objectives, as applicable.



- Goal: Improve Aircraft and Passenger Flight Security - Commercial Aviation
  - Financial Impact Considerations (L: .104)
    - Research & Development Costs (L: .157)
    - Implementation or Deployment Costs (L: .594)
      - Training (L: .086)
        - Comprehensive Training Program Development (L: .308)
        - Administer Initial Training (L: .096)
        - Periodic Retraining & Updates (Annual et al) (L: .596)
      - Equipment & Systems Installations (L: .230)
        - Initial Installation Costs (L: .833)
        - Systems Replacement Costs (L: .167)
      - Aircraft Structural Modifications (L: .570)
      - Re-engineering Costs for Exisiting Aircraft (L: .113)
    - Maintenance Costs (L: .249)
  - Implementation Considerations (L: .195)
    - Implementation Time Schedule Impact (L: .179)
    - Implementation - Degree of Difficulty (L: .113)
    - Urgency Requirements (L: .709)
      - Airworthiness Directive DOT (Required by Law) (L: .900)
      - Service Bulletin (Recommended) (L: .100)
  - Safety and Risk Considerations (L: .644)
    - Collateral Damage Potential (L: .042)
      - Aircraft Structure or Systems (L: .714)
      - Passenger Exposure to Risk (L: .143)
      - Crew Exposure to Risk (L: .143)
    - Loss of Aircraft (L: .778)
    - Survivability Potential (L: .180)
  - Technology Considerations (L: .057)
    - Technological Feasibility (L: .207)
      - Research & Knowledge Availability (L: .875)
      - Developmental Time-Line (L: .125)
    - Technological Applicability & Practicality (L: .041)
      - Ability to Apply Technology to Commercial Aviation (L: .167)
      - Practical Commercial Use of Technology Application (L: .833)
    - Technological Reliability & Dependability (L: .087)
      - Systems Reliability & Repeatability (L: .250)
      - Systems Availablity & Dependability (L: .750)
    - Technological Accuracy (L: .665)

Exhibit 1 Extracted EC 2000 View Showing Overall Goal with Major Nodes and Sub-Nodes

III. Alternatives – Identification

The development of logical alternatives to be evaluated were a result of some brainstorming and a general search of the available electronic and print media wherein a number of topics were widely discussed as counter-terrorism measures. Moreover, some of these alternatives were mentioned in passing by executives of commercial airlines, the Secretary of Transportation, the Hon. Norman Mineta; the Airline Pilots Association, the International Air Passenger Association plus numerous "experts" hosted by the news media on various talk shows.

The list was edited and consolidated into a manageable number of topics or finite alternatives to be assessed. By no means is the alternatives list of viable or plausible solutions fully inclusive or thoroughly exhaustive. Moreover, a number of the selected alternatives are integral to physical security (i.e., barriers, structures, modifications, etc.), whereas other alternatives address preventative counter-terrorist measures to include screening, armed intervention and other means of deterring air piracy.

The generated list of alternatives reflects an ample cross-section of viable possibilities or solutions to the goal. While the aim of this decision-making project is to select one alternative, any combination of alternatives therein could be ultimately deployed effectively.

IV. Alternatives – Listing and Definitions

A. <u>Air Marshals</u> – Institutes the comprehensive training, deployment and use of highly skilled and armed Federal air marshals on selected domestic flights, most transcontinental and all international and inter-continental flights originating in the United States and selected foreign countries for return flights to the United States.

B. <u>Arming Pilots and Crews</u> - Includes the complete and thorough training and arming of flight crews (namely the pilot and co-pilot, and navigator, as available on selected wide-body aircraft, et al) to preclude the actual loss of control of the cockpit to terrorists. A derivation of this alternative would extend armed capabilities to selected cabin personnel or selected flight attendants.

C. <u>Evasive Pilot Actions or Maneuvers</u> – Involves the pilot executing evasive pilot actions in-flight as a means to provide diversionary tactics which may include those airborne maneuvers used to throw hijackers and terrorists off guard and to destabilize the potential seizure of the aircraft. Evasive pilot actions may include sudden loss of altitude, power diving and or violent rolling of the aircraft from level flight, or other high risk maneuvers or turns at significantly higher G forces including potential blackout for the uninitiated or inexperienced (i.e., terrorists and passengers alike). May be used in conjunction with the loss of cabin pressurization alternative. This alternative is classified as a last resort, high-risk counter-terrorist measure.

D. <u>Reduce or Prohibit Carry-on Luggage</u> - Significantly reduce or entirely prohibit the practice of allowing carry-on luggage from entering the aircraft main deck and cabin. Alternative defined as follows:

   1. <u>Reduced Carry-on Luggage</u> - The reduced requirement would allow one single piece of small luggage per passenger plus a purse, handbag or a briefcase. Children do not get any allocation.
   2. <u>Prohibit Carry-on Luggage</u> - A full prohibition would allow only for a maximum of one purse or a briefcase only with no allowances for any unchecked luggage, packages or garment bags.

    3. Sharp Objects - Includes prohibition of knives, blades, razors, needles, sharp instruments or any other objects, which may be used as potential weapons. All elements of the alternative are considered preventative action measures.

E. Pressurization Loss – Main Cabin – Provides for a high-risk maneuver to intentionally lose cabin pressurization (with immediate oxygen provided for cockpit crew). The pressurization loss includes the intentional blackout of passengers and terrorists while oxygen remains available for cockpit crew (i.e., pilots and navigator, if available). Considered a high-risk counter-terrorist measure to be utilized as a last resort to preclude the loss of control of the aircraft to terrorists.

F. Redesign of Transponders - Transponder redesign requires securing the device to ensure terrorists cannot turn it off deliberately, to have a fail-safe backup to ensure transponder codes are not compromised and that the unit works in conjunction with refinements made at the ground level at all domestic airports. This will enhance the ability to monitor flights deviating from established flight routes or glide paths and to allow for early military interception. [Important note: the affected aircraft transponders were turned off during each of the September 11th tragedies.]

