ACRP

REPORT 50

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Improved Models for Risk Assessment of Runway Safety Areas

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ACRP REPORT 50

Improved Models for Risk Assessment of Runway Safety Areas

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), and the Air Transport Association (ATA) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

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The authors are very grateful for the guidance and help provided by the ACRP Panel for ACRP 4-08.

A very important contribution to this study was provided by MITRE Corporation. They made available their comprehensive database of accidents, and it significantly improved the availability of information to develop the risk models presented in this study. The research team is particularly grateful to Mr. Wallace Feerrar and Mr. John LeBron, who kindly made the information available. The research team is also very grateful for the participation of eight volunteers listed in Appendix G to test the analysis software, and for the courtesy of Mr. Luis Rosa to authorize the use of his photos.

FOREWORD

By Theresia H. Schatz
Staff Officer
Transportation Research Board

ACRP Report 50: Improved Models for Risk Assessment of Runway Safety Areas expands on the research presented in *ACRP Report 3: Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas* to include the analysis of aircraft veer-offs, the use of declared distances, the implementation of the Engineered Material Arresting System (EMAS) and the incorporation of a risk approach for consideration of obstacles in or in the vicinity of the RSA. A user-friendly risk analysis tool is provided for airport and industry stakeholders to quantify risk and support planning and engineering decisions when determining RSA requirements to meet an acceptable level of safety for various types and sizes of airports. The tool is interactive and versatile to help users determine the risk based on various input parameters.

Current standards for RSAs are fairly rigid because they depend only on the type and size of aircraft using the runway. However, numerous factors affecting operations may lead to aircraft overruns, undershoots, and veer-offs. In many instances, standard RSAs are not feasible because of constraints, such as obstacles or land unavailability. In such cases, it is essential that alternatives be evaluated to minimize risk, to the extent practicable, in relation to site-specific conditions. For example, depending on the type of operation, the relationship between actual runway distance required and the actual runway distance available for both landing and takeoff can significantly affect the risk.

An approach for risk assessment of RSAs has been developed under *ACRP Report 3: Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas. ACRP Report 3* provides a risk-based assessment that is rational and accounts for the variability of several risk factors associated with aircraft overruns and undershoots. The findings in *ACRP Report 3* are the basis for further research to quantify and assess risk in the RSA environment. Understanding this level of risk under a given set of conditions is essential to address RSA enhancement opportunities.

ACRP Report 50 contains an analysis tool on the accompanying CD. The user guide to the analysis tool is in Appendix I of the report and is also on the CD and software help file. In addition, a presentation documenting the research method has been posted on the project web page, under ACRP Project 04-08. This research effort was conducted by Applied Research Associates, Inc. as the prime contractor, with Dr. Manuel Ayres serving as Principal Investigator, and Robert E. David & Associates and Four Winds Consulting as sub-consultants.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Improved Models for Risk Assessment of Runway Safety Areas

The objective of this research project was to develop and validate a user-friendly software analysis tool that can be used by airport and industry stakeholders to quantify risk and support planning and engineering decisions when determining runway safety area (RSA) requirements to meet an acceptable level of safety for various types and sizes of airports.

The underlying basis was the approach presented in *ACRP Report 3: Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas.* The improved models and methodology provided by this research effort provide the capability to evaluate declared distances and the use of engineered material arresting system (EMAS), as well as the ability to consider the effects of obstacles inside or in the vicinity of the RSA.

The RSA is intended to prevent the following five types of events from becoming an accident: landing overruns, landing undershoots, landing veer-offs, takeoff overruns and takeoff veer-offs. The risk analysis for each type of event is threefold and considers probability (aka frequency), location, and consequence. The models for probability and location are specific for the event type, while the model for consequences is applicable to all five event types.

The models are based on evidence from worldwide accidents and incidents that occurred during the past 27 years. The analysis utilizes historical data from the specific airport and allows the user to take into consideration specific operational conditions to which movements are subject, as well as the actual or planned RSA conditions in terms of dimensions, configuration, type of terrain, and boundaries defined by existing obstacles.

The combined estimates for the probability model and location model provide an estimate that the event will take place and that the aircraft will stop or touch down beyond a certain distance from the runway area or strike an existing obstacle at a given speed. Using these estimates for the distances defined by the RSA bounds or by existing obstacles, it is possible to estimate the risk of accidents.

User-friendly software was developed and tested to help with the analysis. Input data to the analysis includes historical information on operations and weather and the definition of the RSA conditions and obstacles. The computer program runs a simulation to assess the risk for each historical operation and outputs average risk levels and probability distributions for each type of incident and each RSA section challenged by the operations. Results help the user identify areas of higher risk as well as compare different RSA alternatives.

Finally, the models developed in this research were validated using actual data for a sample of eight airports. The analysis results using actual data for these airports were compared to actual accident and incident rates over the past 25 years for each of these airports. The objective of this validation effort was to gain industry confidence on using the new methodology and software tool.

The outcome of this project is an RSA analysis tool that may benefit airport planners and engineers and that can be used to support safety risk assessments and actions. The approach

used and the software developed can be applied to evaluate any type of RSA improvement, including extending the RSA, using declared distances, and using EMAS, In addition, it is possible to analyze irregular RSA shapes and to consider the type of terrain and the presence of obstacles inside or in the vicinity of the RSA.

