Airport Surface Movement Enhancement and Runway Incursion Prevention Phase 1 – ASDE-X

Investment Analysis Report

August 15, 2000

Mission Need Statement #323

Executive Summary

Background

The Federal Aviation Administration (FAA) and the aviation community at large have identified the reduction of runway incursions and collision risks as top priority. Given that runway incursions have consistently worsened since 1993, and that United States (U.S.) air traffic is expected to double by 2010, runway collision risks may pose the greatest safety threat to U.S. aviation.

The Airport Surface Movement Enhancement/Runway Incursion Reduction Investment Analysis Team was formed to analyze the best set of solutions to meet the Agency's objectives to prevent, detect, and reduce runway incursions, incidents and impending accidents, and to also improve the safe and efficient movement of aircraft and materials on the airport surface. The Investment Analysis (IA) Team examined various alternative solutions in order to recommend the most effective solutions to address runway safety. The Team's initial focus on multi-faceted strategies identified in the Initial Requirements Document (IRD) to reduce runway incursions and accidents was changed to Airport Surface Detection Equipment-Model X (ASDE-X) technologies, per executive level direction, congressional mandate, and aviation community concerns. Consequently, the IA is currently being accomplished in two phases.

Phase I of the IA focused entirely on the ASDE-X system, a technology aimed at preventing accidents resulting from runway incursions. ASDE-X technologies (surveillance, conflict detection and alerting, and multilateration) will improve runway safety and contribute to the reduction of runway collision risks by providing controllers with greater situational awareness. The system consists of a primary radar subsystem, multilateration subsystem, multi-processor/data fusion subsystem, and controller display. Congress has mandated that FAA employ it, leaving the decision of how many and which locations to the Agency.

On May 22, 2000, the IA Team Lead presented a briefing to Jane Garvey, the FAA Administrator, on "Proposed Agency Decision for ASDE-X Quantity," briefed earlier to the Deputy Administrator, Monte Belger. This briefing led to the Administrator's decision to adopt the results of the IA Team's rigorous safety risk analysis. She announced her decision on June 26, 2000, at a two-day Runway Safety National Summit, held in Washington, D.C., - an announcement that received extensive national and international coverage by the media.

This Investment Analysis Report (IAR) provides, in detail, the methodology, analysis, activities, findings, and recommendations that comprised the basis for the decision. The expected cost, benefits, and performance schedule are also outlined in this report. Below is a brief summary of the analyses and findings, followed by the IA Team's recommendations to the Joint Resources Council (JRC).

Economic Analysis / Safety Risk Analysis

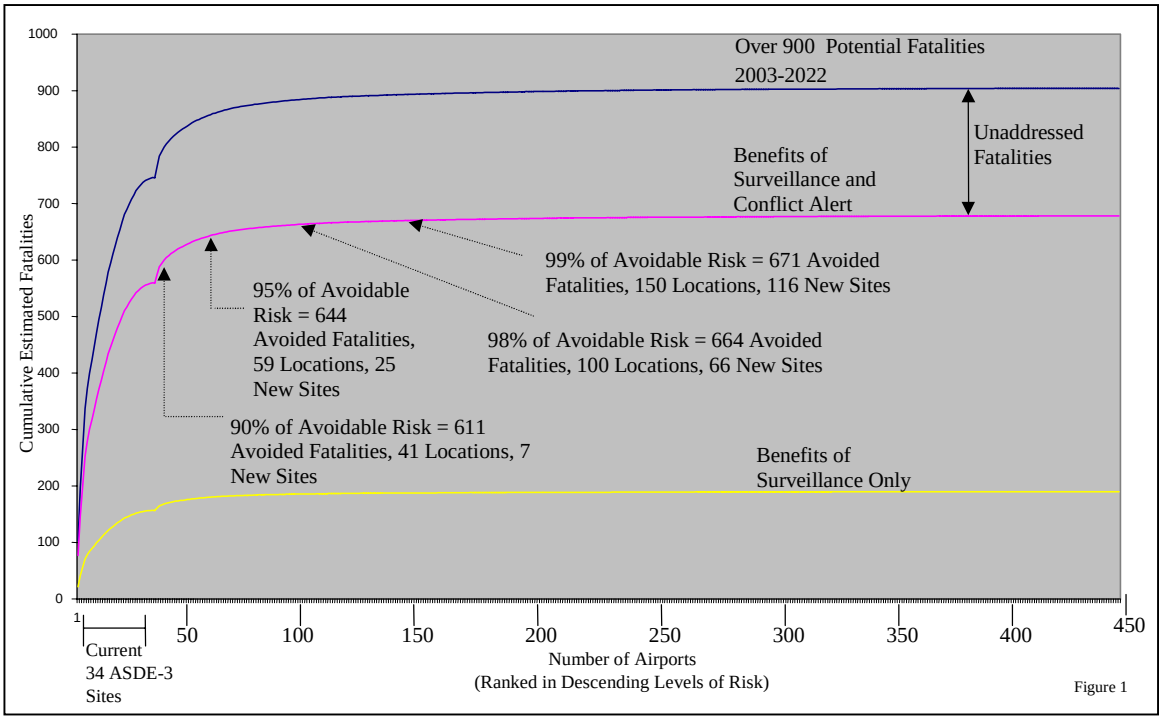
The IA Team conducted a detailed economic analysis of the ASDE-X system to determine the appropriate number of ASDE-X to acquire based on costs and calculated monetary benefits. In order to conduct the economic analysis, the following were developed: a) a forecast of potential

accidents at each towered U.S. airport, b) a rough-order-of-magnitude (ROM) estimate of monetary safety benefits for each airport, c) a detailed life cycle cost estimate of the ASDE-X system (2003-2026), and d) an estimate of monetary benefits versus costs.

The results of the economic analysis – estimating costs and benefits in economic terms – presented to the JRC on January 20, 2000, justified five ASDE-X systems. Acquisition decisions normally rely on a B/C case. However, in this case, the JRC members felt that the addition of five systems could be perceived as not doing enough to address the problem of runway incursion accidents, given that ASDE-X will help to reduce the risk of runway incursion accidents. Consequently, the JRC asked the IA Team to explore other ways to approach the problem of determining the appropriate ASDE-X quantity. For this reason, with the assistance of FAA lines of business and outside experts such as Dr. Arnold Barnett, NEXTOR/Center of Excellence/MIT, the IA Team completed a rigorous safety risk analysis as a supplement to the economic analysis, which helped to determine an appropriate number of new ASDE-X systems to buy.

This analysis built as its foundation, a projection of the total number of fatalities (approximately 900) over the next twenty years (2003-2022) that could be attributed to future runway incursion accidents on a NAS aggregate basis, as opposed to a per airport basis, if nothing further were done to improve safety on the airport surface. Approximately 75% of the total risk is avoidable on a NAS aggregate basis, through the use of surveillance with conflict detection/alerting equipment, such as ASDE-X, or ASDE-3 with AMASS. Implementing ASDE-X operational systems at 25 locations, in conjunction with the 34 ASDE-3/AMASS systems already planned would cover 95% of the avoidable risk (see Figure ES-1 below).

Figure ES-1. Safety Risk Analysis of Projected Fatalities (2003-2022)
Cumulative Potential Fatalities Avoided



If a decision is made to pursue another IA, Phase II of the IA will focus on addressing remaining safety risks not covered by current (ASDE-3/AMASS) and future ground surveillance technologies (ASDE-X). Beyond ASDE-X, we believe that additional investments identified in the IRD are needed to cover unaddressed safety risks. However in the meantime, to put closure to Phase I (ASDE-X) of this IA, the Team proposes the recommendations listed below to the JRC for decision making.

Recommendations

- Approve "Estimated" Acquisition Program Baseline (APB) for 25 ASDE-X systems, plus four support systems, prior to contract award in September 30, 2000, with a strategy to return to the JRC approximately six months after contract award, with a formal baseline for congressional tracking purposes.
- Approve expenditure of $15.5M through next JRC (six months after contract award).
- Proceed to award a contract for ASDE-X by September 30, 2000.
- Assign program responsibility for ASDE-X solution implementation to AND-400 Integrated Product Team (IPT).

Intentionally Left Blank

Table of Contents

1.0 INTRODUCTION 1

1.1 Background 1
1.2 Runway Incursion Definitions, FAA Concerns/Goals 1
1.3 Background: Investment Analysis Phase I (ASDE-X) 2
1.4 Scope 3
1.5 FAA Administrator's Decision on ASDE-X Acquisition Quantity 4
1.6 Major Assumptions 5

2.0 MISSION NEED, BENEFITS, AND REQUIREMENTS 7

2.1 Mission Need 7
2.2 Safety Benefits 7
2.3 Requirements 8

3.0 ALTERNATIVE ANALYSIS 9

4.0 THE NATURE AND BACKGROUND OF THE RUNWAY INCURSION PROBLEM: PREVIOUS ANALYSES OF PATTERNS AND TRENDS (1981-1999) 11

4.1 Trends 11
4.2 Causal Factors and Patterns in the Runway Incursion Data 12
4.2.1 Operational Errors 12
4.2.2 Pilot Deviations 13

5.0 HUMAN FACTORS ANALYSIS OF TOWER OPERATIONS 15

5.1 Introduction 15
5.2 Discussion 15
5.3 Summary 16

6.0 ECONOMIC ANALYSIS/BUSINESS CASE AND SAFETY RISK ANALYSIS 19

6.1 Economic Safety Benefits Analysis (Initial Results Presented to JRC on January 20, 2000) 19
6.1.1 Overview 19
6.1.2 Economic Safety Benefits Analysis Methodology 19
6.1.2.1 Forecast of Potential Runway Incursion Accidents 21
6.1.2.2 Estimate of Monetary Safety Benefits (Initial Economic Case Presented to JRC on January 20, 2000) 21
6.1.2.3 Initial Estimate of ASDE-X Life Cycle Costs (Ten-Lot Buy) 22
6.1.2.4 Initial Estimate of Monetary Benefits Versus Costs 23
6.2 Business Case (Initial Analysis) 23
6.2.1 Net Present Value 23
6.2.2 Benefit/Cost Ratio 24
6.2.3 Business Case Summary (Initial Results Presented to JRC on January 20, 2000) 24
6.3 Safety Risk Analysis - Supplement to the Economic Analysis/Core Piece 26
6.3.1 Background 26
6.3.2 Safety Risk Analysis 27
6.3.3 Safety Risk Analysis Recommendations Presented to Administrator on 5/22/00 30
6.3.4 Safety Risk Analysis Summary 31

7.0 INCLUSION OF AIR TRAFFIC OPERATIONAL REQUIREMENTS 33

Table of Contents

8.0 INVESTMENT ANALYSIS RISK ASSESSMENT 35

8.1 Introduction 35
8.2 Overall Risk Assessment Process 35
8.2.1 Identify Risk Facets and Relative Weights 35
8.2.2 Risk Assessment 36
8.3 Risk Facets With Medium Risk 37
8.3.1 Technical Risks 37
8.3.1.1 Technical Risk Discussion 37
8.3.1.2 Technical Risk Mitigation 38
8.3.2 Human Factors Risks 39
8.3.2.1 Human Factors Risk Discussion 39
8.3.2.2 Human Factors Mitigation Actions and Cost 40
8.3.3 Schedule Risk 41
8.3.4 Safety Benefits Estimate Risk 41
8.3.5 Supportability 42
8.3.5.1 Operations and Maintenance 42
8.3.5.2 Logistics 42
8.3.5.3 Testing and Support 42
8.3.5.4 Support Documentation 43
8.3.5.5 System Implementation 43
8.3.6 Information Security 43

9.0 OTHER MITIGATION STRATEGIES TO ADDRESS REMAINING SAFETY RISKS 45

10.0 AFFORDABILITY ASSESSMENT 47

11.0 ARCHITECTURE ASSESSMENT 49

12.0 RECOMMENDATIONS 51

13.0 GLOSSARY 53

14.0 BIBLIOGRAPHY 55

Table of Contents

LIST OF APPENDICES

APPENDIX A: THE NATURE AND BACKGROUND OF THE RUNWAY INCURSION PROBLEM: PREVIOUS ANALYSES OF PATTERNS AND TRENDS

APPENDIX B: METHODOLOGY FOR ASDE-X ECONOMIC ANALYSIS, SAFETY RISK ANALYSIS, AND FOR AIR TRAFFIC OPERATIONAL FACTORS ANALYSIS

APPENDIX C: ASDE-X ECONOMIC ANALYSIS – COST ANALYSIS

APPENDIX D: ASDE-X ECONOMIC ANALYSIS – BENEFITS ANALYSIS

APPENDIX E: SAFETY BENEFITS ANALYSIS ASSUMPTIONS AND BASIS OF ESTIMATES

APPENDIX F: BASIS OF ESTIMATE FOR ASDE-X ECONOMIC ANALYSIS

APPENDIX G: BASIS OF ESTIMATE FOR SAFETY RISK ANALYSIS

Table of Contents

Intentionally Left Blank

1.0 INTRODUCTION

This report documents activities conducted by the Airport Surface Movement Enhancement and Runway Incursion Reduction Program Investment Analysis (IA) Team that led to the development of the Investment Analysis Report (IAR) and Acquisition Program Baseline (APB). As specified in the Acquisition Management System (AMS) and the Investment Analysis Process Guidelines, the report summarizes the mission need, requirements, costs, benefits, schedules, alternatives, assumption, and risks. The report also documents the economic assessment, a safety risk analysis, the inclusion of an Air Traffic Service (ATS) operational factors assessment, and the results of the affordability assessment conducted by the System Engineering Operational Analysis Team (SEOAT). Finally, it summarizes the IA Team's Investment Decision recommendation to the Federal Aviation Administration (FAA) Joint Resource Council (JRC) to provide Airport Surface Detection Equipment – Model X (ASDE-X) capabilities at specified locations to improve runway safety.