G. Reinforcement of Cockpit Doors - Requires the reengineering and structural modification retrofit of all cockpit doors on existing and deployed aircraft as used by commercial airlines. Original equipment manufacturers will incorporate superior materials and locking mechanisms into new aircraft while in production. Includes the following applications or any combination therein:

    1. Physical Latching and Barring – Secures the aircraft cockpit door from the cockpit or crew station side only. Opening the door requires action of pilot, co-pilot (or navigator on larger aircraft).

    2. Cockpit Door Reinforcement – Requires the upgrade of materials to include bulletproof Kevlar®, high tensile strength steel or other high strength shock absorbing materials.

H. Remote Flight Controls – A highly advanced technological approach to the remote flight control of airborne aircraft, albeit quite similar to the technologies utilized by NASA to send signals to the Space Shuttle, satellites and other space vehicles while in orbit. These signals are used to control flight, change course, speed, altitude, and re-entry attitude and may affect many other space vehicle performance characteristics. The proposed concept is a theoretical extension of known technologies with wide-ranging ramifications in regard to research, design and development costs, deployment and installation costs plus the actual installation impact and any associated on-going maintenance of affected airborne and associated ground systems. Conversely, the opportunity to provide a technologically advanced system to take over an aircraft in distress and bring it down safely by means of sophisticated ground control commands appears to be more feasible in light of the 11th of September disasters. Considered both a high technology and a high cost risk.

I. Screen 100% of All Checked Luggage - Includes provisions to screen all checked luggage and other baggage 100% by most sophisticated screening and detection technologies available. Includes all baggage currently put into the aircraft hold by means of containerization or loose baggage loaded by belt-loader or ramp.

    1. Match 100% of All Checked Luggage – Requires 100% matching all checked luggage to boarding manifest. No checked baggage will fly if the owner does not physically board the aircraft.

    2. No Curbside Check-In - Includes a caveat to eliminate all curbside check-ins and to centralize the baggage staging area for the 100% screening of all luggage and packages.
    3. Comprehensive Training and Search Techniques – All airport security screening personnel and the utilization of trained security dogs to sniff packages and general baggage for explosives.[6] This alternative is a preventative action and a counter-terrorist measure.

J. Solid Cockpit Bulkhead – A solid cockpit bulkhead, a primary example of physical security, requires the complete reengineering of the access to the cockpit from the outside of the aircraft only and places a completely solid bulkhead across the fuselage to separate the cockpit permanently from the remainder of the aircraft. Access to the cockpit would only be from outside (hence, while the aircraft is on the ground and never in flight). Considered a future option as this alternative necessitates a major engineering redesign and implementation effort by the original equipment manufacturers (i.e., Airbus Industrie, Boeing, Bombardier Aéronautique, Embrarer, Fairchild Dornier, Gulfstream, et al) into current production. Retrofits into existing in-service aircraft are highly unlikely due structural integrity and stress concerns for the affected airframes.

K. Stun Guns for Crew and Pilots - Implements the use of stun guns through formal training applications at each airline and to train all affected cabin crews in the proper use of stun guns. [Note: This is intended primarily for the Flight Attendants and not for the cockpit crew. The cockpit crew would be the second line of defense with additional stun gun equipment deployed in the cockpit.] This alternative was assessed separately from armed pilots with live ammunition. This is considered a medium risk preventative counter-terrorist measure.

L. Comprehensive Training for Flight Crews - Includes the development and deployment of a comprehensive training program for all airline personnel and flight crews delineating all measures regarding any potential handling hijacking attempts, and appropriate counter-terrorist measures.

M. Comprehensive Training for All Airport Security Checkpoint Personnel - Includes the qualification training and retraining certification of airport security and baggage screening personnel at all domestic airports in the United States. Alternative includes the following security program attributes and characteristics of a comprehensive approach to airport checkpoint security:

    1. Passenger Screening – Questioning of passengers and random searches based upon responses, behavioral patterns and threat assessment. Includes methods for spotting and assessing potential security risks and improved baggage screening measures.
    2. Background Checks – Air carrier personnel to cross check information with law-enforcement and immigration sources. Security I.D. cards to be issued for frequent flyers.[7]
    3. Secure Gate Areas – only ticketed passengers allowed in gate areas beyond main concourse of airport.

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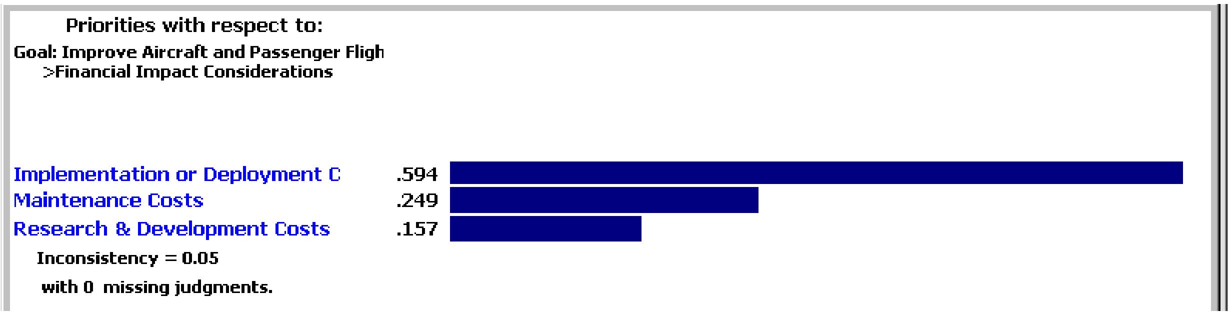
[6] While international flights are usually pre-screened, few pieces of checked luggage are security screened for most transcontinental and regional domestic flights inviting another bombing similar to the Lockerbie, Scotland tragedy.