The RSA analysis tool should be used only for planning purposes rather than to evaluate risk for real-time conditions or individual operations. In addition, the data used to develop the risk models included only multi-engine aircraft with maximum takeoff weight (MTOW) higher than 5,600 lb. The approach for consequences incorporated in the analysis was based solely on engineering judgment, rather than crashworthiness data.

ACRP makes no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability of any particular purpose of the information or the data contained in the program. The software tool should be used by airport professionals who are familiar with and qualified to perform RSA analysis.

CHAPTER 1

Background

Introduction

Landing and takeoff overruns, landing undershoots, and landing and takeoff veer-offs account for most of the accidents that occur on or in the immediate vicinity of the runway. Accident statistics show that, from 1959 to 2009, 55% of the world's jet fatal aircraft accidents occurred during landing and takeoff phases of the flight and accounted for 51% of all onboard fatalities (Boeing 2010). Although in many cases the causal factors involve some type of human error, the conditions at the airport may contribute significantly to the probability and severity of the accidents.

The runway safety area (RSA) is a graded and obstacle-free rectangular-shaped area surrounding the runway that "should be capable, under normal (dry) conditions, of supporting airplanes without causing structural damage to airplanes or injury to their occupants" (AC 150/5300-13 1989). The RSA improves the safety of airplanes that undershoot, overrun, or veer off the runway and has helped turn potential accidents into minor incidents.

The rectangular dimensions of the RSA have changed over the years and depend on the category of aircraft using the runway. In the 1960s, in an attempt to mitigate the severity of aircraft accidents, the FAA revised the airport standards for RSA. The FAA RSA standard for most runways serving 14 CFR Part 121 air carrier operations is an area that is 500 feet wide centered on the runway and extends 1000 feet beyond each end of the runway.

Because many airports were built before the 1960s, when RSA dimension standards were smaller, some airports were not complying with the new dimensions. In 1999, the FAA released Order 5200-8 and embarked upon a major effort to upgrade safety areas that do not meet the current standards. The goal is to have all possible improvements for Part 139 airports completed by 2015. However, it is not practical for some airports to extend their current RSA dimensions to meet the standards because they are landlocked or face insurmountable challenges due to terrain or environmental restrictions such as wetlands.

More recently, the introduction of Engineered Material Arresting Systems (EMASs) has provided an alternative to achieve safety levels similar to those provided by the standards, but using only 60% of the area. Another alternative that has been used worldwide is the use of declared distances. For either of these alternatives there were no tools to help assess the true safety benefits associated with the solution selected.

The study presented in *ACRP Report 3* introduced a methodology for risk assessment of RSAs that has been used to evaluate RSA alternatives by the industry. However, the methodology cannot be used to evaluate the use of EMAS, declared distances, or safety areas for veer-off incidents. Moreover, the analysis is complex and only prototype software was developed under that study.

This report is organized into seven chapters. This first chapter provides the background and the objectives of the study, as well as the basic alternatives used by the industry to improve RSAs. The second chapter describes the five major types of incidents included in the analysis with major causes and contributing factors. Moreover the chapter presents the data used for the modeling process.

Chapter three explains the three-part approach to model each type of incident. Also it presents the probability and location models developed in this study and incorporated in the approach. The next chapter describes the consequence approach and how it was implemented.

The approach and the models developed in this study were incorporated into RSA analysis software named Runway Safety Area Risk Analysis (RSARA). Chapter 5 describes the software, and the required input and output information. Both the software and the models were validated using a sample of airports and their historical records for accidents and incidents to run the analysis and compare actual and predicted incident and accident rates. The results for validating the analysis are presented in Chapter 6.

Finally, Chapter 7 describes the major conclusions and recommendations from this study. It also explains major achievements and limitations.

Project Goals

The ultimate objective of this research was to develop a risk assessment tool that can be used to evaluate alternatives for RSA improvements, with a capability to account for the use of EMAS, declared distances, the presence of obstacles, specific operations, weather, and runway conditions.

New models were developed, and the capability to evaluate risk for veer-off events was added to the approach presented in *ACRP Report 3*. Five sets of models were developed in this study: landing overruns, landing veer-offs, landing undershoots, takeoff veer-offs, and takeoff overruns. Each set includes three models: incident frequency, stop/touchdown location, and consequences.

The following were the specific goals that were achieved for ACRP Project 4-08:

1. Update the *ACRP Report 3* accident/incident database to incorporate aircraft overrun and undershoot accidents and incidents occurring after 2006.
2. Collect data on aircraft runway veer-off accidents and incidents and integrate these data into the existing database.
3. Develop risk models for frequency and location for each type of incident: landing overruns (LDOR); landing undershoots (LDUS); landing veer-offs (LDVO), takeoff overruns (TOOR), and takeoff veer-offs (TOVO).
4. Develop a practical approach to assess the impact of runway distance available on the probability of overruns, undershoots, and veer-offs.
5. Develop a practical approach to assess risk and the impact of using EMAS as an alternative to standard RSAs, or to use declared distances and evaluate the safety impact of reduced runway distance available.
6. Develop a practical approach to model incident consequences based on existing conditions and the presence of obstacles inside or in the vicinity of the RSA.
7. Develop user-friendly software that incorporates the methodology and models developed as a practical tool that airport stakeholders may use to evaluate RSA alternatives.
8. Field test the software developed.
9. Validate the new tool based on data gathered according to an airport survey plan.