1.1 Background

Detection, mitigation, and prevention of runway incursion incidents/accidents and facilitating the safe and efficient movement of aircraft and materials on the airport surface is of key concern to the FAA. The airport surface environment is highly dynamic and ever changing. Maintaining safety in the airport movement areas, runways, and taxiways is critical. This task becomes even more difficult during periods of degraded visibility or at night. The ever-increasing pace of air traffic operations, coupled with airport expansion plans, dictates the need for a continued emphasis to increase safety on the airport surface. In order to reach the objective of reducing runway incursion incidents and accidents, the FAA must emphasize educational and training programs for controllers, pilots, and vehicle operators, improved procedures and guidelines, airport improvements, as well as the integration of technology tools and airport enhancements.

1.2 Runway Incursion Definitions, FAA Concerns/Goals

Runway Incursion Definition: The FAA defines a runway incursion as "any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, intending to take off, landing, or intending to land." Runway incursions are considered to have three root causes – pilot deviations (PDs) air traffic control (ATC) operational errors (OEs), and vehicle or pedestrian deviations (VPDs). Further, runway incursions vary in the extent to which they represent a safety threat. The IA Team defined four levels of incursions for this analysis as follows:

- **Incursions with an extremely high potential for a collision:** An incident where separation decreases to a point where the margin of safety is so low that the participants barely avoid a collision, taking into consideration aircraft performance and whether the tower was aware of the impending collision and took corrective action. (Example: an aircraft on takeoff roll and close to rotation suddenly has a vehicle/aircraft cross in front of it and must prematurely pull the aircraft into the air to avoid a collision.)

- **Incursions with a high potential for a collision:** An incident in which the margin of safety decreases to a point where action is required to maneuver the aircraft to avoid a collision, taking into consideration aircraft performance and whether the tower was aware of the impending collision and took corrective action. (Example: an aircraft on a three-fourth mile final approach and a vehicle/aircraft crosses the path of the landing aircraft.)
- **Incursions with a medium potential for a collision:** An incident in which there is the potential for a safety threat (e.g., loss of separation) if not acted upon in a timely manner. (Example: an aircraft holding at the departure end of the runway and cleared for takeoff just as a vehicle/aircraft enters the active runway.)
- **Incursions with a low potential for a collision:** An incident in which there is no immediate danger of a collision or loss of separation between aircraft or an aircraft and vehicle. (Example: an aircraft holding at the departure end of the runway is not yet cleared for takeoff, and an unauthorized aircraft/vehicle enters the active runway.)

FAA's Concerns: The annual runway incursion figures have consistently worsened since 1993. On average, the runway incursion rate has risen approximately 15 percent each year from 1993 (186 reported incursions) through 1998 (325 reported incursions), and has remained "steady" through 1999 (322 reported incursions). For year 2000, as of August 9, 2000, 251 runway incursions have occurred on our nations' runways. Given that U.S. air traffic is expected to double by 2010, runway incursions may pose the greatest safety threat in U.S. aviation.

FAA's Goals: Reduce runway incursions by (1) preventing the occurrence of a runway incursion; (2) improving the detection and correction of runway incursions, thereby reducing the potential for runway incursion accidents; and (3) awarding an ASDE-X contract by September 30, 2000. Per congressional language, the mandate stated "by the end of fiscal year 2000, the conferees expect the FAA to have awarded at least one contract for producing an ASDE-X system for deployment." Of the top five Agency priorities, this effort is the number one priority.

1.3 Background: Investment Analysis Phase I (ASDE-X)

Phase I of the IA focused entirely on the ASDE-X system, a technology aimed at preventing accidents resulting from runway incursions. The FAA and the aviation community at large have identified the reduction of runway incursions and collision risks as top priority. ASDE-X technologies (surveillance, conflict detection and alerting, and multilateration) will improve runway safety by providing controllers with greater situational awareness, thereby reducing runway collision risks. Congress has mandated that FAA employ it, leaving the decision (which was recently announced to FAA, aviation community, and the media on June 26, 2000) of how many and which locations to the FAA.

The ASDE-X system will consist of a primary radar, multilateration subsystem, controller display, and multi-processor/data fusion technology needed to integrate future surveillance sensor inputs. Also, ASDE-X includes future capabilities for an automated conflict detection/alarming system, similar to AMASS, which will provide aural and visual warnings of impeding conflicts on the airport surface. **(The estimate in the APB includes a rough cost estimate for these future capabilities.)**

The ASDE-X will increase controller situational awareness by providing the tower controller a visual representation of the traffic situation on the airport surface in the form of aircraft position information, flight identifications or call signs, and audible and visual warning of impeding conflicts or collisions.

The primary radar portion of the ASDE-X system, with conflict detection/alarming capabilities, is similar to the existing ASDE-3/future AMASS, currently deployed at 34 locations.

Characteristics of ASDE-3/future AMASS, ASDE-X with multilateration subsystem are as follows:

ASDE-3/AMASS:

- ASDE-3 primary radar depends on reflections off metal objects to locate aircraft and airport vehicles on the airport surface, and provides situational awareness to tower controllers through aircraft/ground vehicle position information.
- The conflict detection/alarming capabilities of future AMASS will provide aural and visual warnings of potential conflicts/collisions, resulting from runway incursions.

DRAWBACKS OF ASDE-3/AMASS:

- System provides no aircraft flight ID (call sign)
- System has blind spots
- Multipath problems that result in false targets
- System experience shows performance degradation in rain
- System more prone to false alarms

ASDE-X:

- All the components and benefits associated with the ASDE-3/AMASS above exist with ASDE-X, with the addition of the multilateration subsystem.
- The multilateration subsystem in ASDE-X requires that aircraft and ground vehicles be equipped with transponders.
- With the addition of multilateration to the primary radar with conflict detection/alarming capabilities, the system provides a broader coverage of the airport surface. In addition to position information, it will also provide aircraft identification information (call sign) and cover most blind spots missed by the primary radar.
- Additional benefits are less multipath false targets and less performance degradation in rain.

DRAWBACKS OF ASDE-X:

- The multilateration subsystem requires that the transponder be on at all times in order to detect and identify the aircraft or ground vehicle. Presently, aircraft turn off transponders upon landing; there are efforts underway to address this operational change.

1.4 Scope

Phase I of the IA focused only on ASDE-X technology to prevent runway incursion accidents on the airport surface.

Phase II of the IA concentrates on efforts that will have the earliest and most significant impact on reducing runway incursions. In addition to the focus on education and training, improved procedures and guidelines, and improvements in airports, Phase II identifies and analyzes major acquisitions of additional technological solutions that will require an investment decision by the JRC.

1.5 FAA Administrator's Decision on ASDE-X Acquisition Quantity

On May 22, 2000, the IA Team Lead presented a briefing to the FAA Administrator, titled "Proposed Agency Decision for ASDE-X Quantity." The three recommendations presented to the Administrator are as follows:

- Procure 32 ASDE-X systems plus four support systems at selected locations, with options for additional sites and flexible capabilities. (The recommendation of 25 ASDE-X systems was based on rigorous and detailed economic and safety risk analyses. The IA Team proposed the procurement and implementation of 25 ASDE-X systems. Seven additional systems were added to the list to support air traffic operational requirements, thus bringing the recommended total from 25 to 32. Later, the FAA Administrator elected to proceed with the 25 locations supported by the safety risk analysis.)
- Reconvene the JRC to approve an ASDE-X working baseline (Phase I) prior to the anticipated September 30, 2000, contract award. The purpose is to give the JRC members an opportunity to perform a "sanity check" before contract award in September 2000, in order to ensure clarity concerning how many ASDE-X systems to acquire, their cost, and the anticipated delivery date.
- Conduct the Phase II Investment Analysis (IA) to address safety risks that will not be mitigated by ASDE-X or by ASDE-3, with a future conflict detection/alerting system (e.g., AMASS). Since ASDE-3/AMASS and ASDE-X are capable of addressing 75 percent of the total risk at a given location, remaining risks need to be addressed through another IA.

On June 26, 2000, at a two-day Runway Safety National Summit, held in Washington D.C., the FAA Administrator announced the Agency's decision to install ASDE-X surveillance radar systems at 25 specified airports. This decision was based on a rigorous safety risk analysis performed by the Airport Surface Movement Enhancement/Runway Incursion Reduction IA Team. (The addition of these 25 ASDE-X systems, together with the current 34 ASDE-3 sites plus future AMASS capabilities, are estimated to cover 95 percent of the estimated fatalities that could result from future runway incursion accidents, assuming the systems perform as advertised.)

1.6 Major Assumptions

Several assumptions, constraints, and conditions initially guided the IA. They are described below:

- This analysis evaluated improvements for both FAA and FAA-contract towered airports.
- The Runway Incursion Reduction Program is segmented into Phase I and Phase II due to the multiple strategies available for resolving runway incursion problems.
- Recommended technological solutions are not intended to replace existing systems, but complement them. ASDE-X is only considered for airports that have not been designated to receive ASDE-3/AMASS.
- Recommended technological solutions recommended only include solutions capable of being implemented within five years.
- This IA does not consider issues involving non-FAA-controlled areas at the airport (e.g., ramp controllers).

Page Intentionally Left Blank

2.0 MISSION NEED, BENEFITS, AND REQUIREMENTS

2.1 Mission Need

The IA has as its source Mission Need Statement (MNS) #323, which focused on four primary areas: (1) improve safety on the airport surface; (2) improve airport surface surveillance to enhance controller, pilot, and vehicle operator situational awareness; (3) provide needed capability through technology to improve situational awareness for controllers, pilots, and vehicle operators; and (4) remedy capability shortfalls through automated conflict detection capabilities, seamless coverage (through ADS-B, multilateration) and more effective training, procedures and enforcement initiatives. The objective of the IA is to evaluate the benefits (and costs) that bound the analysis for each of these four areas. The needed capabilities include:

- **Cooperative Work Environment.** Strengthening teamwork and communication among controllers, pilots, and vehicle operators through education and training is considered critical to the Runway Incursion Reduction Program. Improvements in collaborative strategic planning, data collection and analysis, human resource management, and stakeholder participation (i.e., management, unions, aviation, and airport community) are also important steps in generating a cooperative work environment to support runway safety.
- **Seamless Coverage Environment.** A "Seamless Coverage Environment" capability is needed to provide controllers with precise information about aircraft/vehicular movement on the airport surface. Seamless coverage would be achieved by taking in inputs from a variety of surveillance sensors. The compiled information is "fused" so that it presents a more accurate picture of the airport movement area. This capability eliminates the specific "deficiencies" inherent in each individual system by providing an overlapping coverage.
- **Additional Training/Education/Enforcement Initiatives.** Statistical analysis of previous runway incursion incidents reveals some specific areas where increased training, education, and enforcement initiatives could have a positive impact:
  - Improved recurring training for controllers,
  - Specific training aimed at the commercial and general aviation (GA) pilot communities, and
  - Better enforcement of airport security measures.
- **Conflict Detection/Alerting Capabilities.** The 1997 Government, Industry, Labor Aviation Safety Plan, upon which the Administrator's "Safe Skies" agenda is based, specifically calls for installing conflict detection/alerting systems at the top 100 airports as soon as possible.

2.2 Safety Benefits

The major benefits of the ASDE-X are to prevent accidents due to runway incursions, and thus significantly reduce potential fatalities and injuries. ASDE-X technologies (surveillance, conflict detection and alerting and multilateration) will improve runway safety and prevent runway

incursion accidents by improving airport controller situational awareness. ASDE-X improves controller situational awareness by providing visual representation of the traffic situation on the airport surface in the form of aircraft position information, flight identifications, or call signs, and by alerting controllers through aural or visual alarms that a runway incursion has occurred.

2.3 Requirements

The following are the key requirements for the ASDE-X system. For a detailed requirements description refer to the "*Requirements Document for Airport Surface Movement Enhancement and Runway Incursion Prevention, Airport Surface Detection Equipment System (ASDE-X),*" approved September 30, 1999.

- ASDE-X shall employ collision safety logic processing to detect and notify controllers of movement area collision hazards.
- The ASDE-X system shall accept inputs from multiple surveillance sources and process the data into a single solution.
- ASDE-X shall be maintained as an "essential" system in accordance with the requirements of Section 3.8.1, NAS-SR-1000, *"NAS System Requirements Specification"*.
- The ASDE-X system shall enable a modular expansion capability to meet airport movement area, user growth, and new processing demands.
- The ASDE-X system shall detect and display all aircraft and vehicles within the coverage area.
- The ASDE-X system shall interface with existing FAA ATC automation systems to display the arrival aircraft data tag position, aircraft identification, and predicted runway information.
- The ASDE-X system shall display a single track and track identification for a target.
- ASDE-X system shall provide target/track updates at a minimum of once per second basis.
- The *"Human Factors Design Guide"* (DOT/FAA/ACT-96/1), *"Human Factors in the Design and Evaluation of Air Traffic Control Systems"* (DOT-VNTSC-FAA-95-3), the "FAA Human Factors Job Aid" shall be followed for general guidance and development of requirements for solutions selected.