[7] Security I.D. cards to be issued for frequent flyers to facilitate and expedite processing through airport security screening. Already, this system has been initially tested in the United Kingdom. Barbara S. Peterson, "Security The New Standard," *Condé Nast Traveler Magazine*, November 2001, 88.

V. Priority Evaluations With Respect to the Goal

The most important deliberations were to perform the pair-wise comparisons and evaluate or assess our own priorities as these related to the overall goal itself. These comparisons were completed and have been incorporated into this research paper. Charts have been extracted directly from Expert Choice 2000 and are inserted to provide a synopsis of the results of our evaluation of the various priorities. Within the area of financial considerations, the implementation or deployment costs were not unexpectedly the highest priority since this area should entail the greatest potential financial impact for all air carriers.

In the realm of financial considerations, the pair-wise comparisons and analyses were based upon projected recurring and non-recurring costs and the extent of the projected financial impact for each element. Exhibit 2 reveals the financial impact considerations priorities with respect to the goal.



Priorities with respect to:
Goal: Improve Aircraft and Passenger Fligh
>Financial Impact Considerations

Implementation or Deployment C .594
Maintenance Costs .249
Research & Development Costs .157
Inconsistency = 0.05
with 0 missing judgments.

Exhibit 2 Financial Priorities

Using the guidelines of the widely accepted and established CS^{2}[8], each projected cost was broken down into a one-time non-recurring cost or a recurring cost of doing business. Moreover, certain projected costs were classified as an indirect burden whereas other estimated costs associated with our financial considerations were determined to be a direct charge thereby allowing for some recovery (or write-off) of the financial impact to the affected enterprises.

In the pair-wise comparisons, it was very important to know whether a projected cost would include nonrecurring, recurring or both costs. In addition, the type of charge (e.g., direct versus indirect) is significant in order to get a clearer picture of what costs may be recoverable and those that are a charge solely against overhead. With these criteria as a baseline for the pair-wise-comparison, Implementation or Deployment Costs emerged as the most diverse and complex costs associated with the financial impact considerations. These projected expenditures include:

a. Training (Indirect, Nonrecurring or Recurring)
b. Comprehensive Training Program Development (Indirect, Nonrecurring)
c. Administration of Initial Training (Indirect, Nonrecurring)
d. Periodic Retraining and Updates of Training Program (Indirect, Recurring)
e. Equipment and Systems Installations (Direct, Nonrecurring or Recurring)
f. Initial Installation Costs (Direct, Nonrecurring)
g. System Replacement Costs (Direct, Recurring)
h. Aircraft Structural Modifications (Direct, Nonrecurring)
i. Re-engineering Costs For Existing Aircraft (Direct, Nonrecurring)

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[8] Cost/Schedule Control System is typically used by airframe and powerplant manufacturers as well as a number of major air carriers at their depot maintenance facilities to segregate and track costs associated with aircraft maintenance, refurbishment, modification and reengineering.

Reasonably, Implementation or Deployment Costs would be the highest priority since these would include the costs associated with all corrective and preventative actions taken to preclude recurrence of further terrorism and air piracy. Depending upon the alternative selected, these costs could financially impale already weakened domestic air carriers. When costs were projected, it was preeminently clear that Implementation or Deployment Costs were the greatest potential threat that air carriers could face.

As a comparison, Maintenance Costs are a stand-alone only entity and consist of direct, recurring expenditures only. These costs can be somewhat mitigated against scheduled Programmed Depot Maintenance (C & D Checks) thereby reducing the potential impact. Similarly, Research and Development (R&D) Costs are singularly unique costs, which consist of indirect nonrecurring expenses. In the pair-wise evaluation, the trade-off between the one-time costs of "R&D" was assessed and evaluated against the on-going cost of maintenance.

Recurring maintenance costs were the second highest with the costs for research and development being the lowest single priority, albeit potentially the highest single cost factor or financial impact should the U.S. Government fail to defray part or all of the deployment of major new technologies. By all appearances, the Federal Government appears willing to bail out the airlines to preclude widespread bankruptcies.

In real terms, the financial impact assessment accounts for all direct nonrecurring costs associated with incorporating any alternative selected. Repetitive and on-going maintenance costs for aircraft, personnel retraining and program re-evaluation and update (i.e., direct and indirect recurring) costs were a distant second priority. Lastly, the indirect nonrecurring costs associated with research and development, while generally significant, were evaluated as a last priority due to the immediate urgency for the implementation of changes for aircraft security, flight integrity and needed counter-terrorism measures.

The implementation evaluation, shown in Exhibit 3, indicates a clear priority for the urgency requirements as defined by the mandate by which these modifications or changes are implemented (e.g., Airworthiness Directives, Service Bulletins, et al). The influence of potential government intervention clearly outweighs all other considerations relative to implementation or schedule considerations. The impact of Federal law or OEM sensitive Service Bulletins grossly out-weighed all other priorities combined. As a general note, the degree of technical difficulty, while currently evaluated to be in last place, may be wholly dependent on the alternative technologies identified thereby possibly exacerbating the implementation schedule.