RSA Improvement Alternatives

General Considerations

To facilitate understanding the role of an RSA, it can be divided into three sections as a function of the types of incidents that may occur in those locations. Two of those sections are located on each runway end and include the RSA portion immediately before the arrival thresholds and beyond the departure end of the runway. These are the sections that help mitigate consequences of aircraft overruns and undershoots. The third RSA section is lateral to the runway and extends over the runway length on both sides of the runway. This is the area that can help mitigate the severity of aircraft veer-off incidents.

For the RSA sections located laterally to the runway, improvements can be made by removing obstacles and preparing the area according to RSA standards to increase the runway object free area (ROFA) width. In some cases this may be necessary to introduce the operation of larger aircraft to increase capacity; however, they may be restrained to increase the existing runway separation distances to accommodate the larger airplane design group (ADG).

There are four basic alternatives available to improve an RSA when it does not meet the standards:

- Extend the RSA laterally and longitudinally.
- Modify or relocate the runway to expand the RSA.
- Implement declared distances by reducing the available runway distances and extending the RSA section adjacent to the runway ends.
- Use arresting systems to obtain a level of safety similar to that provided by the standard RSA.

Any combination of such alternatives is also possible, and the methodology presented in this report has the capability to analyze any such combinations. Each of these alternatives has advantages and disadvantages that are specific to each situation and that need to be assessed, as described in ensuing sections of this report.

It is important to note that airport operators can take additional actions to mitigate the probability of aircraft overruns, undershoots, and veer-offs. Some possible alternatives may include the following:

- Improve skid resistance and reduce undulations of runway surface.
- Monitor runway friction level to determine need to close the runway (e.g., ice conditions) and time for maintenance (e.g., rubber removal).
- Ensure accurate weather information and runway surface conditions are available to flight crews.
- Improve airport capability to detect unusual weather conditions (e.g., wind shear).
- Minimize the presence of obstacles in the vicinity of RSAs.
- Upgrade visual and instrument landing aids to improve accuracy of approach path.
- Coordinate operational restrictions with airlines and air traffic control (ATC) when adverse weather conditions arise.

- Publish RSA provision in the Aeronautical Information Publication when RSA's cannot comply with standards.

Although these actions can decrease the probability of undesirable events, it is not possible to measure the impact of these risk mitigation actions on the total airport risk of serious aircraft overruns, undershoots, and veer-offs.

This study introduces a risk-based methodology for quantitative evaluation of any of the alternatives or combinations of RSA improvement alternatives identified in FAA Order 5200.8 (1999). These alternatives are described below.

Extend the RSA

An example of extending the RSA is shown in Figure 1. In this case, the RSA adjacent to the right runway end and the lateral area originally did not comply with the standard.

This is a straightforward solution to improve an RSA and is used to extend it to the runway ends or the lateral sections. However, this alternative is not always feasible due to physical, environmental, or other constraints involved with implementation.

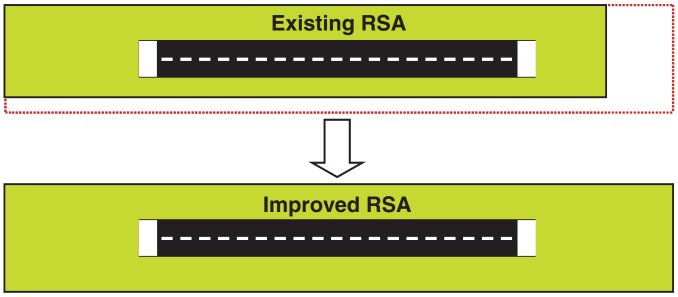


Figure 1. Extending the RSA.

Modify or Relocate the Runway

In Figure 2, the runway was relocated to the left to obtain a standard RSA of 1000 ft in length. The relocation also may involve the change of runway direction.

Similar to the previous alternative, this solution may involve very high costs, particularly if changing the runway direction is necessary. In this case, a new runway must be constructed to replace the existing one. For the example shown, to keep the distance available for landing, it is necessary to extend the runway to the left.

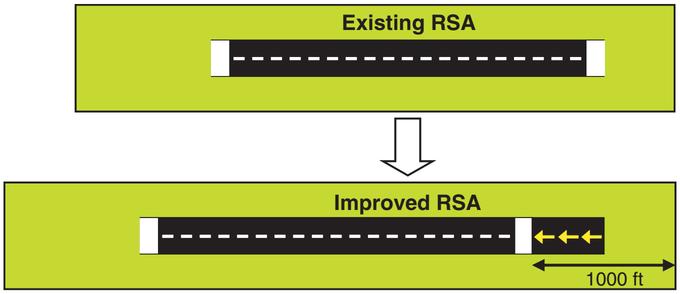


Figure 2. Relocating the runway.

Implement Declared Distances

Declared distances are a means of obtaining a standard safety area by reducing the usable runway length. When the RSA cannot be extended or the runway relocated, it may be necessary to implement declared distances to accommodate a larger RSA. Figure 3 shows an example to extend the RSA using this alternative.

This is a fast and low cost alternative for the airport operator; however, it may impact airport capacity, reduce payloads, and/or degrade the level of safety under specific situations, which may lead to long-term consequences to the airport. In the example provided, the runway was reduced to accommodate a larger RSA by reducing the landing distance available.