3.0 ALTERNATIVE ANALYSIS

The IA Team initially focused on analyzing alternatives based on the following four multifaceted strategies to reduce runway incursions, incidents, and accidents as outlined in the IRD.

- Education and training for controllers, pilots, and vehicle operators,
- Integration of technology tools,
- Procedural changes, and
- Improvements in airports, such as designs, lighting, signs, and surface markings.

The IA Team's focus was later directed to consider only alternatives that included ASDE-X, based on the following:

- FAA Administrator's goals as expressed in "Safer Skies" directive,
- Congressional mandate to award ASDE-X contract by the end of September 2000,
- FAA executive level direction,
- Aviation community concerns, and
- Public perception of safety.

After the initial economic analysis was performed, multilateration was added to the ASDE-X alternative, per executive direction, based on promising results of a demonstration at Dallas/Ft. Worth (DFW) airport. Multilateration costs were included after the safety risk analysis, described in Section 7, was performed. Multilateration uses the reception of transponder replies by multiple receivers to determine aircraft/ground vehicle location in a similar manner to triangulation. The aircraft identification is also obtained from these replies.

Consequently, the only alternatives considered in the Phase I economic analysis are ASDE-X with multilateration and conflict detection/alert.

Page Intentionally Left Blank

4.0 THE NATURE AND BACKGROUND OF THE RUNWAY INCURSION PROBLEM: PREVIOUS ANALYSES OF PATTERNS AND TRENDS (1981-1999)

The FAA has studied runway incursions extensively for a number of years and has shown a consistent 11 percent increase in traffic combined with a 73 percent jump in incursions from 186 in 1993 to 322 in 1999. The FAA has recorded 178 incursions through mid-June 2000, an 18 percent increase compared to 146 for the same period in 1999. Incursions are attributable to controller errors (OEs), PDs, and errors made by ground crews or vehicles operating on the airport surface (VPDs). According to Table 4-1, from 1993 through 1999, OEs account for about 30 percent of runway incursions, VPDs account for about 20 percent, while PDs are responsible for the majority of the incursions; that is, about 50 percent of the total.

Table 4-1. FAA Runway Incursion Statistical Trends Runway Incursions

Year	Airport Ops	OEs	PDs	VPDs	Total
1993	61,946,482	74	84	28	186
1994	62,452,572	82	69	49	200
1995	62,074,306	64	126	50	240
1996	61,817,425	63	149	63	275
1997	64,440,947	87	132	73	292
1998	66,218,975	91	183	51	325
1999	68,687,442	80	182	60	322

4.1 Trends

Although runway incursions have been increasing since 1993, the majority of incursions occur during good visibility conditions and routine traffic activity. It is also true that all fatal incursion-related accidents have occurred at night or in periods of reduced visibility. Significantly, the majority of runway incursions occur at the larger, more active and more complex airports (i.e., airports with over 150,000 annual operations and with multiple runways/taxiways and crossings). Although these airports make up only 35 percent of all towered airports, they account for 63 percent of total operations, and are responsible for 72 percent of the runway incursions. This does not exonerate the remaining airports but it does put into perspective where resources and improvements should be directed for the most productive allocation of those resources. A detailed analysis by the IA Team of runway incursion data from 1995 to 1997 found the following trends (See Appendix A for more detailed trend data):

- Of 212 OEs analyzed, 10 airports accounted for 27 percent of the OEs and 109 airports account for the remaining OEs. This indicates that there may be at least 39 airports with over 150,000 annual operations that did not report a single OE over a three-year period. It suggests that local factors at particular airports may be just as important as high operation levels at determining the risk of an OE.

- Of 403 PDs analyzed, 12 airports account for 24 percent of the PDs and 177 airports account for the remaining PDs.
  - 69 percent of all PDs involve GA aircraft
  - 77 percent of these GA pilots had either a student or private pilot certificate or 200 hours or less experience
- Of 184 VPDs analyzed, seven airports account for 26 percent of the VPDs and 101 airports account for the remaining VPDs. Thus, there are, at a minimum, 50 airports with over 150,000 annual operations that did not report a single VPD over a three-year period.
  - 82 percent of all VPDs occur late at night (between 8:00 PM and 7:00 AM)
  - VPDs predominantly involve civilians (72 percent are vehicle deviations and 28 percent are pedestrian deviations)

4.2 Causal Factors and Patterns in the Runway Incursion Data

The FAA is making a very significant commitment to reduce the potential for runway incursions/accidents through proposed tower and airport improvements (e.g., technology, training, procedures, airport improvements). However, the lack of hard empirical data on the pattern or factors that contribute to the unfolding of an incursion/accident makes it difficult to assess the impact of those improvements on enhancing safety at the airport. In the absence of empirical data, one is left with a retrospective analysis of the accumulated evidence from previous reports on runway incursions and accidents (see Appendix A for a summary of this evidence). Nevertheless, these retrospective analyses are particularly valuable in distilling the pattern of errors and deficiencies that have resulted in a runway incursion or a loss of separation on the airport surface (i.e., a collision hazard). The following findings summarize the most significant causal factors and their sources derived from retrospective analyses (from 1978 to 1999) of FAA reports of controller OEs, PDs, National Transportation Safety Board (NTSB) incident reports, Aviation Safety Reporting Program (ASRS) reports filed by pilots, and an IA Team analysis of decision making errors by controllers and pilots involved in runway incursions (from 1997 and 1998).

4.2.1 Operational Errors

The most significant causal factor (accounting for roughly 60-65 percent of all OEs) is that the controller fails to acquire sufficient information to detect or become aware of an impending problem due to deficiencies in monitoring or scanning the airport surface. The major sources of these failures, distilled from a number of reports, studies, and analyses are:

- Divided attention due to workload related factors
- Attentional or memory lapses
- Communication deficiencies (e.g., inadequate information exchange due to frequency congestion, incomplete messages, poor voice communication, misunderstandings, etc.)
- Coordination deficiencies (e.g., lack or incomplete coordination between controllers)
- Supervisory deficiencies as a result of the supervisor or controller-in-charge working at least one control position or engaged in alternative activities

- Staffing deficiencies due primarily to combining positions at just the wrong time

The second most significant causal factor is that the controller provides incorrect or inappropriate ATC instructions, primarily because the controller is unaware of the impending safety hazard or the controller fails to adequately monitor those instructions by means of readback/hearback messages. The major source of these deficiencies appear to be:

- Divided attention due to workload related factors
- Attentional or memory lapses
- Preformed notions (albeit incorrect) of what aircraft/vehicles are doing or where they are, thus giving up on information collection and monitoring activities
- Communication deficiencies

The third most significant causal factor (accounting for roughly 10 to 20 percent of all OEs) is that the controller fails to correctly diagnose the impending safety hazard. In most cases, this involves a failure to anticipate or miscalculate the loss of separation on the airport surface. The two main sources of this failure appear to be:

- Divided attention due to workload related factors
- Premature termination of diagnostic activity

4.2.2 Pilot Deviations

As indicated previously, PDs account for the majority of runway incursions, about 50 percent.

The most significant causal factor (accounting for roughly 75 to 95 percent of all PDs) is that pilots do not follow ATC instructions or procedures. The major sources of this failure include:

- Attentional or memory lapses
- Communication deficiencies or misunderstandings
- Lack of familiarity with the airport or getting lost as a result of airport deficiencies (e.g., inadequate markings, signage, etc.)
- Lack of experience or training

As an aside, although land and hold short operations (LAHSO) – in one case, intersection takeoffs and crew resource management problems have been implicated as causal factors in PDs, they appear to account for only a relatively small number of the total PDs.

Page Intentionally Left Blank

5.0 HUMAN FACTORS ANALYSIS OF TOWER OPERATIONS

5.1 Introduction

The human factors community has recognized the need to help reduce runway incursions and improve safety on the airport surface. A variety of suggestions have been advanced to enhance controller, pilot, and vehicle operator performance on the airport surface, including improvements in surveillance technologies, training, written procedures, airport markings, signage, and the like. Many of the proposed changes would be quite costly. The FAA must determine how to allocate limited resources among these alternatives, as well as others, each of which have their own advocates. Because this IA focuses on surveillance technologies potentially useful to tower controllers (i.e., ASDE-X), and in recognition of the need to better understand the factors that influence controller performance and decision making in tower operations, a study was conducted on the nature of controller performance failures that resulted in a runway incursion. This study was designed to assess the impact of potential improvements (e.g., ASDE-X, automated warning systems) on each such failure.

Decision making performance by tower controllers was studied in the context of 75 OEs in order to assess the potential impact of various tower improvements and innovations. A model of controller decision making was applied to critical controller decisions that resulted in a runway incursion in order to determine how each proposed modification could help prevent or resolve decision-making errors by tower controllers.

The results indicated that lack of situational awareness was the dominant causal factor in performance failures resulting in an incursion. The results also indicated that workload factors, attentional or memory lapses, and communication/coordination deficiencies played an appreciable role in loss of situational awareness. If this is the case, it suggests that controllers could benefit considerably from the existence of surveillance systems and automated warning systems that make performance errors evident quickly and unequivocally, particularly under conditions of low visibility or uncertainty. The results also suggest that it is unrealistic to expect that training or improved procedures alone can do much to eliminate errors completely among the multitude of potential situations that controllers face. A combination of improvements appear necessary, integrated by a strong underlying operational concept that could be embodied in technological, training, and procedural improvements. The recommended approach would emphasize the automated detection of errors so that controllers can correct them when they do occur, in addition to the prevention of errors through training and procedures.

5.2 Discussion

Our analysis of the results indicates that because the majority of OEs result from a lack of awareness of an impending problem. One solution would be aimed at improving surveillance monitoring of all airport movement areas, thereby making potential problems more readily available for visual display and detection by the controller. A display providing a schematic overview of all movement areas could provide valuable information to the controller, particularly during low visibility conditions (e.g., fog, night) or during periods of uncertainty. The second solution would be aimed at making problem detection/awareness more immediate to the

controller. This is an area where levels of support offered by conflict detection and alerting systems and aircraft identification systems (e.g., Airport Target Identification System [ATIDS]) would have considerable payoff. In order for an alerting or warning system to have diagnostic value, the alert must be relatively specific indicating where and which aircraft and vehicles are involved. Of course, such systems must also be designed to avoid high false alert rates (Feldman & Weitzman, 1999; Parasuraman & Hancock, 1999) and provide sufficient time for the controller to take appropriate action. Nevertheless, the integrated presentation of critical traffic and trend information offered by such systems would aid considerably in reducing workload associated with the continuing need to remain cognizant of traffic conditions on the airport surface. By virtue of their routine nature, such monitoring tasks may seem to be cognitively undemanding. However, recent studies have shown that mental workload for such tasks is substantial (Hitchcock, Dember, Warm, Maroney & See, 1999; Deaton & Parasuraman, 1993).

It is important to note that the deficiencies in situational awareness were more likely to occur as the result of high workload related conditions (e.g., division of attention and information overload) or from attentional or memory lapse. In such an environment, the effects that can be achieved by practice, training, or procedures alone are limited. For example, it is clearly impossible to anticipate all the circumstances in which a controller can find him/herself while controlling traffic at a busy airport and to obtain, via training or procedures, any reasonable assurance that no performance failures will occur. Nevertheless, the question remains whether controllers would perform more successfully given more practice under high workload conditions or in solving novel or complex control problems. It is possible that further training and practice under simulated complex/novel conditions may further improve monitoring, communication/coordination, and workload management skills. Accordingly, a combination of improvements will be necessary, integrated by a strong underlying operational concept that could be embodied in both training improvements and computerized display, and decision support systems. Therefore, in parallel with an effective training effort, it is important to provide technical support systems to make impending runway incursions apparent to the controller quickly and unequivocally when they do occur. The proposal for the addition of basic monitoring and surveillance systems, and computer-assisted decision aids for conflict detection/alerting and identification that provide direct aid to maintaining situational awareness would appear to be essential for any Runway Incursion Reduction Program. This becomes even more important as U.S. air traffic is expected to double by 2010.

5.3 Summary

The human factors analysis found that critical decision making errors made by tower controllers while engaged in controlling traffic provided important insights about controller performance and the errors underlying the causes of runway incursions. This information is extremely useful in assessing benefits associated with proposed improvements in airport surveillance technologies, automated warning systems, and training improvements. This study also provides a basis for establishing priorities for proposed improvements to aid tower controllers.

Analysis of the results indicate that the leading cause of performance failures is lack of awareness, and the issuing of inappropriate or incorrect instructions stemming from the lack of awareness. The primary insight gained from this analysis was that lack of awareness was chiefly

the result of deficiencies in monitoring activity of the airport surface and that workload related factors, attentional and/or memory lapses, and communication/coordination deficiencies played a significant role in these monitoring deficiencies. The results strongly suggest that tower controllers could benefit considerably from improved surveillance technologies (e.g., ASDE-X, ADS-B, inductive loop technology) that can display an impending problem quickly and unequivocally. The results also indicate that to enhance situational awareness, one of the most important improvements is in the area of automated conflict detection and identification systems. In both cases, these improvements represent a promising means of reducing controller workload by providing direct aid to the controller in problem detection and data collection. By relieving part of the controller's workload, they can also yield an indirect reduction in the time it takes to select and execute a procedure, resulting in fewer procedural errors. This can increase the probability that procedural errors that do occur will be observed by the controller executing the procedure or by other tower controllers.