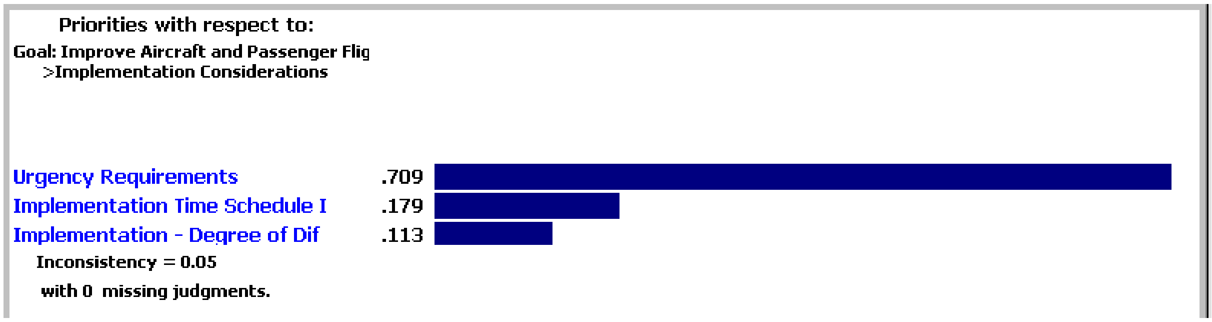


Exhibit 3 Implementation Considerations

The importance of the implementation time schedule relative to incorporating the necessary or mandated changes is the second highest priority and this element can radically impact the PDM schedule at the depot maintenance facilities. Most air carriers have the PDM frequency interval down to a science and any deviation from the established schedule can mean a reduction in revenue and adverse cash flows.

Lastly, the degree of difficulty (i.e., magnitude of work orders affecting in/out times at depot) was judged to be the least critical when compared directly to the weight of Federal law or the airline PDM service rotation plan.

The technology evaluation indicated a clear preference for systems and processes that would offer a decisive advantage to accuracy and precision. The definition, as applied here, included the fail-safe abilities of new technologies, systems or processes to preclude further acts of terrorism. The preference for accurate systems and technologies was considered somewhat interesting since the general pre-conceived notion was to lean towards the inherent feasibilities of known technologies to be applied in a commercial environment. The results of the technology pair-wise comparison are shown in Exhibit 4.

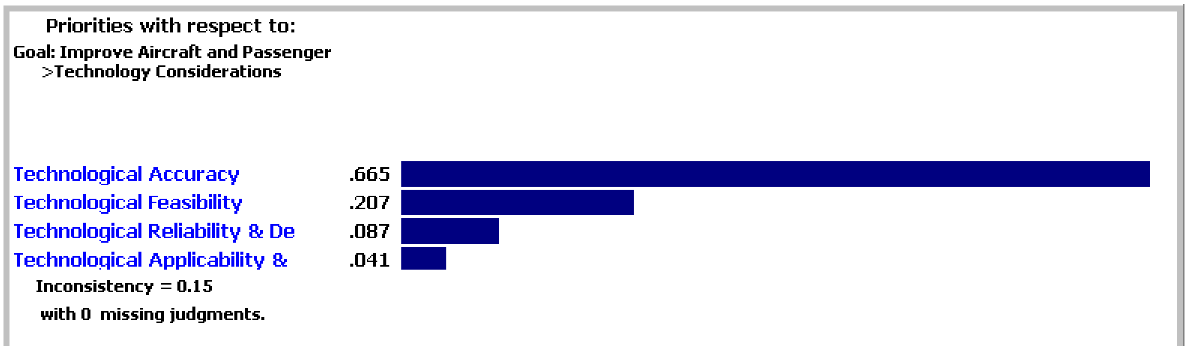


Exhibit 4 Technology Considerations

Technologies proved to be the most difficult perspective to assess since we are addressing those known applications and their immediate derivatives versus those technologies requiring further technical and scientific research. These technologies may require the extensive tailoring of existing military applications to make these same technologies practically and feasibly available for commercial endeavors. In virtually all cases, the need for accuracy greatly outweighed any other priority. This priority decision would be a reasonable conclusion since the subject of this project is airborne transportation. Inaccurate aircraft systems are highly detrimental to flight safety and are widely discouraged by airline management.

The concern for the feasibility of the technologies was evaluated as the second highest priority. The evaluation addressed the economic imperative that the technology can be developed or derived from an existing technology. Moreover, the research and development timeline was considered as important to deploying the technology within a reasonable time period.

Finally, in the pair-wise comparison, reliability and dependability of new or derived technologies placed ahead of the concern for applicability and practicality. From an engineering standpoint, the evaluated pair-wise decisions for accuracy, feasibility, reliability and applicability are in a logical sequence with the emphasis remaining on accuracy of aircraft technologies to ensure safety of flight.

Safety and risk considerations were evaluated and in the pair-wise comparisons, the loss of aircraft was evaluated to be the highest concern. Catastrophic loss of the aircraft was, by far, the greatest single concern with survivability being a distant second in the pair-wise. By definition, the loss of the air vehicle would most likely entail the loss of crew and passengers thereby greatly increasing the magnitude of this element.

Survivability addresses the assessment of the fail-safe or backup systems assuming an incident or incidents occur(s) during flight. In addition, this element includes the ability to recover from evasive maneuvers; loss of pressurization or other tactics employed as counter-terrorist measures. Such maneuvers place a high degree of stress on the airframe and may result in fatigue failure of fracture or durability-critical airframe components.

Lastly, the concern for collateral damage paled in relation to the loss of the aircraft or the concern for survivability. Overwhelmingly, the pair-wise decision emphasized the priority of the loss of aircraft. Primarily, these pair-wise decisions for safety and risk considerations were based on common sense. The EC 2000 software emphasizes the order of magnitude separating the priorities. While all safety factors are considered important, the ultimate loss of the aircraft grossly outweighs collateral damage to an aircraft that still can land safely. The pair-wise decisions for safety and risk considerations are shown in Exhibit 5.