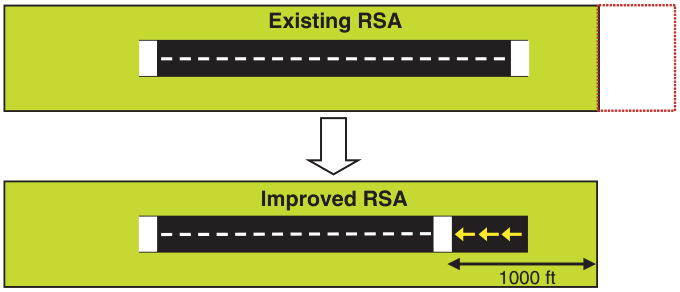


Figure 3. Using declared distances.

Use of Arresting Systems

When a full RSA cannot be achieved, the airport may use a bed of lightweight concrete that is crushed under the wheels of a stray aircraft, causing energy from its forward motion to be absorbed, to bring the aircraft to a stop within a shorter distance. A standard EMAS bed can reduce what would normally be a 1000-ft RSA to 600 ft, or even less if the land is not available, depending upon the aircraft types using the runway. Figure 4 presents an example of RSA improvement using EMAS.

This is an alternative that only became available in recent years and provides a feasible solution, particularly for landlocked runways. The major disadvantages are the high initial cost, maintenance costs, the need to replace the bed when used, the need to periodically replace the bed due to natural deterioration, and it still requires some land area to be available for installation.

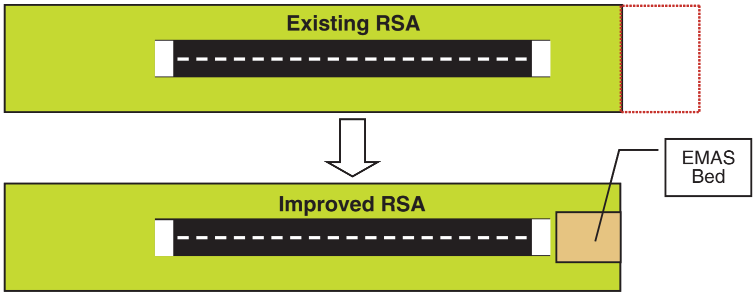


Figure 4. Using EMAS.

CHAPTER 2

Research Approach

The development of this study included 11 tasks. These steps are illustrated in Figure 5.

The project started with a kick-off meeting and collection of updated information, particularly to review the literature associated with runway veer-off incidents, which was not part of the previous ACRP study. Following the literature review, the research team collected information to develop the risk models, including accident and incident information, aircraft data to build a criticality factor into the frequency models, as well as complementing the normal operations data (NOD) for general aviation (GA) flights of aircraft with MTOW below 12,000 lb.

Three parallel tasks were carried out after the model data were completed and reviewed: the development of risk models for aircraft overruns, veer-offs, and undershoots; the development of a test plan to validate the approach, the models, and the analysis software; and the development of a software outline to present to the panel. An interim report was prepared and submitted to the panel for discussion during the interim meeting.

Following the meeting, the research team pursued tasks on two fronts. The first was the development, testing, and review of the analysis software, and the second consisted of the preparation of data and actions to validate the study.

The approved software framework was implemented using Microsoft .Net and Microsoft Office tools (Excel and Access), and a user manual was developed. Eight industry volunteers were selected to test the beta version and provide comments to enhance the solution and eliminate bugs. In parallel, the software team conducted tests to identify and eliminate bugs. A revised version of the software was used to run the analysis for airports selected for validation.

Eight airports were selected to run the analyses for validation. Accident and incident data for these airports, as well as operations and weather information covering 1 year, were collected. The risk estimates were then compared to the actual accident and incident rates for the airports. The research tasks, the models, and the results are summarized in this report, the last task in this study.

Functional Hazard Analysis

As part of the literature review for this project, the research team reviewed information on operational experience to develop a functional hazard analysis (FHA) for the types of incidents relevant to this study. A similar analysis conducted by Eddowes et al. (2001) was used for overruns and undershoots in the *ACRP Report 3* study, and a summary is presented in Appendix A.

An FHA is a formal and systematic process for the identification of hazards associated with an activity. The purpose of the FHA was to determine relevant causal and contributing factors of veer-off, overrun, and undershoot accidents and hazards to aircraft associated with aerodrome operations and the physical design of airfields.

Overrun, veer-off, and undershoot incidents may be considered in terms of the deviation of the aircraft from its intended path. The definition of the deviation for each incident type may be summarized as follows:

- For overrun incidents, the “longitudinal deviation” is described by the longitudinal distance traveled beyond the expected accelerate/stop distance (for takeoff events) and beyond the landing distance available (for landing events).
- For veer-off incidents, the “lateral deviation” is described by the lateral distance traveled from the runway longitudinal edge.
- For undershoot incidents, the “longitudinal deviation” is described by the longitudinal distance from the point where the aircraft actually touched down to the runway threshold.
- For both overrun and undershoot events, the “lateral deviation” is the lateral distance to the extended runway centerline.

The identification of factors associated with aircraft overruns, undershoots, and veer-off was an important step prior to collection of accident and incident data, as this information was required to develop the risk models presented in this study.