By trying to understand the circumstances under which runway incursions develop, it should be possible to evaluate proposed improvements designed to reduce runway incursions and assist in their development.

Page Intentionally Left Blank

6.0 ECONOMIC ANALYSIS/BUSINESS CASE AND SAFETY RISK ANALYSIS

6.1 Economic Safety Benefits Analysis (Initial Results Presented to JRC on January 20, 2000)

The economic safety benefit analysis focuses on ASDE-X as a system designed to prevent an accident once a runway incursion has occurred. To understand which types of runway incursions and locations have the greatest potential for an accident, it was necessary to analyze runway incursions for a typical year. Runway incursions that occur during periods of poor visibility and darkness at major airports (i.e., airports with high levels of operations and complexity) have been found to pose the greatest risk for accidents. A model was developed for forecasting the probability of an accident occurring at an airport based on the historical domestic runway incursion accident rate, number of future annual airport operations, and average annual airport less than three-mile visibility rates. The model can determine the severity of an accident for each airport based on estimated casualty (both fatality and injury) rates, forecasted enplanements, and average passenger loads. Standard FAA economic cost factors were applied to fatalities and injuries to obtain the benefits of preventing accidents for each airport. Airports are ranked by benefits.

The economic analysis considered the following criteria: FAA life cycle costs, FAA safety benefits, NPV, and B/C ratio. All costs are expressed in then-year dollars or 2000 present value PV dollars, whichever is appropriate to the analysis.

6.1.1 Overview

The initial focus of the IA was the integrated safety benefits economic analysis. In general, the analysis identifies safety risk factors related to runway and surface movement. Findings from earlier runway incursion safety studies also were reviewed during the analysis. Specifically, the goals of the safety benefits economic analysis team include the following:

- Evaluate causal relationships between runway incursions and runway incursion accidents,
- Identify those factors that result in an incursion becoming an accident,
- Provide an explanation(s) for the recent rise in runway incursions,
- Analyze previous runway safety initiatives (e.g., the effectiveness of training in reducing runway incursions), and
- Assess airport complexity as a precursor of runway incursions and accidents. Complexity includes such factors as the number of airport operations, the runway-taxiway configuration, fleet mix, visibility, and weather.

6.1.2 Economic Safety Benefits Analysis Methodology

The IA Team conducted a detailed economic analysis of the ASDE-X system to determine the appropriate number of ASDE-X to acquire based on costs and calculated monetary benefits.

The following is an overview of the safety benefits economic analysis methodology:

- Develop a breakdown of runway incursions for the year 1997 (sample size = 300) in terms of:
  - Runway incursions with low accident potential
  - Runway incursions with medium accident potential
  - Runway incursions with high accident potential
  - Runway incursions with extremely high accident potential

  The breakdown provides an indication of the frequency of runway incursions that had the potential to cause an accident. Additional analyses of runway incursions provide information on the underlying causes or contributing factors of these runway incursions.
- Estimate, by a panel of experts, the operational effectiveness of ASDE-X to prevent runway incursion accidents. Technical data and data from previous studies are factored into the estimates. The panel consisted of a number of stakeholders from AFS-400, AND-410, ARR-100, ASD-140, ASD-400/SETA, ASY-100, ATO-102, COE/MIT, and MCR.
- Calculate the economic value of installing an ASDE-X over the economic service life of an ASDE-X. The economic value will be based on the following:

The basic safety benefits economic calculation is as follows:

Accident Cost Avoided in Given Year for Airport X =

Probability of Having at least One Accident in that Year	X	Costs Avoided in Fatalities, Injuries, Aircraft Damage	X	Effectiveness of ASDE-X

- Identify locations of candidate sites for an ASDE-X based on the safety benefits analysis
- Identify additional solutions to ASDE-3 airports to further reduce runway incursions

In order to conduct the economic analysis of the ASDE-X system, the following analyses/reports were developed:

- A forecast of potential runway incursion accidents at each U.S. towered airport
- A ROM estimate of monetary safety benefits for each airport, based on standard FAA cost factors and accident history
- A detailed estimate of ASDE-X system life cycle costs (2003-2022)
- An estimate of monetary benefits versus costs for systems to be acquired

6.1.2.1 Forecast of Potential Runway Incursion Accidents

Seven runway incursion accidents from 1989-1998 were analyzed to determine the most salient factors associated with the occurrence of an accident. For example, the accident data shows that runway incursion accidents are more likely to occur at airports with higher traffic loads (those with annual operations of more than 150,000) which also corresponds to airports with more complex runway/taxiway crossing configurations. The data also supports previous findings that show that runway incursion accidents tend to occur under instrument meteorological conditions (IMC). Accordingly, airports with high traffic loads and more frequent IMC conditions will, in general, have a higher probability for a runway incursion accident. Since airports with a higher percentage of poor visibility have a higher probability of having a runway incursion accident, an adjustment for poor visibility was applied to the accident probability for each airport.

Three of the seven accidents for the time period (1989-1998) occurred during poor visibility (i.e., fog or haze). Nationally, average airport time for IMC (i.e., less than three-mile visibility) is approximately 5.9 percent; therefore, the average time in VMC is 94.1 percent. In the absence of surveillance, reduced visibility conditions in IMC are 12.1 times more hazardous than in VMC (i.e., it is approximately 12 times as dangerous for an aircraft to be in bad visibility due to IMC, as VMC). (Refer to Appendix A for more details.)

6.1.2.2 Estimate of Monetary Safety Benefits (Initial Economic Case Presented to JRC on January 20, 2000)

A computer simulation model was used to determine the total monetary safety benefits achieved by preventing accidents at each airport, based on estimated fatality and injury rates, forecasted enplanements, average passenger loads, and projection of future traffic growth. Standard FAA economic cost factors were applied to fatalities and injuries to obtain the monetary benefits of preventing accidents for each airport. Airports were then ranked in terms of monetary benefits achieved. (Refer to Appendix A for more details.)

The probability of having an accident was calculated (to a first approximation) on the basis of the square of the average number of annual operations at an airport (N). An adjustment for IMC conditions at an airport was applied to this computation.

Using this probability calculation, a computational model was developed to forecast the likelihood of an accident at individual airports. The model was based on the historical domestic runway incursion accident rate and airport operations for the period 1989-1998, the number of annual airport operations anticipated between 2003 and 2022 at each airport[1], and the percent time, on an annual basis, when visibility is less than three miles at each airport. (Refer to Appendix B for more details.)

The accident costs avoided in terms of fatalities, injuries, and physical damage were based on average passenger load at each airport; historical worldwide runway accident fatality

[1] Because airport complexity (e.g., number of crossing runways/taxiways) and number of airport operations are highly correlated, only airport operations is used to forecast runway incursion accident potential. High operations are assumed to be essentially collinear with airport complexity.

percentages; injury and damage rates; and standard FAA and Office of Management and Budget (OMB) economic values. (Refer to Appendix B for more details.)

A panel of experts comprised of various FAA stakeholder organizations, pilots, controllers, airport specialists, operations research analysts, engineers, and human factor specialists estimated effectiveness. ASDE-X effectiveness estimates, provided by the best professional opinions available, were obtained for surveillance-only capabilities and for surveillance with conflict detection/alerting capabilities. Over 800 runway incursions were evaluated to determine how effective each set of capabilities would be in alerting the controller in time to prevent the incursion from becoming an accident. The assumption was that the ASDE-X system would operate as advertised. On average, effectiveness was estimated to be 21 percent for the primary radar portion of the ASDE-X system and 75 percent for ASDE-X (radar plus conflict detection/alerting capabilities). (Refer to Appendix B for more details.)

The complete basis of estimates for economic safety benefits is listed in Appendix E.

6.1.2.3 Initial Estimate of ASDE-X Life Cycle Costs (Ten-Lot Buy)

Initially, the life cycle cost estimate assumes a purchase quantity of 10 systems and covers the estimated 20-year economic service life of ASDE-X (2003-2022). Costs for the ASDE-X system are FAA costs only, and are categorized as Facilities and Equipment (F&E) and Operations and Maintenance (O&M). The F&E and O&M costs include the estimated acquisition, development, implementation, operations and maintenance, and disposition costs. (Refer to Appendix C for more details.)

The "most likely" [2] total life cycle cost estimate for the ASDE-X system, in constant dollars, is shown in Table 6-1. (Refer to Appendix C for more details.)

Table 6-1. ASDE-X 'Most Likely' Life Cycle Cost (Ten-Lot Buy) Estimate

	Interim Alternative Primary Radar with Conflict Detection and Alerting
F&E ($M)	$ 51.2
O&M ($M)	$ 20.3
Total ($M)	$ 71.5

The complete basis of estimates for economic life cycle costs is listed in Appendix F.

[2] The "most likely" estimate is based on a Monte Carlo Simulation (Crystal Ball) used to quantify the risks associated with the given values. The risk assessment indicated that there is only a 20 percent chance that the life cycle costs will exceed the estimated costs shown in Table 1.

6.1.2.4 Initial Estimate of Monetary Benefits Versus Costs

Monetary safety benefits were compared to the life cycle cost estimates to determine the excess of monetary benefits over costs, if any, for each airport; that is, to determine whether ASDE-X is or is not economically viable at that airport.

The monetary value of the benefits and costs were calculated and used to determine the NPV of benefits and cost. NPV is the difference, in today's dollars, between the present monetary value (PV) of safety benefits (i.e., money saved by preventing accidents) and the PV of system life cycle costs. The B/C ratio, which is used to determine the relative economic merit of a system or program, is calculated by dividing the PV of safety benefits by the PV of system life cycle costs. If the ratio is greater than 1.0 (monetary benefits exceed costs) then the system or program is economically justifiable. (Refer to Appendix D for more details.)

6.2 Business Case (Initial Analysis)

6.2.1 Net Present Value

NPV is the difference between the PV of safety benefits and the PV of system life cycle costs. If the results are positive, then the safety benefits are greater than the system life cycle costs, and a project is economically beneficial. Using the 80 percent confidence values for the system life cycle costs, and 20 percent confidence value for the economic safety benefits, the NPV for a ten-lot buy ranges between (-$12.2M) and $48.3M. The most likely level is $24.5M. Table 6-2 summarizes how the NPV for the acquisition of 10 ASDE-X systems was determined.

Table 6-2. ASDE-X Life Cycle Cost and Benefits Estimate for 10 Systems

ASDE-X Costs	Most Likely Values (input values)	Low Confidence (20%)	High Confidence (80%)
FAA F&E Costs (Current $M)	*$55.9*	*$55.1*	*$58.2*
FAA O&M Costs (Current $M)	*$27.2*	*$28.2*	*$29.8*
Total Costs (Current $M)	*$83.1*	*$83.3*	*$88.0*
Present Value Total Costs (PV $M)	**$51.7**	**$51.7**	**$54.1**
ASDE-X Benefits	**Most Likely Values (input values)**	**Low Confidence (20%)**	**High Confidence (80%)**
Present Value Benefits (PV $M)	**$76.2**	**$41.2**	**$100.6**
ASDE-X Benefit/Cost Ratio	**Most Likely Values (input values)**	**Low Confidence (20%)**	**High Confidence (80%)**
Net Present Value (NPV) (PV $M)*	**24.5**	**(-12.2)**	**48.3**
Benefit/Cost (B/C) Ratio*	**1.50**	**0.8**	**1.9**

***Note that the high confidence NPV does NOT equal high confidence benefits minus high confidence costs. Similarly, the high confidence B/C ratio does NOT equal high confidence benefits divided by high confidence costs.**

6.2.2 Benefit/Cost Ratio

The B/C ratio is calculated by dividing the PV of economic safety benefits by the PV of the total system life cycle costs. The B/C ratio is used to determine the relative economic merit of candidate solutions. If the ratio is greater than 1, then the economic safety benefits are greater than the costs, and the project is economically justifiable. Using the 80 percent confidence values for the system life cycle costs, the ASDE-X B/C ratio for a ten-lot buy ranges between 0.8 and 1.9. This range is based on the assumption that there are some variables that could change or vary the final outcome. The most likely level for a ten-lot buy provides a B/C ratio of 1.5, and represents a conservative assessment. Table 6-2 summarizes the results of the B/C ratio for an ASDE-X ten-lot buy.

In addition to evaluating the B/C ratio for a ten-lot buy, the B/C ratio for each of the top ten airports in safety benefits was evaluated. The results are shown in Table 6-3 below. Table 6-3 also shows that while 10 systems in the aggregate carries a B/C ratio of 1.5, the marginal B/C contribution of systems ranked sixth through tenth is negative.

Table 6-3. Top 10 Airports Range of Estimates at the 20/80% and 80/20% Confidence Level

Airport	Locid	NPV Range	NPV Most Likely ($00 M)	B/C Ratio Range	B/C Ratio Most Likely
Phoenix	PHX	4.5 – 18.9	13.1	1.8 – 4.6	3.5
Orlando	MCO	3.9 – 17.8	12.2	1.7 – 4.4	3.4
Honolulu	HNL	(-1.1) – 5.3	2.8	0.8 – 2.0	1.5
Oakland	OAK	(-1.2) – 4.6	2.3	0.8 – 1.9	1.5
John Wayne	SNA	(-2.4) – 1.8	0.1	0.5 – 1.3	1.0
San Jose	SJC	(-2.7) – 1.1	(-0.4)	0.5 – 1.2	0.9
Chicago Midway	MDW	(-3.0) – 0.3	(-1.0)	0.4 – 1.1	0.8
Indianapolis	IND	(-3.1) – (-0.2)	-1.1	0.4 – 1.0	0.8
Tampa Int.	TPA	(-3.3) – (-0.4)	(-1.5)	0.4 – 0.9	0.7
Columbus	CMH	(-3.6) – (-1.1)	(-2.0)	0.3 – 0.8	0.6

Note: Those airports in which ASDE-X is economically justified under a literal application of traditional criteria are highlighted

6.2.3 Business Case Summary (Initial Results Presented to JRC on January 20, 2000)

Table 6-4 summarizes the results of the ASDE-X NPV and B/C ratio calculations.