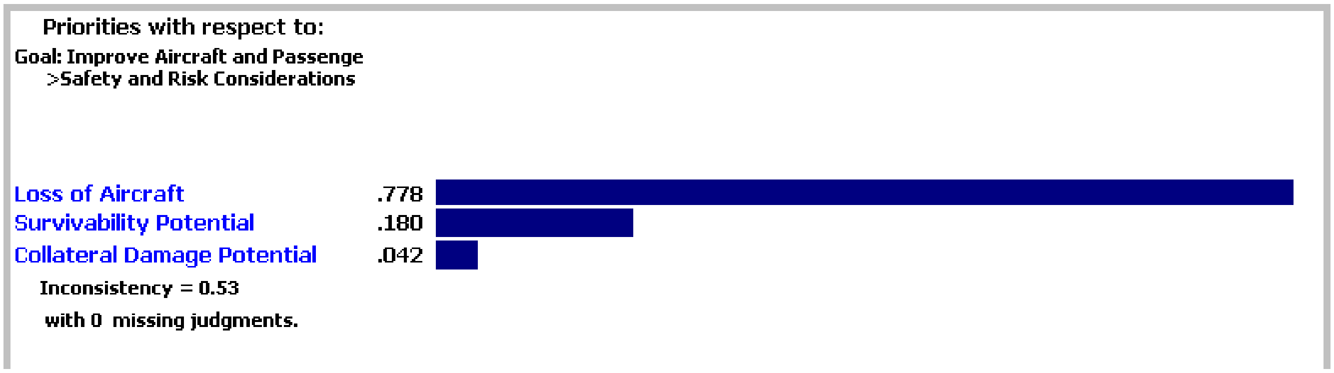


Exhibit 5 Safety & Risk Considerations

As for the all-up priority evaluation of the four major perspectives or criteria, Exhibit 6 clearly summarizes the results of the pair-wise comparison with respect to the overall goal.

Paramount among priorities is the overriding concern for safety and risk, which greatly outweighed all other considerations when prioritized with respect to the ultimate goal. Again, this would be anticipated considering the airborne mode of transportation.

The impact of implementation clearly outweighs the financial impact since the implementation schedule directly affects revenue and the airlines' ability to generate cash in-flows. As shown earlier, the impact on depot maintenance facilities and aircraft out-of-service will adversely affect the air carriers' ability to perform efficiently.

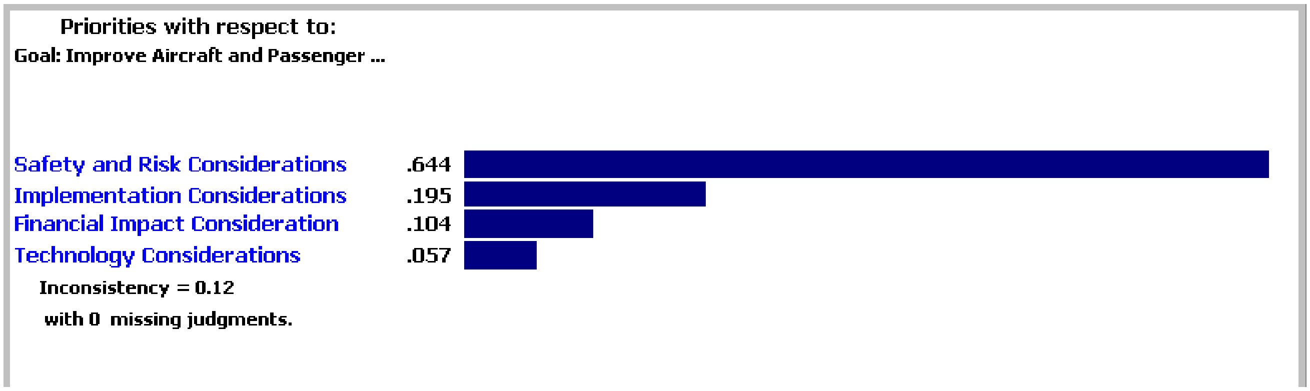


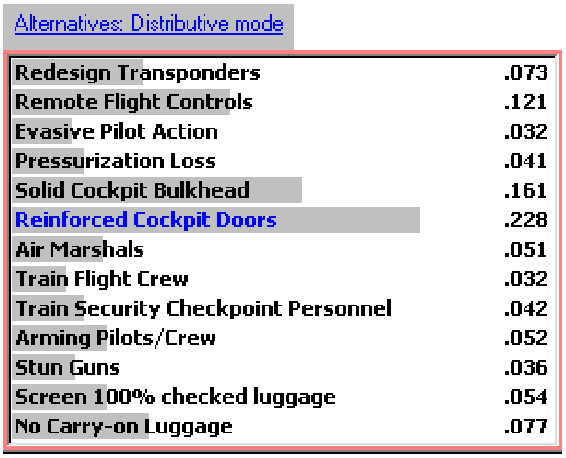
Exhibit 6 Goal Considerations

Lastly, during the pair-wise assessment, technology was evaluated to be much less of a priority when compared to the paramount priority of safety, and the strategic business planning strategies of running and efficient and financially sound airlines. This evaluation re-emphasizes the traditional business core values as opposed to the decade-long fascination with technology as reiterated by the financial markets.

The pair-wise assessment did not reveal any unanticipated rankings of the priorities, however, the weights assigned were interesting regarding the magnitude of the safety and risk considerations and the significantly less emphasis on technology as the primary driver when compared with the overall goal to improve aircraft and passenger safety and security.

VI. Alternatives – Evaluation and Assessment - Results

The alternatives were evaluated using the EC 2000 software. The project’s thirteen alternatives were thoroughly evaluated, albeit the assessment was involved and time-consuming to complete every pair-wise assessment, especially in view of the high number of alternatives being evaluated against the established criteria, which had been previously prioritized.



Alternatives: Distributive mode

Redesign Transponders	.073
Remote Flight Controls	.121
Evasive Pilot Action	.032
Pressurization Loss	.041
Solid Cockpit Bulkhead	.161
Reinforced Cockpit Doors	.228
Air Marshals	.051
Train Flight Crew	.032
Train Security Checkpoint Personnel	.042
Arming Pilots/Crew	.052
Stun Guns	.036
Screen 100% checked luggage	.054
No Carry-on Luggage	.077

Exhibit 7 Alternative Rankings

Exhibit 7 extract from the EC 2000 software reflects the final results of the evaluation of the thirteen individual alternatives. Low inconsistencies noted throughout the entire project on virtually every single comparison exercise completed on the first pass. Only two individual panes were re-evaluated a second time to determine the actual best-fit condition when the inconsistencies were just slightly higher than the balance of those completed in this research project.