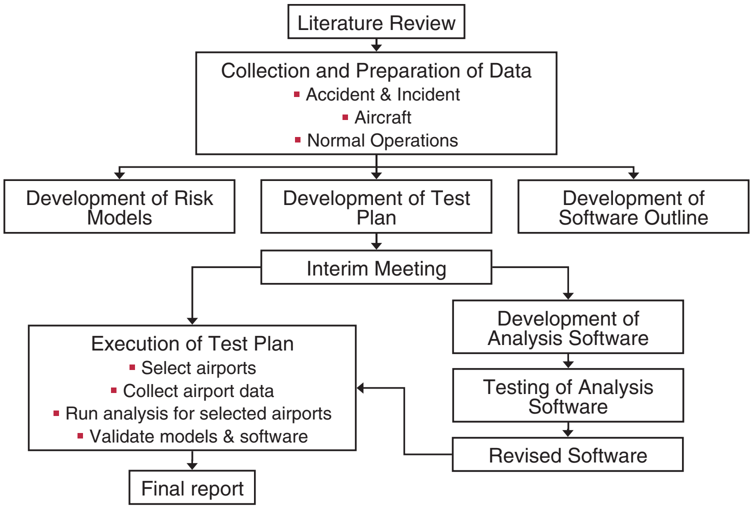


Figure 5. Study tasks.

Accident and Incident Data

Accident and incident data were collected from the following sources:

- FAA Accident/Incident Data System (AIDS).
- FAA/National Aeronautics & Space Administration (NASA) Aviation Safety Reporting System (ASRS).
- National Transportation Safety Board (NTSB) Accident Database & Synopses.
- MITRE Corporation Runway Excursion Events Database V.4 (2008).
- Transportation Safety Board of Canada (TSB).
- International Civil Aviation Organization (ICAO) Accident/Incident Data Reporting (ADREP) system.
- Australian Transport Safety Bureau (ATSB).
- Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA).
- UK Air Accidents Investigation Branch (AAIB).
- New Zealand Transport Accident Investigation Commission (TAIC).
- Air Accident Investigation Bureau of Singapore.
- Ireland Air Accident Investigation Unit (AAIU).
- Spain Comisión de Investigación de Accidentes e Incidentes de Aviación Civil (CIAIAC).
- Indonesia National Transportation Safety Committee (NTSC).
- Netherlands Aviation Safety Board (NASB).

More than 260,000 aviation accident and incident reports were screened from 11 countries to identify the cases relevant to this study. Out of those, more than 140,000 events were screened from U.S. databases. The relevant events were filtered prior to gathering data from each report.

A list of accidents and incidents containing the cases used for model development is presented in Appendix B of this report. The list includes the accidents that occurred within 2000 ft of the runway ends and within 1000 ft of the runway centerline. The criteria represents the area where the overwhelming majority of runway excursions and undershoots occur and are similar to those used in *ACRP Report 3* and by the FAA (David 1990). Using such criteria, 1414 accidents and incidents were identified to provide the information used to develop the frequency and location models. Events that took place since 1980 and for which reports were available were included in the database.

Part of the data used to develop the frequency models was complemented from other sources of information, particularly for aircraft, airport, and meteorological conditions. For example, in some cases the weather information during the incident was missing and the actual METAR for the airport was obtained. In other situations, the runway used was missing and the FAA Enhanced Traffic Management System Performance Metrics (ASPM) was consulted.