Total life cycle costs used in the economic analysis consist of FAA F&E and Ops costs. No user costs are assumed. Ranges and most likely values for costs in current dollars correlate to the costs in Table 6-3, which display the 80 percent confidence values. Total life cycle costs were then calculated in constant 2000 dollars and are shown in Table 6-3.

Since ASDE-X is not a replacement system, incremental and life cycle costs per site are the same.

The PV of system life cycle costs and economic safety benefits was calculated by applying a seven percent discount rate to the total life cycle costs and economic safety benefits in constant 2000 dollars. Normally, NPV is evaluated at the 20 percent level (i.e., there is an 80 percent confidence that economic safety benefits exceeds system life cycle costs). Since an airport either receives or does not receive an ASDE-X (yes/no decision), the benefit of the doubt was given to each site determining its justification for an ASDE-X. Therefore, the most likely value (i.e., 50 percent confidence) is used to decide whether or not an ASDE-X for each candidate airport is economically justifiable. Five sites were determined to be economically justifiable as shown in Table 6-4 below. These five sites were presented to the JRC in January 2000.

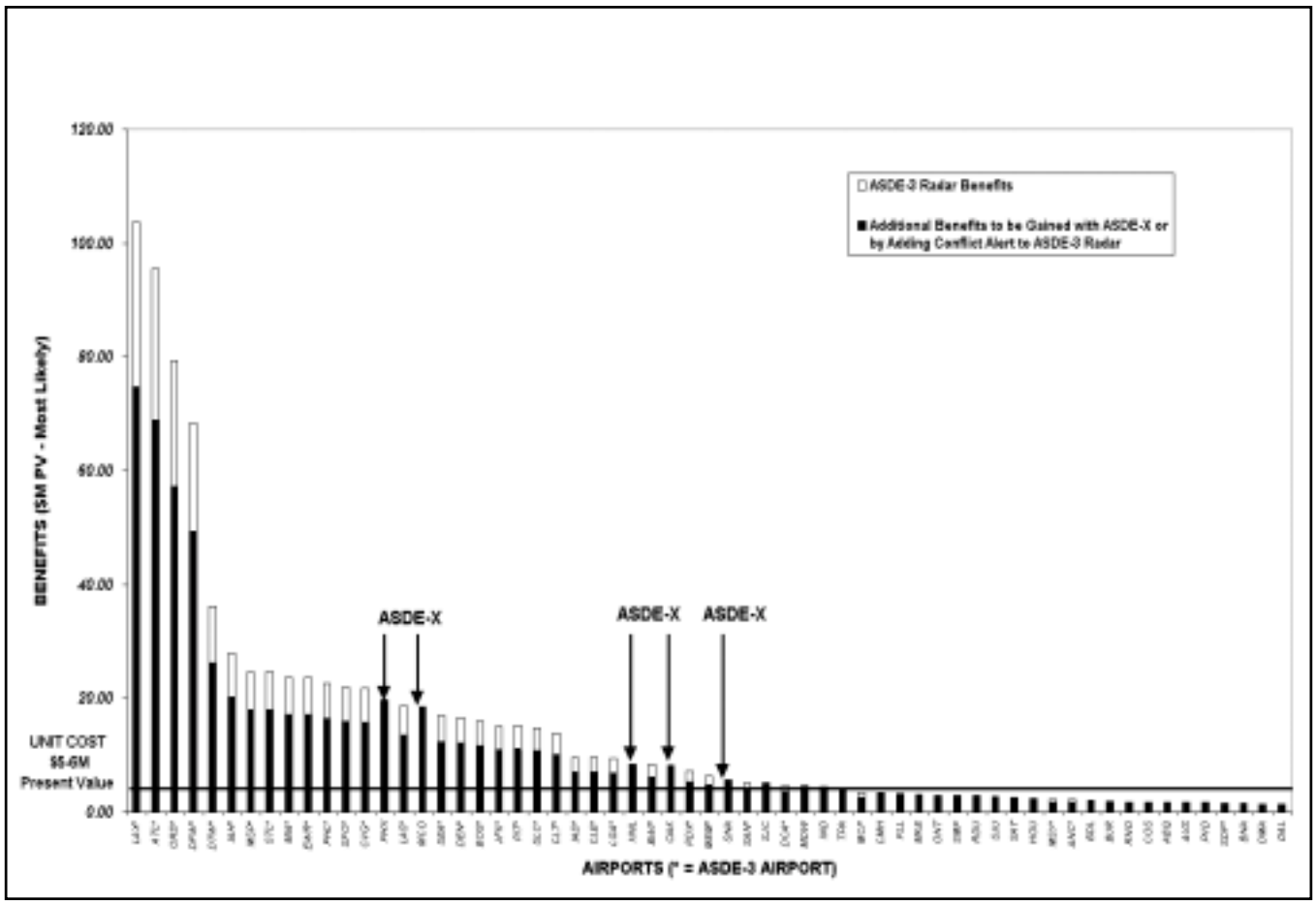
Note: But while five systems are clearly justified under traditional economic criteria, it does not follow that additional systems are not economically justified. Consider, for example, a city in which the B/C ratio is 0.8, like Chicago, that statistic means that if ASDE-X cost $6M rather than $7.5M, a system would be economically justified. But Chicago cannot get 80 percent of an ASDE-X system; the choices available to the FAA are: (1) install the system, and thus give Chicago 1.5M (7.5-6) more than it "deserves" economically, or (2) do not install, and thus give Chicago $6M less than it deserves. In a case like this in which some "rounding off" is inevitable, many people will see no violation of economic principles if the rounding is slightly up rather than sharply down. Instead, they will see a routine application of fair play and common sense.

Table 6-4. Five Economically Justifiable ASDE-X Sites

Site	Locid	Location
1	PHX	Phoenix Sky Harbor International Airport
2	MCO	Orlando International Airport
3	HNL	Honolulu International-Hickham Air Force Base
4	OAK	Metropolitan Oakland International Airport
5	SNA	John Wayne - Orange County Airport
NOTE: As discussed earlier, several other airports are close enough to meet the raw B/C test for installation that, given the "all or nothing" character of the decision, the degree of "economic justice" might be considerably greater if the system were installed than if it were not.		

In summary, Figure 6-1 below shows a graph of the ASDE-X business case. The business case for each airport is the benefits versus unit costs.

Figure 6-1. Business Case – Benefits for Top Sixty Airports



6.3 Safety Risk Analysis - Supplement to the Economic Analysis/Core Piece

6.3.1 Background

The results of the economic analysis or business case - estimating costs and benefits in economic terms, presented to the JRC on January 20, 2000, clearly justified five ASDE-X systems. However, in this case, the JRC members felt that more weight needed to be placed on non-monetary benefits such as the public's perception of safety, improved situational awareness, and the like. The FAA is aggressively working to minimize the risk of runway incursion accidents and requires consideration of non-monetary benefits. For this reason, the JRC asked the IA Team to explore other ways to supplement the business case to address the problem. The approach adopted is based on the predicted number of fatalities over a 20-year period, if nothing was done to mitigate the runway incursion problem. This analysis, referred to as the "Safety Risk Analysis" justified 25 ASDE-X systems that could reduce 95 percent of the avoidable risk (taking into account 34 ASDE-3/AMASS sites).

The IA Team conducted a rigorous safety risk analysis, with the assistance of FAA lines of business and outside experts such as NEXTOR/Center of Excellence/MIT. This analysis built as its foundation, a projection of the number of fatalities that could be attributed to future runway incursion accidents, if nothing further were done to improve safety on the airport surface, beyond the ASDE-3 radars currently installed at 34 airports.

6.3.2 Safety Risk Analysis

The projected number of potential fatalities was estimated to be over 900 (level of risk) over the next 20 years (2003-2022), if no corrective measures were taken (see Figure 6-2). As with the economic safety benefits analysis, the safety risk analysis considered the following important factors:

- Historical accident data (1989-1998) and fatality rate
- Historical operations (1989-1998) plus projection of future traffic growth by airports (2003-2022)
- Projection of future passenger load by airports (2003-2022)
- Projection of traffic mix/growth by airport (2003-2022)
- Percentage of IMC conditions (low visibility conditions) by airport, based on historical data. (Refer to Appendix B for more details.)

Figure 6-2. Safety Risk Analysis of Projected Fatalities (2003-2022)
Cumulative Potential Fatalities Avoided

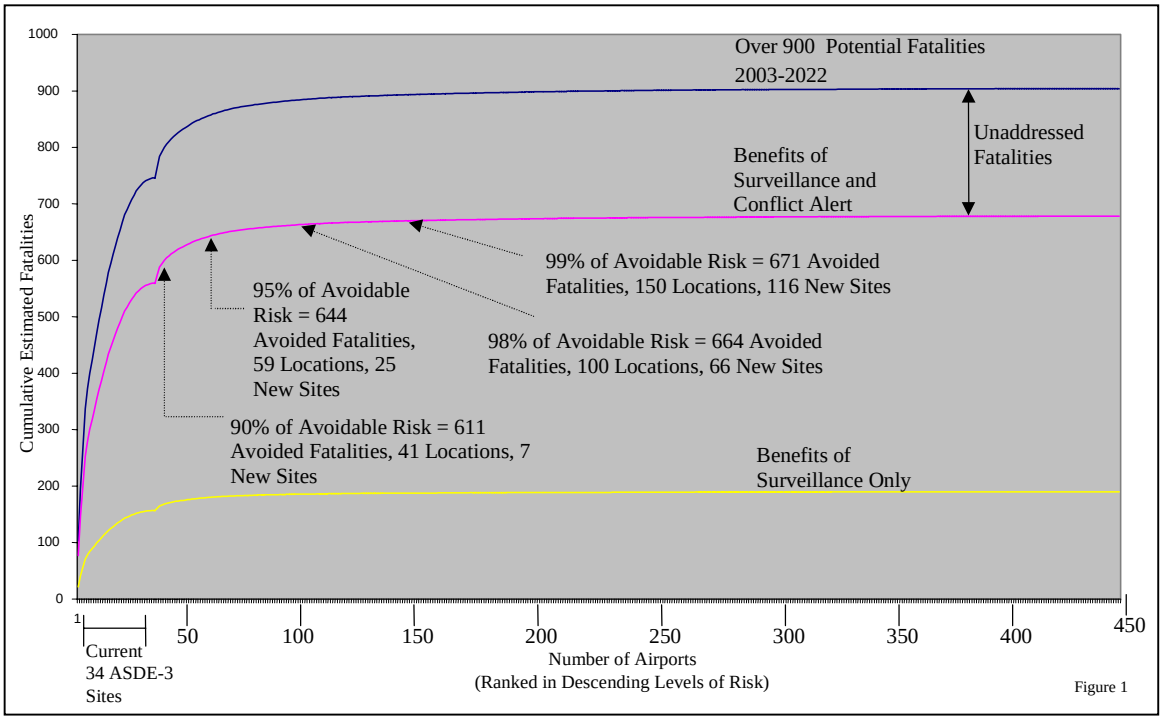


Figure 6-2 shows the projection of fatalities with no mitigation strategies in place to cover safety risk (top line) and the projected fatalities avoided (the risk mitigated) with ASDE-X (surveillance only [bottom line]) and with ASDE-X core plus system (with automated conflict alert [middle line]). The following statements further describe Figure 6-2:

- The horizontal axis represents the 450 towered airports that we have today, ranging from the high-risk locations (e.g., Los Angeles) to the low-risk locations (e.g., Alexandria Esler Regional Airport, Louisiana).
- The vertical axis represents the cumulative estimated fatalities that may be avoided as we cover more airports (buy more protection) with ASDE-X systems.
- The steep part of the curves indicate that the "risk avoided" cumulates at a very rapid rate, with descending level of risk, as we cover more and more airports with ASDE-X, in addition to those covered by ASDE-3/AMASS.
- Please note that by the time we get to about 60 airports, we have covered most of the risks. Covering more airports beyond 60 only improves safety marginally but increases costs tremendously.
- Note, these estimates are based on the assumption that ASDE-X with conflict alert will be capable of mitigating about 75 percent of the total risk (about 675 of the 900 projected fatalities) while ASDE-X (radar only) will be capable of mitigating about 21 percent of the total risk.

While Figure 6-2 represents the cumulative fatalities avoided with ASDE-X, Figure 6-3 below represents the corresponding cost impacts (if no volume discounts are assumed). To state the obvious, the more ASDE-Xs bought the cost increases proportionally. This is in contrast to the number of fatalities avoided where cumulative avoidable risk (i.e., safety benefits) begins to level off significantly beyond the top 60 airports (ranked in descending order of risk).

The 95 percent level of avoidable risk (translating into 25 ASDE-X systems) was the recommendation selected by the Administrator.