In Exhibit 7, the preferred choice is clearly evident as well as the next two highest alternatives. After the top three, the alternatives significantly decline precipitously in the ranking.

The *Synthesis With Respect To Node By Priority* charts (Exhibits 8 – 12) revealed a significant preference for the reinforcement of cockpit doors alternative as shown in the following extracts from the EC 2000 software **(reflecting the top three (03) in each Node):**

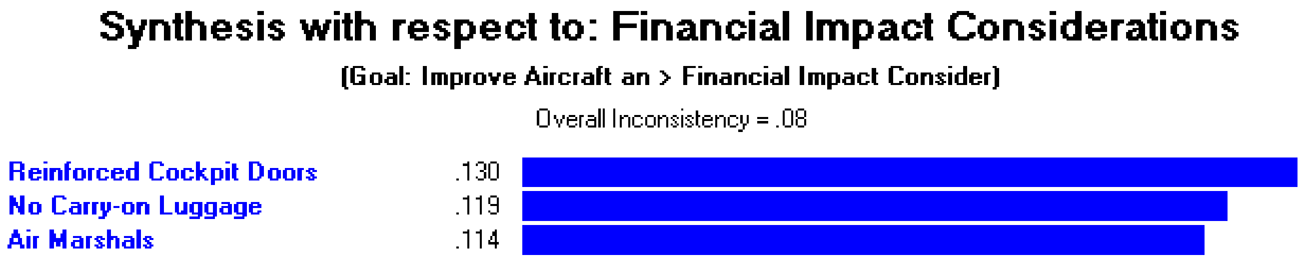


Exhibit 8 Financial Syntheses

The financial perspective indicated a preference for reinforcement of cockpit doors, although the next two highest alternatives were closely ranked due to the judgment that these alternatives were highly cost effective as well. While the reinforcement of cockpit doors is an example of physical security, the other two highly regarded alternatives are examples of preventative counter-terrorist measures.

All three alternatives scored well in the ranking due to their projected effectiveness as a return on investment. The primary difference in the top three alternatives is that the cockpit doors represent a nonrecurring direct charge to the aircraft involved whereas the other two alternatives identified in Exhibit 8 represent recurring indirect expenditures. In this sense, a nonrecurring charge is preferable to those with on-going ramifications.

The reduction in carry-on luggage will impact the screening requirements for baggage entering the cargo hold. Moreover, training and retraining requirements (i.e., nonrecurring, recurring respectively) are affected. The same condition (i.e., nonrecurring and recurring expenditures) exists for air marshals for recruitment, hiring, training and retraining at specified frequency intervals.

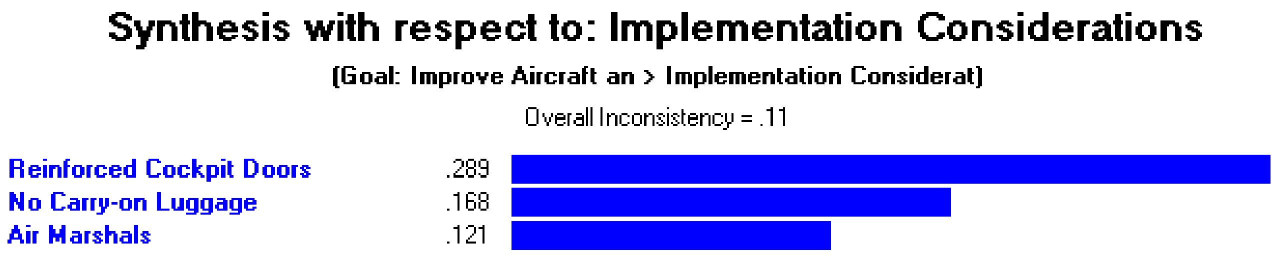


Exhibit 9 Implementation Syntheses

The synthesis of the implementation considerations, shown in Exhibit 9, reflects the exact same "top three" choices in the identical rank-order as indicated by the financial comparison. This time, the reinforcement of cockpit doors was undoubtedly the preferred choice by a much wider margin over then second and third ranked alternatives since the efficiency of the implementation was more evident in the evaluation.

While the cockpit doors adversely impacted the depot maintenance facilities and the PDM schedule, the door issue had an advantage in that the alternative could be completed without further recurring expenditures and on-going programs. Obviously, the reinforcement of cockpit doors can be completed in a finite timeframe and is not demonstrative of on-going commitments, which are clearly required by the other two top scoring alternatives.

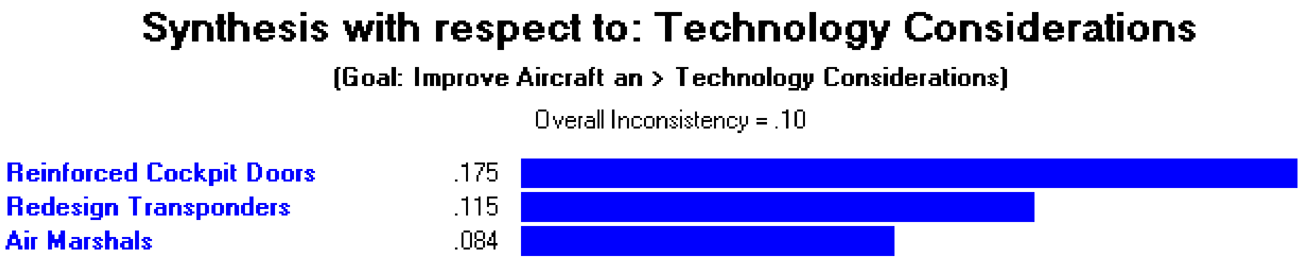


Exhibit 10 Technology Syntheses

The Reinforcement of Cockpit Doors was the evident preferred choice in the technology comparison assessment with the emphasis on using known technologies and materials (e.g., Kevlar®, steel, et al). The cockpit door modification outweighed the transponder redesign since the door technology was immediately available and required no software re-engineering. The top three alternatives are shown in Exhibit 10.