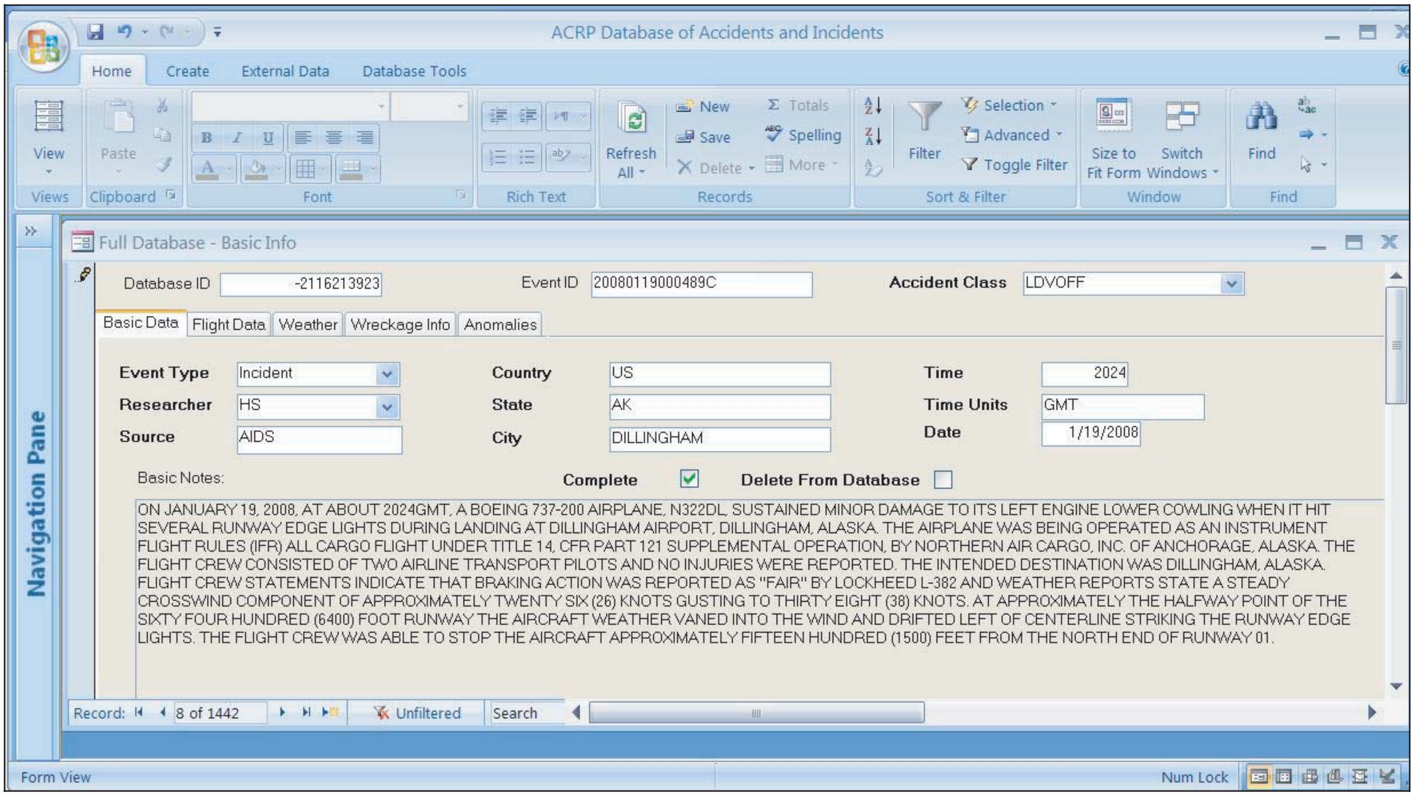
Filter Applied to the Data

Criteria for filtering data were established to make the events comparable. The first filter was an attempt to use information from only specific regions of the world having accident rates that are comparable to the U.S. rate. This information was combined with U.S. data to develop the location models. For the frequency models, only U.S. data were used because comprehensive incident records are only available in the United States. The criteria used are shown in Table 1.

The accident and incident database was organized in Microsoft Access. The *ACRP Report 3* database was modified to simplify its use. The system provides the software tools needed to utilize the data in a flexible manner and includes the capability to add, modify, or delete data from the database, make queries about the data stored in the database, and produce reports summarizing selected contents. Figure 6 shows the database organization.

Table 1. Filtering criteria for accidents and incidents.

Filter #	Description	Justification
1	Remove non-fixed wing aircraft entries	Study is concerned with fixed wing aircraft accidents and incidents only
2	Remove entries for airplanes with certified max gross weight < 6,000 lbs	Cut off criteria to maintain comparable level of pilot qualifications and aircraft performance to increase the validity of the modeling
3	Remove entries with unwanted FAR parts. Kept Part 121, 125, 129, 135 and selected Part 91 operations.	Some FAR parts have significantly different safety regulations (e.g., pilot qualifications). The following cases were removed: o Part 91F: Special Flt Ops. o Part 103: Ultralight o Part 105: Parachute Jumping o Part 133: Rotorcraft Ext. Load o Part 137: Agricultural o Part 141: Pilot Schools o Armed Forces
4	Remove occurrences for unwanted phases of flight	Study focus is the runway safety area. Situations when the RSA cannot help mitigating accident and incident consequences were discarded to increase model validity.
5	Remove all single engine aircraft and all piston engine aircraft entries	Piston engine aircraft are now used less frequently in civil aviation and therefore have been removed, to increase the validity of the modeling. Moreover single and piston engine aircraft behave differently in accidents due to the lower energy levels involved and the fact that the major focus of this study is air carrier aircraft.
6	Remove all accidents and incidents when the point of first impact and the wreckage final location is beyond 2000ft from runway end and 1000ft from runway centerline.	It would be unfeasible to have an RSA with more than 2000ft beyond the threshold or 1000ft from the runway centerline, the gain in safety is not significant and both the previous ACRP study and the FAA study used the 2000ft criteria (David 1990).



Database ID: -2116213923
Event ID: 20080119000489C
Accident Class: LDVOFF
Event Type: Incident
Researcher: HS
Source: AIDS
Country: US
State: AK
City: DILLINGHAM
Time: 2024
Time Units: GMT
Date: 1/19/2008
Complete ☑
Delete From Database ☐
Record: 8 of 1442

Basic Notes:

ON JANUARY 19, 2008, AT ABOUT 2024GMT, A BOEING 737-200 AIRPLANE, N322DL, SUSTAINED MINOR DAMAGE TO ITS LEFT ENGINE LOWER COWLING WHEN IT HIT SEVERAL RUNWAY EDGE LIGHTS DURING LANDING AT DILLINGHAM AIRPORT, DILLINGHAM, ALASKA. THE AIRPLANE WAS BEING OPERATED AS AN INSTRUMENT FLIGHT RULES (IFR) ALL CARGO FLIGHT UNDER TITLE 14, CFR PART 121 SUPPLEMENTAL OPERATION, BY NORTHERN AIR CARGO, INC. OF ANCHORAGE, ALASKA. THE FLIGHT CREW CONSISTED OF TWO AIRLINE TRANSPORT PILOTS AND NO INJURIES WERE REPORTED. THE INTENDED DESTINATION WAS DILLINGHAM, ALASKA. FLIGHT CREW STATEMENTS INDICATE THAT BRAKING ACTION WAS REPORTED AS "FAIR" BY LOCKHEED L-382 AND WEATHER REPORTS STATE A STEADY CROSSWIND COMPONENT OF APPROXIMATELY TWENTY SIX (26) KNOTS GUSTING TO THIRTY EIGHT (38) KNOTS. AT APPROXIMATELY THE HALFWAY POINT OF THE SIXTY FOUR HUNDRED (6400) FOOT RUNWAY THE AIRCRAFT WEATHER VANED INTO THE WIND AND DRIFTED LEFT OF CENTERLINE STRIKING THE RUNWAY EDGE LIGHTS. THE FLIGHT CREW WAS ABLE TO STOP THE AIRCRAFT APPROXIMATELY FIFTEEN HUNDRED (1500) FEET FROM THE NORTH END OF RUNWAY 01.