Figure 6-3. Safety Risk Analysis of Projected Fatalities Cumulative Cost of ASDE-X

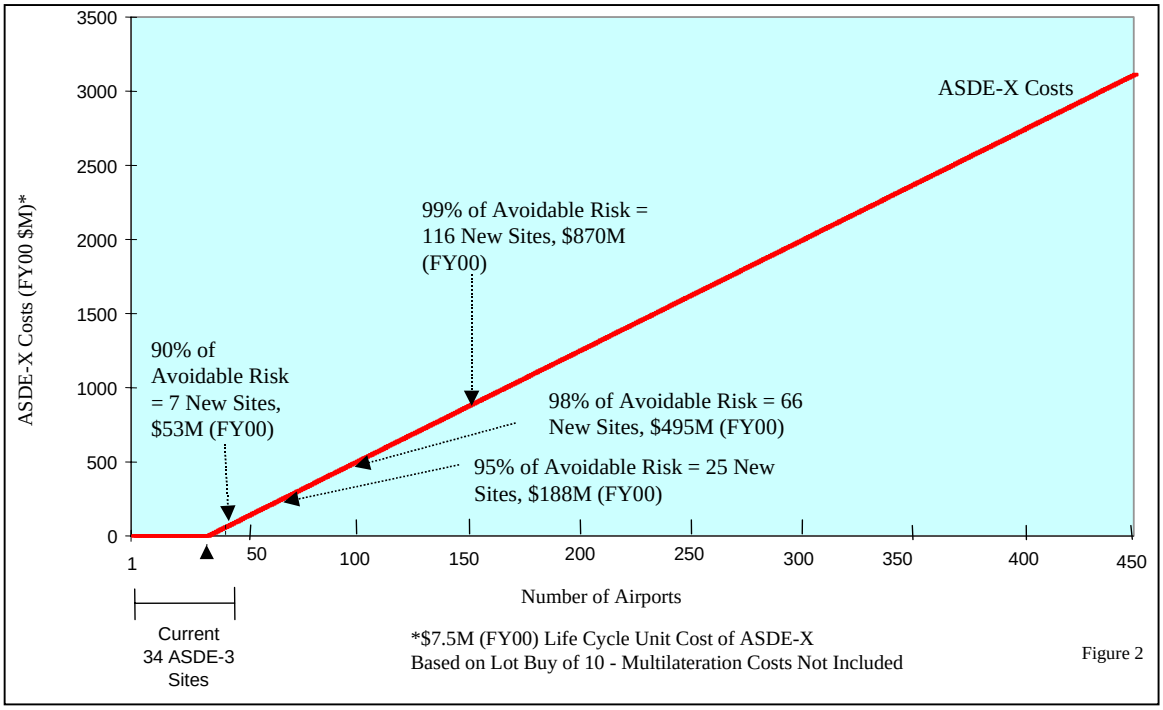


Table 6-5 below shows the percent of fatalities avoided relative to the estimated costs. Additionally, it shows that:

- Of the 900 potential fatalities estimated over 20 years (2003-2022), approximately 675 (75 percent) are avoidable with ASDE-X and ASDE-3/AMASS, assuming the systems operate according to requirements.
- Even before we add new ASDE-X systems, the existing 34 ASDE-3/AMASS systems already cover about 82 percent of the avoidable risk, translating into 559 of the 675 fatalities that can be avoided.
- The economic analysis/business case that justified five systems, based on the B/C ratio, would cover about 89 percent of the avoidable risk; an increase of seven percent.
- The IA Team then performed a safety risk analysis to determine what it would take to cover 95 percent of the avoidable risk. That equated to 25 ASDE-X systems.
- In various public forums, discussion was focused on having the system at the top 100 airports. Buying 66 ASDE-X systems in addition to the existing 34 ASDE-3/AMASS would reduce potential fatalities by an additional three percent, but increase the cost by over two and one half times.
- Finally, the ability to predict where the potential for accidents are most likely to occur becomes more difficult as we begin to move further and further away from the largest and busiest airports.
- Based on these specific points, and on the safety risk analysis, the IA Team's recommendation to the agency on the number of ASDE-Xs to acquire is 25 systems. As

stated earlier, since ASDE-3/AMASS or ASDE-X are potentially capable of addressing 75 percent of the total risk at a given location, further mitigation strategies to cover remaining risks have been identified.

Table 6-5. Summary of Safety Risk Analysis

New ASDE-X Sites Beyond Existing ASDE-3/AMASS	Potential Fatalities Avoided (Out of 675)	Percent of Avoidable Risk with ASDE-X	Life Cycle Cost (FY00 Constant Dollars[M])
0	~559	~82%	N/A
5	~604	~89%	$38
25	~644	~95%	$188
66	~664	~98%	$495
116	~671	~99%	$870
Note: Total risk: over 900 potential fatalities over the next 20 years with no mitigation measures taken; approximately 675 of 900 potential fatalities are avoidable with ASDE-X and ASDE-3/AMASS			

6.3.3 Safety Risk Analysis Recommendations Presented to Administrator on 5/22/00

In summary, based on the safety risk analysis by the IA Team, the following recommendations were presented:

- Procure 32 ASDE-X systems plus four support systems at selected locations, with options for additional sites and flexible capabilities. (The recommendation of 25 ASDE-X systems was based on rigorous and detailed economic and safety risk analyses. The IA Team proposed the procurement and implementation of 25 ASDE-X systems. Seven additional systems were added to the list to support air traffic operational requirements, thus bringing the recommended total from 25 to 32. Later, the FAA Administrator elected to proceed with the 25 locations supported by the safety risk analysis.)
- Reconvene the JRC to approve an ASDE-X working baseline (Phase I) prior to the anticipated September 30, 2000, contract award. The purpose is to give the JRC members an opportunity to perform a “sanity check” before contract award in September 2000, in order to ensure clarity concerning how many ASDE-X systems to acquire, their cost, and the anticipated delivery date.
- Conduct the Phase II IA to address safety risks that will not be mitigated by ASDE-X or by ASDE-3, with a future conflict detection/alerting system (e.g., AMASS). Since ASDE-3/AMASS and ASDE-X are capable of addressing 75 percent of the total risk at a given location, remaining risks need to be addressed through another IA.

Table 6-6. Candidate Sites for ASDE-X (Based on Analysis)

Order	Locid	Facility
1	PHX	Phoenix Sky Harbor International Airport
2	MCO	Orlando International Airport
3	HNL	Honolulu International Airport - Hickam AFB
4	OAK	Metropolitan Oakland International Airport
5	SNA	John Wayne - Orange County Airport
6	SJC	San Jose International Airport
7	MDW	Chicago Midway Airport
8	IND	Indianapolis International Airport
9	TPA	Tampa International Airport
10	FLL	Ft Lauderdale/Hollywood International Airport
11	CMH	Port Columbus International Airport
12	ONT	Ontario International Airport
13	MKE	General Mitchell International Airport
14	SMF	Sacramento International Airport
15	SJU	Luis Munoz Marin International Airport
16	RDU	Raleigh-Durham International Airport
17	SAT	San Antonio International Airport
18	HOU	William P. Hobby Airport
19	BDL	Bradley International Airport
20	BUR	Burbank-Glendale-Pasadena Airport
21	RNO	Reno/Tahoe International Airport
22	COS	City of Colorado Springs Muni Airport
23	AUS	Austin-Bergstrom International Airport
24	ABQ	Albuquerque International Sunport Airport
25	PVD	Theodore Francis Green State Airport

6.3.4 Safety Risk Analysis Summary

The IA Team developed the life cycle costs for the safety risk recommendation of a 25-lot buy. The life cycle cost estimate for the safety risk analysis recommendation assumes a purchase quantity of 25 systems and covers an estimated 20-year economic service life of ASDE-X. The 20-year life for each system begins with the year of commissioning, so that the total ASDE-X life cycle periods extend from 2003 to 2026. The commissioning schedule is shown in Table 6-7.

Table 6-7. Commissioning Schedule

Item	FY03	FY04	FY05	FY06	FY07	Total
Operational	1	2	9	9	4	25

Note: Benefits for four support systems were not calculated since they were not included in the safety risk analysis that resulted in covering 95 percent of the avoidable risk.

The F&E and O&M costs include the estimated acquisition, development, implementation, operations and maintenance, and disposition costs.

Economic analysis considers more than "most likely" input values, since many input values have a range of values due to uncertainty. Risk assessment is a technique used in economic analysis to capture the uncertainties of input variables. In this report, when a range of values is shown, the low number 20 as in the 20/80% value, means that there is an 80 percent chance the actual value will exceed the estimated value. The high number 80 as in the 80/20% value, means that there is only a 20 percent chance the actual value will exceed the estimated value.

The NPV is the difference between the PV of benefits and the present value of costs. The B/C ratio is calculated by dividing the PV of benefits by the PV of costs. If the ratio is greater than 1, then the benefits are greater than the costs.

The "most likely" total life cycle cost estimate for the ASDE-X system, in current dollars, is shown in Table 6-8. The PV of costs and safety benefits was calculated by applying a seven percent discount rate to the total life cycle costs and safety benefits in constant 2000 dollars and is also shown in Table 6-8. Using the 80/20 percent confidence values, the ASDE-X B/C ratio for a 25-lot buy ranges between 0.25 and 0.63. As in Section 6.2, this range is based on the assumption that there are some variables that could change or vary the final outcome. The most likely level for a 25-lot buy provides a B/C ratio of 0.50, and represents a conservative assessment.

Table 6-8. ASDE-X Life Cycle Cost and Benefits Estimate for 25 Systems

ASDE-X Costs	Most Likely Values (input values)	Low Confidence (20%)	High Confidence (80%)
FAA F&E Costs (Current $M)	*$317.9*	*$325.0*	*$332.5*
FAA O&M Costs (Current $M)	*$98.4*	*$97.3*	*$100.6*
Total Costs (Current $M)	*$416.2*	*$423.8*	*$433.1*
Present Value Total Costs (PV $M)	**$212.5**	**$218.0**	**$225.3**
ASDE-X Benefits	**Most Likely Values (input values)**	**Low Confidence (20%)**	**High Confidence (80%)**
Present Value Benefits (PV $M)	**$105.3**	**$55.3**	**$139.3**
ASDE-X Benefit/Cost Ratio	**Most Likely Values (input values)**	**Low Confidence (20%)**	**High Confidence (80%)**
Net Present Value (NPV) (PV $M)*	**(-107.1)**	**(-166.0)**	**(-82.8)**
Benefit/Cost (B/C) Ratio*	**0.50**	**0.25**	**0.63**

***Note that the high confidence NPV does NOT equal high confidence benefits minus high confidence costs. Similarly, the high confidence B/C ratio does NOT equal high confidence benefits divided by high confidence costs.**

7.0 INCLUSION OF AIR TRAFFIC OPERATIONAL REQUIREMENTS

The recommended number of 25 ASDE-X systems resulted from the IA Team's rigorous economic and safety risk analyses. To satisfy AT operational requirements, seven additional system were added to the list of 25, thus bringing the recommended total from 25 to 32 (see Appendix B, Table B-7). However, the Administrator limited the approved list of 25 systems as supported by the safety risk analysis (see Appendix B, Table B-8).

Table B-8 depicts different rankings because the IA Team and AT used different criteria to select airports. The AT analysis was based on 1999 traffic count, complexity, and IMC, whereas the IA Team analysis was based on historical (1989-1998) and future (2003-2022) operations, complexity, IMC, enplanements, and passenger load factors. (Refer to Appendix B for more details.)

Page Intentionally Left Blank

8.0 INVESTMENT ANALYSIS RISK ASSESSMENT

8.1 Introduction

Based on expert knowledge and experience, the IA Team identified programmatic risks and mitigation plans. The IA Team performed the risk assessment following the guidelines of the Volpe Risk Assessment Model as presented in *Risk Assessment Guidelines for the Investment Analysis Process, Update of July 1999*, prepared for Investment Analysis and Operations Research, ASD-400, Volpe National Transportation Systems Center (WP-59-FA7N1-97-2).

The IA Team evaluated, ranked, and weighted 13 risk facets with respect to programmatic risk for ASDE-X. Each risk facet was rated low, medium, or high in terms of the probability that the risk facet will cause an adverse event to occur. Each risk facet also was rated substantial, moderate, or minor in terms of the potential severity of impact that the adverse event would have on the program. Numerical scores were assigned to each facet based on the ratings. An overall weighted alternative risk score was calculated based on each facet's numerical rating and assigned weight. An overall risk rating of 4.31 was assigned to the ASDE-X program, which puts ASDE-X as a medium risk program.

8.2 Overall Risk Assessment Process

8.2.1 Identify Risk Facets and Relative Weights

The IA Team identified the major risk facets that applied to the Runway Incursion Reduction Program. This was done by evaluating how each of the 13 risk facets, shown in Table 8-1, related to the Runway Incursion Reduction Program. The thirteen risks are rank-ordered with respect to their relevance to the Runway Incursion Reduction Program, and relative weights are assigned to each risk factor. The relative weights are used in developing a final risk assessment score. Subteams were assigned to at least one risk identification facet to perform the risk assessment. The subteam identified potential risks and estimated the probability of those risks, and the severity of impact of those risks on the ASDE-X program.

Table 8-1 summarizes risk facets for runway incursion with relative rankings and weights, as determined by the IA Team.