The Redesign of the Transponders rated much higher in this comparison analysis since the transponders would be a derivative of known technologies with limited risk potential and huge benefits. It is important to remember that the transponders were compromised in the 11th of September tragedies.

The transponders are a critical entity to the flight crew and to all affected ground stations tracking the flight. Basically, the technology is available, albeit would require a redesign and some testing prior to deployment.

Air Marshals also reflect the dependency on the known "technologies" versus the introduction of unknown or unproven alternatives. While armed Air Marshals are not a high technology, these agents were effectively used in the past on selected flights as a strong deterrent to air piracy and potential terrorist threats.

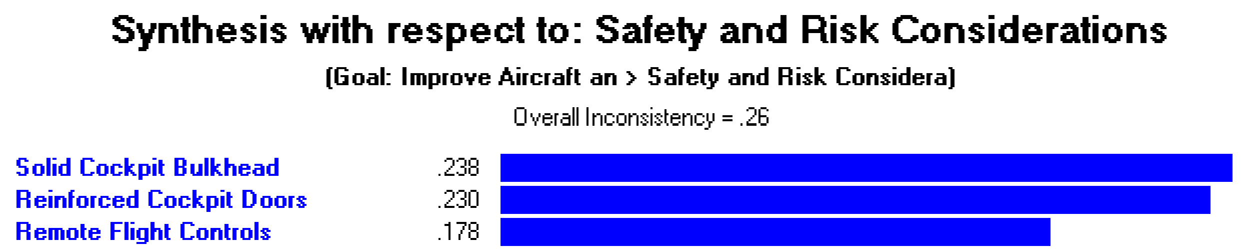


Exhibit 11 Safety & Risk Syntheses

In the safety and risk synthesis, the alternative for the reinforcement of cockpit doors was marginally edged out for the most preferred choice. This result is considered entirely logical since a solid cockpit bulkhead would be more secure, in an absolute sense, than a reinforced cockpit door. Stationary solid walls (i.e., bulkheads) are far more secure than walls with door openings since it would be the door opening in the wall that would be compromised first. The first and second ranked alternatives represent the same type of physical security. The top three choices are reflected in Exhibit 11.

The remote flight controls ranked high in the safety and risk assessment in that this alternative could provide a high confidence level to airborne aircraft under threat of air piracy, terrorism or other life-threatening incident. This was the only synthesis where this alternative placed high in the ranking,

In Exhibit 12, the all-up synthesis with respect to the goal or objective shows the top three alternatives. The reinforcement of the cockpit doors was the overall preferred choice. This is in complete alignment with the three lower tier syntheses shown in Exhibits 8-10. In Exhibit 11, the cockpit door reinforcement was ranked as a very close second.

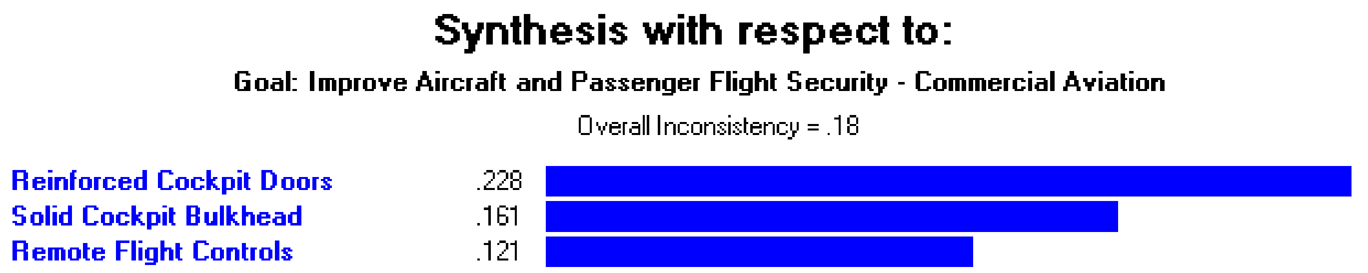
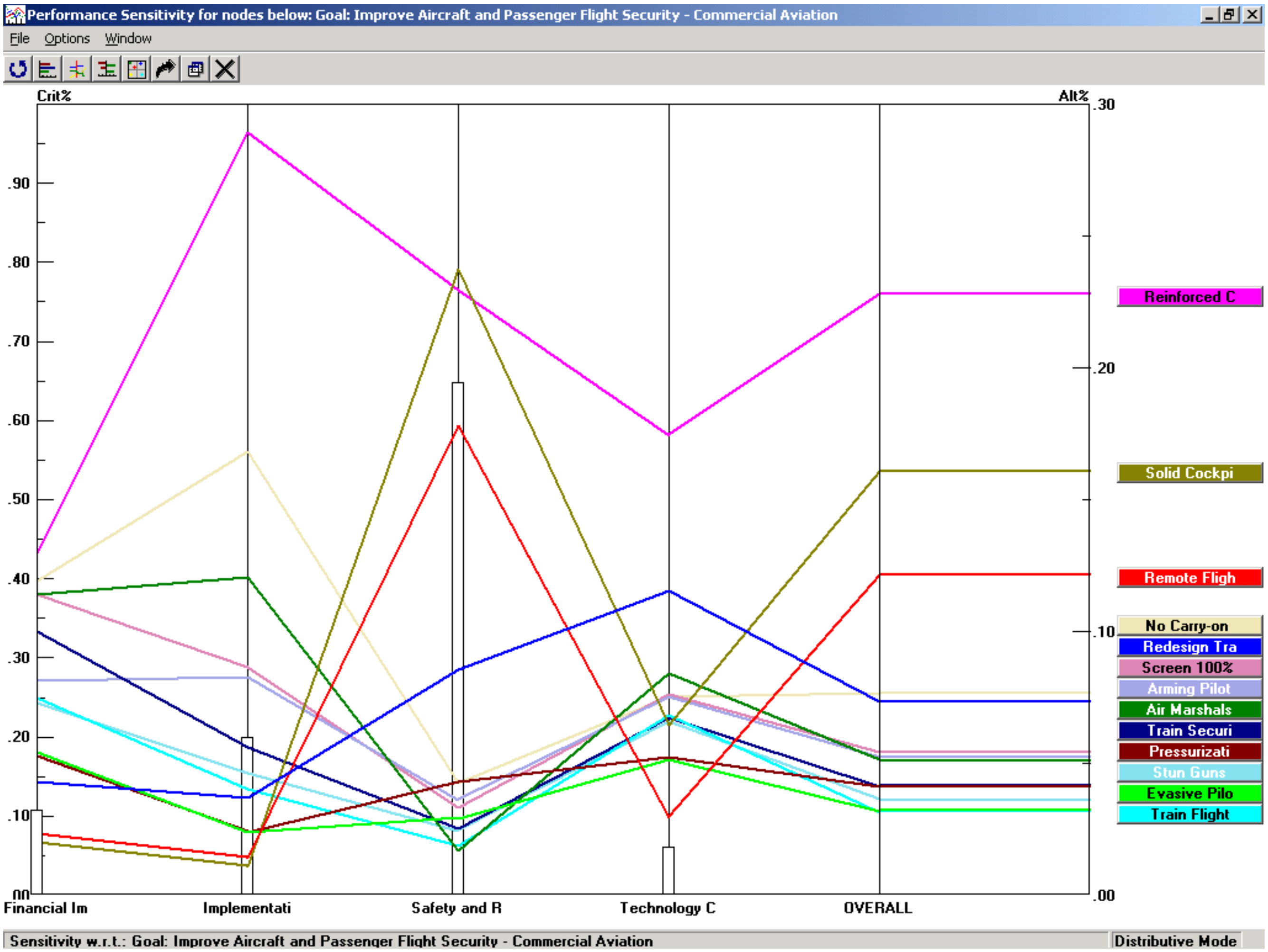