Figure 6. Accident and incident database for aircraft overruns, undershoots, and veer-offs.

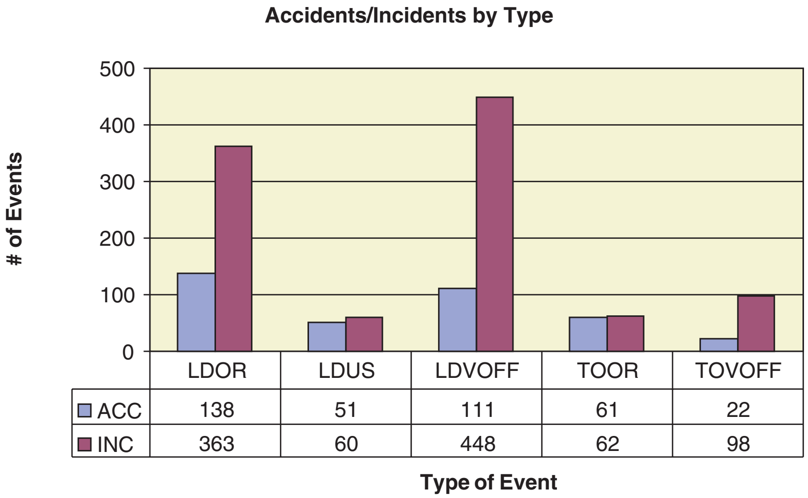


Figure 7. Summary of accidents and incidents by type.

The database includes, for each individual event or operation, the reporting agency, the aircraft characteristics, the runway and environmental conditions, event classification (accident or incident), and other relevant information such as consequences (fatalities, injuries, and damage) and causal or contributing factors required to develop the probability models. A unique identifier was assigned to each event.

Summary of Data

Figure 7 presents the summary of accidents and incidents by type, and Figure 8 shows the relative percentages for each type. Landing events accounted for 83% of the events. Overruns (landing and takeoffs) accounted for 44% of accidents and incidents; veer-offs accounted for 48%; and undershoots accounted for only 8% of the total number of events.

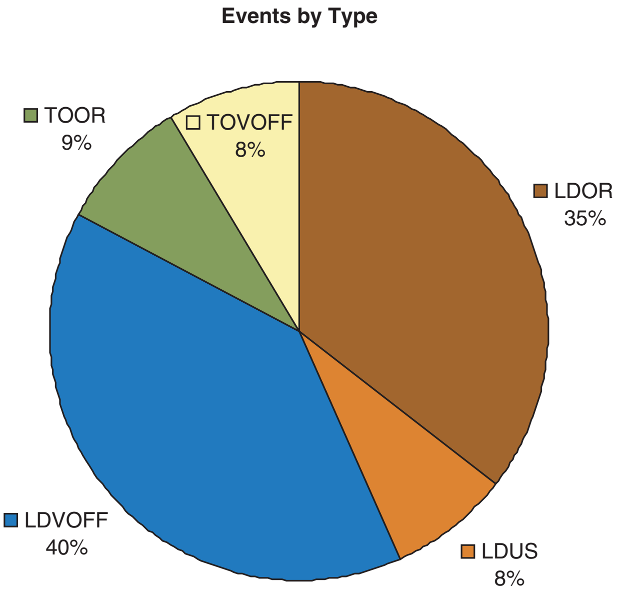


Figure 8. Percentage of accidents and incidents by type.

Figure 9 presents the number of incidents and accidents by year from 1978 to 2008. The number of events reported in the 1970s was relatively low, most likely due to underreporting and lower volumes of traffic. The number of events increased slowly, and there is a sharp drop during the past 3 years. It is possible that some events are still undergoing the investigation and that reports were not available by the time data collection was completed.

Figures 10 to 14 show the distribution of accidents and incidents according to their location. For overruns and undershoots, the locations refer to the longitudinal distance from the runway end. For veer-offs, it is the lateral distance from the runway longitudinal edge.

Five hundred one landing overrun events were identified. In approximately 95% of the events, the aircraft stopped within 1000 ft after overrunning the runway, and close to 77% stopped within 500 ft.

One hundred eleven landing undershoot events were identified, and in approximately 94% of the cases, the aircraft touched the terrain within 1000 feet of the runway arrival end. Approximately 85% touched down within 600 feet and 80% within 500 feet.

Veer-off distances were measured from the runway edge. Of the 559 cases of landing veer-off identified, in approximately 80% of the cases the fuselage of the aircraft deviated less than 175 feet from the runway edge. For 88% of the events, the aircraft was within 250 feet of the runway edge.