Table 8-1. Runway Incursion Risk Facets: IA Team's Relative Rankings and Weights

Facet	Description	Rank	Weight
Technical	Associated with developing technology or achieving a level of performance.	1	.20
Human Factors	Risks associated with effectiveness of human-system interface and with making system usable in operating environment	1	.20
Schedule	Likelihood alternative will be completed on schedule	3	.15
Benefit Estimate	Difficulty in estimating the safety benefits including the accuracy and availability of data	4	.10
Stakeholder	Risks associated with stakeholder support	5	.08
Safety	Risks associated with preserving operational safety	6	.04
Supportability	Associated with fielding and maintaining system	7	.04
Operability	Risk associated with how well system will operate in NAS	8	.04
Cost Estimate	Difficulty in estimating costs	9	.03
Producibility	Risk associated with capabilities to manufacture desired system	10	.03
Management	Complexity required to manage alternative	11	.03
Funding	Availability of funds when needed	12	.03
Information Security	Systems vulnerability to threats	13	.03
		Total Weight	1.0

8.2.2 Risk Assessment

The risk assessment process (1) identified specific risks for each individual risk facet, (2) estimated the probability of an adverse event for each facet, and (3) estimated the severity of impact of an adverse event, should it occur. IA Team risk assessment subteams (area experts) provided these estimates. The most significant risks to the ASDE-X program are identified below:

- Technical – difficult to estimate the extent to which ASDE-X technologies (e.g., radar surveillance, collision safety logic) are vulnerable to measurement and statistical errors.
- Human Factors – difficult to estimate the functional suitability (e.g., problem solving/decision aiding capabilities) and user acceptability of ASDE-X, particularly with respect to collision safety logic.
- Schedule - to meet congressional expectations, a very tight ASDE-X acquisition schedule is required with little allowance for slippage. The program will not stay on schedule if technical problems cannot easily be resolved.
- Benefit Estimate – difficult to estimate societal and other benefits in monetary terms such as improvements in safety, improvements in the public's perception of safety, improvements in controller situation awareness, reduced delays, and the like.

Table 8-2 identifies each risk facet, their rankings, their weighted scores, and overall weighted risk score.

The total overall weighted risk score for ASDE-X is 4.31 out of 10.0. This implies that ASDE-X is a medium risk (high, medium, low) program (see Table 8, Risk Assessment Guidelines for the Investment Analysis Process, 1999). Medium risk programs should have candidate mitigation strategies, metrics, a plan of action, and milestones.

Table 8-2. ASDE-X Risk Score Based on Facet Weight, Probability of Adverse Event, and Severity of Adverse Event

Rank	Facet	Probability of Adverse Event (High, Medium, Low)	Severity of Impact (Substantial, Moderate, Minor)	Facet Risk Rating (0-10) From ASD/Volpe Guidelines	Facet Weight	Weighted Facet Score (0-1)
1	Technical	Medium	Moderate	5	.20	1
1	Human Factors	Medium	Moderate	5	.20	1
3	Schedule	Medium	Moderate	5	.15	.75
4	Benefit Estimate	High	Low	5	.10	.50
5	Stakeholder	Low	Moderate	2	.08	.16
6	Safety	Low	Moderate	2	.04	.08
7	Supportability	Medium	Moderate	5	.04	.20
8	Operability	Low	Moderate	2	.04	.08
9	Cost Estimate	Low	Moderate	2	.03	.06
10	Producibility	Low	Low	0	.03	.00
11	Management	Low	Moderate	2	.03	.06
12	Funding	Low	Moderate	2	.03	.06
13	Information Security	Medium	Substantial	8	.03	.24
					Total	4.19

8.3 Risk Facets With Medium Risk

8.3.1 Technical Risks

8.3.1.1 Technical Risk Discussion

The primary rationale for identifying the ASDE-X technical risk as having a medium likelihood of occurring is the uncertainty regarding the amount of development necessary to meet the system requirements, specifically Remote Monitoring System (RMS), Computer-Human Interface (CHI), All-purpose Structured Eurocontrol Surveillance Information Exchange (ASTERIX)/interfacing, and fusion of the multiple sensors to be used. While a number of components have been deployed at major airports around the world, they have not been deployed as a coherent unit at an operational site. Also, the use of various commercial components with proprietary software will require the FAA to consider non-traditional approaches for second level maintenance.

8.3.1.2 Technical Risk Mitigation

The mitigation strategy for these technical risks is to ensure full communication between the government and industry in order to have clarity on the requirements, and also to have clarity on what technology is existing and what needs to be developed. The team is holding extensive discussions with vendors, before the contract is awarded, to make sure that product specifications are clear and maps back to the requirements. During this process, the technical team worked with each offeror and actually tailored the specification to each offeror's product. The process will resume after the evaluation and award, with the technical reviews called for in the Statement of Work, the System Requirements Review (SRR), the Preliminary Design Review (PDR), and the Critical Design Review (CDR). There is also a Final Design Review (FDR) at the end of the first article to make sure everything is right for the production systems. In addition, the team is using the Lessons Learned from the Research & Development (R&D) efforts dating back to 1978 to minimize the technical risk. These efforts are in progress and include the following activities:

- Public announcements
- Pre-Screening Information Request (SIR) discussions
- Post-SIR, pre-Request for Offer (RFO) negotiations
- Specification tailoring
- SRR
- PDR
- CDR
- FDR

For the specific risk areas of development:

- RMS: to reduce risk in the development of the RMS interface, the strategy is to have AOS develop the RMS interface instead of the vendor; the vendor will be required only to design an open architecture to facilitate that development by AOS.
- CHI: to reduce risk in the development of the CHI, the team is developing a visual specification for the display (hardware and software), using human factors and National Air Traffic Controller’s Association (NATCA) resources in order to get buy-in up front.
- ASTERIX/interfacing: to reduce risk in the ASTERIX/interfacing development, the team has provided ASTERIX documentation as part of the specification, and will provide any legacy interface documents upon request.
- Fusion: to reduce risk in the fusion development, the FAA is providing as Government Furnished Equipment (GFE) an independently validated fusion algorithm analysis software tool to accurately and specifically test and validate the fusion algorithms.
- Second-level maintenance: AOS has been participating from the beginning of the acquisition to reduce the maintenance risks, and is working with the team to work out non-traditional approaches to second-level maintenance.

The costs of these mitigation strategies will include the costs for AOS to develop the RMS interface, the costs of the visual spec effort, the costs of the fusion analysis software, and the normal costs of doing business (spec development, vendor negotiations, testing, etc.)

8.3.2 Human Factors Risks

8.3.2.1 Human Factors Risk Discussion

Table 8-2 above shows that there is a medium likelihood of an adverse event occurring as a result of human factor risks, while the severity of impact of such an adverse event was estimated as moderate. The rationale for these estimates is described below. Human factors risk issues fall into three broad categories:

- Usability
- Functional suitability
- User acceptability

Usability refers to the risks associated with the perceptual and physical characteristics of the CHI and includes general issues regarding the ability of users to read, detect, access, and manipulate information. ASDE-X issues in this category address the readability of the ASDE-X display(s), the ease with which data can be accessed, manipulated and managed, the layout of the workstation to facilitate monitoring requirements, task integration, or to provide access for equipment maintenance, and the like. Yet usability issues do not provide insight into the suitability of the system to support operational tasks, decision making or problem solving. Here, functional suitability must be considered, which refers to the content and organization of displayed information suitable to support problem solving and effective and timely decision making. ASDE-X issues in this category include the appropriateness of the displayed information and functions for supporting the surveillance requirements of the tower controller, as well as the effectiveness of the decision aiding algorithms (i.e., collision safety logic) to detect impending runway incursions/collisions relative to the numbers of false alerts. Accordingly, it is possible for ASDE-X to be usable but not functionally suitable, and thus both must be considered.

User acceptability risk issues refers to the extent to which ASDE-X will actually be used. A general assumption is that if displayed information is easy to access and manipulate (usability), and if the system supports the right kind of problem solving and decision making situations (suitability), then controller acceptability will be high. Clearly, acceptability is influenced by these two factors. However, in ATC, there is an awareness that “indirect consequences” of new technology, i.e., changes in the work environment, the requirement for new skills, and their potential effects on job satisfaction may also influence user acceptability of the system and ultimately, system safety and efficiency. In short, human factors risk assessment must be able to acknowledge these potential indirect consequences of new technology.

Because ASDE-X is not currently developed, human factor risks must be inferred from previous evaluations of similar systems (i.e., ASDE-3/AMASS) or from analytical studies. Feedback from usability studies of ASDE-3/AMASS revealed a number of usability issues that can be mitigated with a reasonable amount of resources. However, there has been no effort to systematically evaluate the functional suitability of the decision aiding algorithms associated with automated incursion/collision detection (e.g., AMASS). Nevertheless, analytic studies reveal that despite the best intentions of developers, the availability of advanced sensor technologies, and the development of very sensitive detection algorithms, one fact will conspire to limit the effectiveness of an automated conflict warning system: the very low base rate or frequency of runway incursions/collisions, which, in turn, will likely cause the false alert rate to be high relative to "true" alerts.

(Illustration: compare the probability of an alert for the "rare" runway incursion when it occurs (i.e., the detection rate) with the probability of an incursion if there is an alert. These two probabilities are not the same. The second probability will be much less than the first because it is very unlikely for an incursion to occur, even when the system signals an alert [National Research Council, 1977]).

Accordingly, in its present configuration, any automated incursion/collision detection system runs a very high risk of producing too many false alarms; that is, it runs the risk of failing to support that aspect of controller performance necessary to detect and mitigate all impending incursions/collisions. User acceptability or trust must remain an unknown until more information becomes available on system usability and suitability. It will also be necessary to identify what, if any, new skills or training is required or how it might change the controller's role during task performance. Until these issues are resolved, it appears prudent to believe that the probability of adverse events will be medium and the severity of those events will be moderate.

These risk ratings appear warranted because previous usability testing of the ASDE-3/AMASS system with controllers at the FAA William J. Hughes Technical Center helped identify usability requirements, weaknesses, and mitigation strategies. This information is considered applicable to the development and design of ASDE-X.

8.3.2.2 Human Factors Mitigation Actions and Cost

Given the identified risks, the IPT should strongly consider undertaking actions to mitigate these risks. These include:

- Adopting solutions to usability issues previously identified for ASDE-3/AMASS. For example, there is a need to improve display readability and interpretability, to improve the quality of the aural alerts, to ensure "mode awareness," and the like.
- Conduct analyses, prototyping, and test and evaluation (T&E) activities to learn how ASDE-X influences controller tasks and strategies, how it impacts controller situational awareness, how it affects controller confidence in the automated advisories and warnings, and to use these results to improve the usability and functional suitability of ASDE-X.

- Shadow test ASDE-X in an operational mode to assess the operational impact on controller performance at the first facility floor site, and use this information to modify deployment at other sites.
- Develop training procedures to facilitate the operation of ASDE-X in an operational environment.
- Develop and test national procedures for controller responses to ASDE-X alerts in the operational environment (i.e., mandatory vs. controller discretionary procedures).
- Incorporate the redundancy available through multilateration (i.e., independent channels of sensor data) and data fusion to improve automated conflict detection performance – that is, to mitigate the false alert problem that normally accrues to systems designed to detect rare events like runway incursions/impending collisions.
- Identify maintenance accessibility requirements and incorporate them into the workspace configuration.

Preliminary estimates indicate that mitigation strategies may take $5 to $15M.

8.3.3 Schedule Risk

To meet congressional expectations, a very tight ASDE-X acquisition schedule is required with little allowance for slippage. The IA Team's assessment of schedule risk was based on the proposed ASDE-X program's extremely aggressive schedule, which had not factored in the known technical challenges or the production time of the intended solution. As a result, this aggressive schedule has forced Air Traffic Service (ATS) to change its direction and ideas from what was originally expected. In essence, the mandated schedule has become the product and the resulting solution will fall well short of what was originally intended. There is a medium probability that the program will not stay on schedule if technical problems cannot easily be resolved, and consequently the developer would need more time.

8.3.4 Safety Benefits Estimate Risk

The IA Team evaluated the safety benefits estimate as a high probability that the safety benefits could be underestimated, but also estimated that the severity of impact would be low. Estimating safety benefits is difficult in that several of the benefits are difficult to quantify because of insufficient or inadequate data and because many of the safety benefits cannot be easily monetized.

For example, the public's perception of safety is very difficult to quantify in monetary terms. The public places a high value on aviation safety, and certainly wants the FAA to install systems that make the NAS safer. But the dollar value of this perception, which the FAA is required to balance against costs, is difficult to ascertain. Nevertheless, aviation accidents, unfolding in one of the most economically active of public places, can often outweigh the effect of user costs in the public consciousness.

As another example, loss of airline revenue as a result of an accident is difficult to measure and can be underestimated. When an airline is involved in an accident, the public may switch to

another airline. However, overall level of passenger enplanements does not appear to decrease in any substantial way.

To mitigate this risk, the IA Team performed a safety risk analysis subsequent to the economic analysis. The safety risk analysis forecast projected fatalities by airport over the 20-year period 2003 to 2022. Presenting FAA management with forecasted fatalities, as well as economic analysis results, provided management with additional information needed to make a more informed decision.

8.3.5 Supportability

Supportability risk is associated with fielding and maintaining the ASDE-X. The IA Team evaluated the supportability facet as a medium risk overall with moderate severity of impact. Several supportability areas were identified as having risk associated with it. The areas examined were O&M, logistics, testing and support, support documentation, and system implementation. Of the five areas reviewed, four were determined to have the high risk factors associated with them.