Exhibit 12 Overall Synthesis

VII. Summary and Concluding Comments

Our sensitivity graph, Exhibit 13, illustrate the concurrence that during the course of this project, the Secretary of Transportation, Norman Mineta, ordered all American Flag carriers to incorporate the necessary modifications and changes to reinforce aircraft cockpit doors by physically restraining the door through latching mechanisms from inside the cockpit (i.e., barring and/or latching mechanisms) and to strengthen the cockpit doors themselves. In response to the order by Secretary Mineta, air carrier Jet

Blue, based out of New York, will have all doors changed on their aircraft within one month of the secretary’s order. The new aircraft doors incorporate bulletproof Kevlar® materials as a structural reinforcement and as a counter-terrorist measure. These replacements are in addition to the requirement for internal latching and/or barring mechanical installations.



Sensitivity w.r.t.: Goal: Improve Aircraft and Passenger Flight Security - Commercial Aviation

Exhibit 13 Performance Sensitivity Graph

Alaska Airlines, based at Seattle-Tacoma International Airport, will complete the retrofit of their commercial fleet within one month at a projected cost of $1.2 million for replacing the cockpit doors with Kevlar® core-reinforced doors. Larger airlines such as United Air Lines (UAL) and American Airlines (AA) have begun the process of reinforcing the cockpit doors with inside bars and latching mechanisms, albeit no major carrier to date has undertaken the replacement of the cockpit doors with Kevlar® reinforced materials as have both Jet Blue and Alaska Airlines. TWA, now owned wholly by American Airlines, was brought into compliance before their much larger parent company due to their significant overseas exposure.

British commercial aircraft are being fitted with bulletproof cockpit doors for the first time. Virgin Atlantic Airways has been installing armor-plated doors on its fleet of thirty jets, while the flag carrier British Airways has been reinforcing the exteriors of cockpit doors on its 340 commercial aircraft.

The Transportation Secretary issued an order to complete all work on cockpit doors by January 5, 2002, or within the ninety-day timeframe from the date of the order. Meanwhile, aircraft original equipment manufacturers have begun the reengineering process and are incorporating redesigned cockpit doors into new commercial aircraft production.

As of the 8th of November 2001, the Air Transport Association reported that its passenger airlines-representing in excess of ninety-seven percent of passenger traffic flown in the United States-have completed one hundred percent of the work to reinforce cockpit doors on their nearly 4,000 commercial aircraft.[9]

While completely unintended, the final recommendation, as evaluated through EC 2000 software, is in concurrence with the decision announced and ordered by the Secretary of Transportation. The actions of the past two months to reinforce all cockpit doors in existing aircraft and to incorporate new air piracy protection features into new commercial aircraft have substantiated our initial conclusion.

The reinforcement of cockpit doors provides the most safety and security with reduced risk. The implementation schedule for this alternative is not excessively impacted as pre-manufactured doors and/or barring and locking mechanisms can be installed rather quickly. The financial impact, while still significant, is many orders of magnitude less than various other high cost alternatives. The technology for this alternative represents a known resource and no research and development costs are associated with this action. Since this alternative is an example of physical security, no training programs or personnel should be required nor should there be any indirect or recurring costs associated with the installation (i.e., installation is a direct, nonrecurring or one time cost).

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[9] Air Transport Association website "ATA Passenger Airlines: Cockpit Doors Secure from Intrusion" dated 11-08-01.