8.3.5.1 Operations and Maintenance

This area was considered the lowest risk factor. This procurement is very similar to the existing ASDE-3 system already deployed in the NAS. Maintenance concepts have been established and the existing knowledge base for the technicians and operational support already exist. The greatest area of concern in this area was focused on the transition process if contract maintenance was established prior to the FAA assuming the maintenance. To mitigate this potential problem, the FAA must approve and manage contractor developed maintenance/support transition plans.

8.3.5.2 Logistics

Considering the nature of this acquisition, commercial-off-the-shelf (COTS), and its expected life cycle (20 years) spares availability was considered to be a high-risk component of the acquisition. Initial spares planning were deemed sufficient for the near term, but there is insufficient information to make any assumption over the long-term of this deployment. Spares availability is deemed to be a high risk.

To reduce this risk, FAA Logistics Center responsibilities need to be defined and planned prior to deployment and reviewed/updated prior to the transition from contractor to FAA organic maintenance support.

8.3.5.3 Testing and Support

Physical and operating characteristics of this equipment are not known at this time. This makes it difficult to identify support equipment requirements in advance of the acquisition. Support equipment includes testing and diagnostic equipment, automated test equipment, interfaces to existing NAS systems, and facilities equipment at the Logistics Center (both AML and AOS) to

support the ASDE-X. Make every effort to identify support requirements for COTS equipment to prevent additional internal development by the FAA.

8.3.5.4 Support Documentation

Since this is a COTS acquisition, support documentation will have to be provided by the contractor to meet FAA requirements and should be extensively reviewed for acceptability in the NAS environment.

Proprietary data rights to the equipment will either have be placed in escrow for the government or have to be bought outright to enable the FAA to maintain this equipment after the life of the contract or bankruptcy of the contractor. This could be a very large dollar value and is considered a high-risk area.

8.3.5.5 System Implementation

System implementation is deemed to be a medium risk due to uncertainties in the program quantities. There should be no problem coordinating system deliveries and installation, and checkout of the equipment in the NAS. Site specific requirements will have to be dealt with on a site-by-site basis for specific installation concerns. Early coordination with ANI shall reduce risk and enable ANI to execute site preparation tasks within the allocated budget and set schedule.

System power and heating, ventilation, and air conditioning (HVAC) and grounding requirements may impact existing facilities requiring an upgrade of the existing systems infrastructure to support the new deployment. This is deemed to be a moderate to high risk. Site surveys will have to be conducted to capture and coordinate site requirements after the site listings have been generated. Site preparation (based on site survey) may include HVAC upgrades, grounding bonding, electrical work, foundation work, tower cab analysis, structural modification, and access roads establishment.

8.3.6 Information Security

The IA Team evaluated information security overall as a medium risk with substantial severity of impact. Information security has been highlighted as a possible area of risk with an emphasis on data security. The ASDE-X systems will be deployed in controlled airport environments. The threat of an outside source directly interfacing or interfering with the ASDE-X is deemed to be low. Sufficient threats to disrupt the radar activity itself should be easily identified and dealt with.

Data security is deemed to be moderate risk area. Risk associated with the COTS programming code and interfaces with FAA systems is deemed to be moderate. Potential sources of risk may be from vendor personnel, FAA personnel, or other parties with equivalent equipment or knowledge of the system and its operations.

Additionally, all known objects on the airfield will have to be identified to the system to negate false targets. Bad data in the ASDE-X system, either deliberately introduced or inadvertently, have the potential for catastrophic impacts. The command and control interface between the ASDE-X and the controller needs to be worked out in detail to help mitigate erroneous information in the system and to accurately display data.

9.0 OTHER MITIGATION STRATEGIES TO ADDRESS REMAINING SAFETY RISKS

As stated earlier, since ASDE-3/AMASS and ASDE-X are capable of addressing 75 percent of the total risk at a given location, assuming the systems operate according to requirements, mitigation strategies to cover remaining risks have been identified. Please refer to Appendix B for more details.

Figure B-1 in Appendix B shows that the greatest hazards are located at the largest and busiest airports - the largest part of the problem. Our model predicted that of the over 900 fatalities projected, about 675 are potentially avoidable with ASDE-X and ASDE-3/AMASS. Other mitigation strategies such as education and training, improved procedures/guidelines, airport improvements, inductive loop technology, vehicle ADS-B, training simulators and others, as identified - need to be addressed to cover the remaining safety risks (about 255).

The analyses (economic and safety risk) performed by the IA Team form the basis for the recent announcement by the FAA Administrator regarding ASDE-X acquisition quantity. It must be understood that ASDE-X technologies will not eliminate all runway incursion accidents. Our estimate, based on expert opinion, is that ASDE-X, as well as ASDE-3/AMASS will be 75 percent effective in reducing runway incursion accidents by IMPROVING controller situational awareness, if the system performs as advertised. Please refer to Appendix B for more details. This means that the remaining 25 percent of the safety risks, which translates to over 200 fatalities, are unaddressed by new and existing ground surveillance technologies. These uncovered risks must be addressed (Phase II of the IA or through other efforts) by operational and low-tech actions such as training, awareness programs, procedures, airport improvements (e.g. lighting, signage) and regulatory enforcement, especially at the busiest airports where the greatest runway safety risks exist. In doing so, we will achieve greater and more immediate safety improvements, since safety data indicate that the greatest need for safety improvements will continue to exist at the largest, busiest airports, where we currently have ASDE-3 radars.

There are agency initiatives currently underway to address remaining safety risks unaddressed by ASDE-X or ASDE-3/AMASS. To date, there have been nine runway safety regional workshops (led by ATS-20) completed to address low tech actions such as 1) education and training, 2) airport improvements, and 3) improved procedures and guidelines. In addition, a recent National Runway Safety Summit, to address and elevate the several recommendations received throughout the country, was held on June 26-28, 2000. Per action received from the FAA Administrator, the Integrated Team for Runway Safety, led by the Director of ATS-20 will complete and submit the following two plans: 1) a comprehensive implementation plan for the top 10 recommendations by August 1, 2000, and 2) a detailed plan or national blue print for the several recommendations by September 30, 2000.

Page Intentionally Left Blank

10.0 AFFORDABILITY ASSESSMENT

The IA Team briefed the ASDE-X APB to the SEOAT on August 10, 2000. Table 10-1 depicts the funding profiles associated with the ASDE-X program compared to the CIP dated July 6, 2000.

Table 10-1. ASDE-X F&E Funding Profiles (Current $M)

	FY 00	FY 01	FY 02	FY 03	FY 04-26	TOTAL
CIP July 6, 2000	7.6	8.4	22.5	16.8	25.2	80.1
IA profile	7.6	12.6	24.4	63.1	225.0	332.5

Since the July 6 CIP was developed, the scope of the project has changed and the funding requirements have changed accordingly. The number of systems to be deployed has changed, the logistics support requirements are better defined, and the service life extension has been added.

The SEOAT has determined that ASDE-X is one of the top priority programs for the Agency, and therefore its funding requirements are to be considered above most other programs. At the time of the affordability assessment, the FY 2001 budget is being considered by Congress for appropriation at $8.4M. The SEOAT examined the FY 2001 request for increased funding for ASDE-X and determined that the planned activities are consistent with Agency direction and that the increased funding is reasonable. Therefore, the SEOAT recommends that the Committee be requested to increase the FY 2001 appropriation to the IA level. The SEOAT recommends examining the runway incursion funding in budget line 1F01 to determine if some funding can be moved to ASDE X. If not, programs in the Deferrable/Reducible category will be identified for reduction.

For FY 2002, the budget request of $22.5M was submitted to Office of Secretary of Transportation (OST) in June. The $1.9M shortfall will be accommodated when the budget request is revised and submitted to OMB in the fall of 2000. Lower priority programs in the Deferrable/Reducible category will be identified for reduction at that time. Funding adjustments for other programs will be required as well, so all adjustments will be done at one time prior to the OMB submittal.

For FY 2003 and beyond, affordability is assessed to the targets provided in the AIR 21 reauthorization. These targets are significantly higher than the targets used to develop the July 6 CIP, and therefore the increased funding for ASDE X is accommodated in the increased target without making any offsets.

Page Intentionally Left Blank

11.0 ARCHITECTURE ASSESSMENT

This section describes the degree to which ASDE-X is consistent with the NAS Architecture 4.0, January 1999. Once the FAA's JRC updates the FAA plans on the ASDE-X implementation, the NAS Architecture will be updated to reflect the new plans.

ASDE-X is consistent with the NAS Architecture Version 4.0 in terms of capability to further reduce the probability of traffic conflicts on airport surface and increase the efficiency of aircraft operations. The ASDE-X system provides future enhancements for ADS-B or any other surveillance sensors with the multi-processor/data fusion technology. ASDE-X is not dependent on any emerging NAS systems.

Page Intentionally Left Blank

12.0 RECOMMENDATIONS

If a decision is made to pursue another IA, Phase II of the IA will focus on addressing remaining safety risks not covered by current (ASDE-3/AMASS) and future ground surveillance technologies (ASDE-X). Beyond ASDE-X, we believe that additional investments identified in the Initial Requirements Document (IRD) are needed to cover unaddressed safety risks. However in the meantime, to put closure to Phase I (ASDE-X) of this IA, the Team proposes the recommendations listed below to the JRC for decision-making.

The Runway Incursion Reduction Program ASDE-X Phase I IA Team recommends the following to the JRC:

- Approve "Estimated" Acquisition Program Baseline (APB) for 25 ASDE-X systems, plus four support systems, prior to contract award in September 30, 2000, with a strategy to return to the JRC approximately six months after contract award, with a formal baseline for congressional tracking purposes.
- Approve expenditure of $15.5M through next JRC (six months after contract award).
- Proceed to award a contract for ASDE-X by September 30, 2000.
- Assign program responsibility for ASDE-X solution implementation to AND-400 Integrated Product Team (IPT).

Page Intentionally Left Blank

13.0 GLOSSARY

Term/Acronym	Definition
A	
ADS-B	Automatic Dependence Surveillance - Broadcast
AF	Airway Facilities
ANSI	American National Standards Institute
ARP	Administer of Airport Office
AT	Air Traffic
ATIDS	Airport Target Identification System
ATC	Air Traffic Control
ATS	Air Traffic Service
C	
CHI	Computer Human Interface
COTS	Commercial-off-the Shelf
COTS/NDI	Commercial-off-the-Shelf/Non-Developmental Item
D	
DT	Development Test
E	
EEI	Essential Elements of Information
EPA	Environmental Protection Agency
F	
FAA	Federal Aviation Administration
FAALC	FAA Logistics Center
FHA	Functional Hazard Assessment
FRD	Final Requirements Document
H	
HVAC	Heating, Ventilation and Air Conditioning
I	
IA	Investment Analysis
ICAO	International Civil Aviation Organization
IEEE	Institute of Electrical and Electronic Engineers
IMC	Instrument Meteorological Conditions
IOT&E	Independent Operational Test and Evaluation
IOTRD	Independent OT&E Readiness Declaration
IPT	Integrated Product Team
IRD	Initial Requirements Document

L

LAHSO	Land and Hold Short Operations
LRU	Lowest Replaceable Unit

M

MNS	Mission Need Statement
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair

N

NAILS	National Airspace Integrated Logistics Support
NAS	National Airspace System
NEPA	National Environmental Policy Act
NTIA	National Telecommunications and Information Administration
NTSB	National Transportation Safety Board

O

OE	Operational Error
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
OT	Operational Testing
OT&E	Operational Testing and Evaluation

P

PC	Personal Computer
PD	Pilot Deviation

Q

QA	Quality Assurance
QRO	Quality and Reliability Officer

R

RMM	Remote Maintenance Monitoring
RMS	Remote Maintenance Subsystem
RVR	Runway Visual Range

S

SARP	Standards and Recommended Practices

T

T&E	Test and Evaluation

V

VPD	Vehicle Pedestrian Deviations
VMC	Visual Meteorological Conditions

14.0 BIBLIOGRAPHY

The following list of publications were reviewed and provided background information in the development of the ASDE-X IAR. They are listed in chronological order (date of publication).

1. Deaton, J. E. & Parasuraman, R. (1993). Sensory and cognitive vigilance: Effects of Age on Performance and Mental Workload, Human Performance, 6, 71-97.
2. National Research Council (1997). Automation (pp. 273-276). In Flight to the Future: Human Factors in Air Traffic Control (C. D. Wickens, A. S. Mavor & J. P. McGee, eds.), Washington, DC: National Academy Press.
3. Feldman, E. & Weitzman, D. O. (1999). The False Alert Problem in Automated Conflict Detection: Crying Wolf Too Often, Journal of Air Traffic Control, April-June, 51-55.
4. Hitchcock, E. M., Dember, W. N., Warm, J. S., Moroney, B. W. & See, J. E. (1999). Effects of Cueing and Knowledge of Results on Workload and Boredom in Sustained Attention, Human Factors, 41, 365-372.
5. Parasuraman, R. & Hancock, P. A. (1999). Using Signal Detection Theory and Bayesian Analysis to Design Parameters for Automated Warning Systems. In Automation Technology and Human Performance (M. W. Scerbo & M. Mouloua, eds.), New Jersey: Lawrence Erlbaum Associates.

Page Intentionally Left Blank