A total of 123 takeoff overrun accidents and incidents were identified. For approximately 83% of the cases, the stop location was within 1000 feet of the runway departure end, and for 56%, the aircraft stopped within 500 feet.

Of the 120 takeoff veer-off accidents and incidents, in approximately 76% of the cases the fuselage of the aircraft

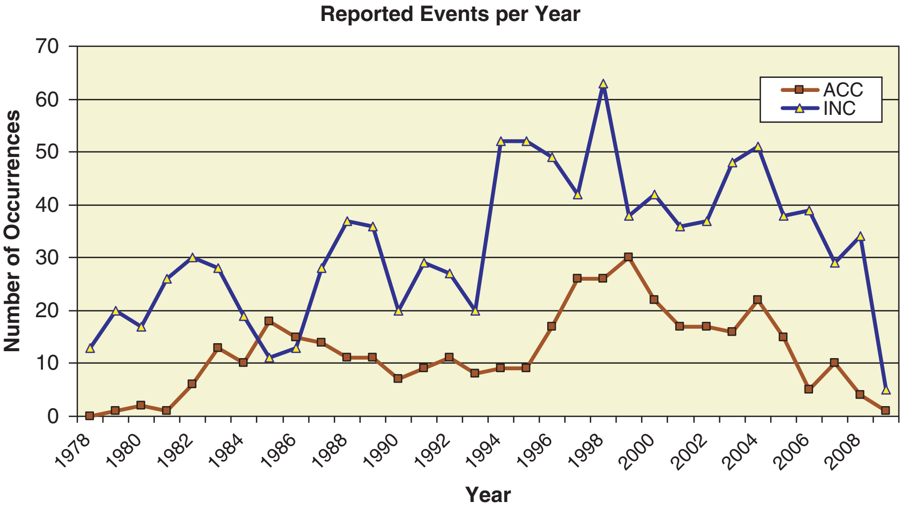


Figure 9. Number of reported accidents and incidents from 1978 to 2008.

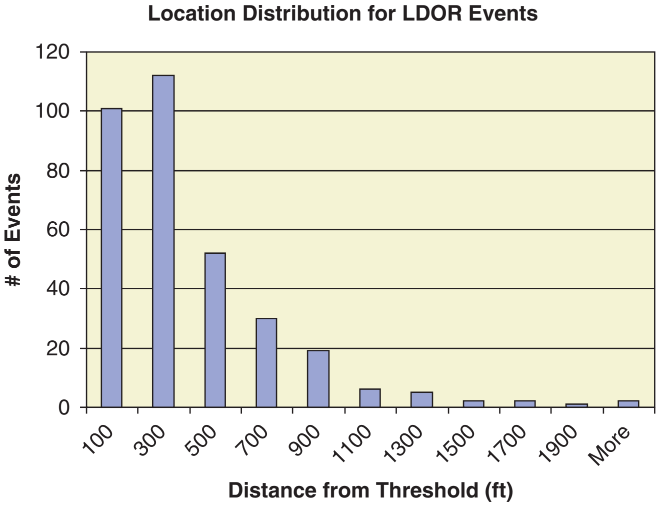


Figure 10. Location distribution for landing overruns.

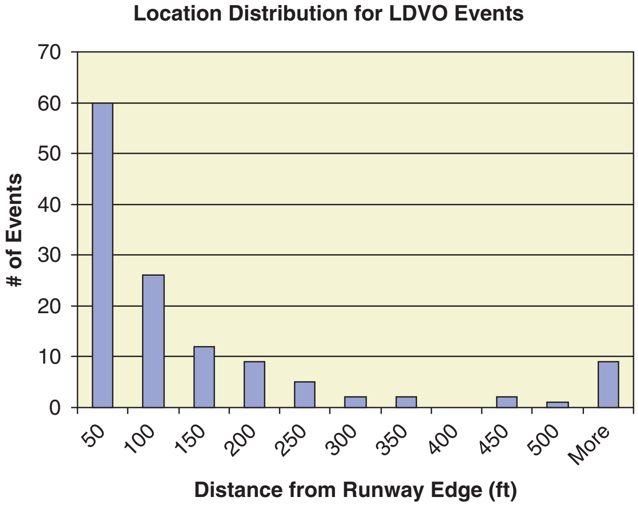


Figure 12. Location distribution for landing veer-offs.

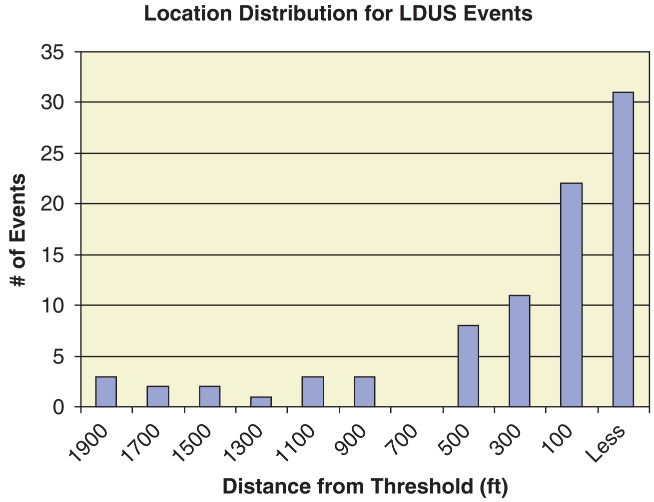


Figure 11. Location distribution for landing undershoots.

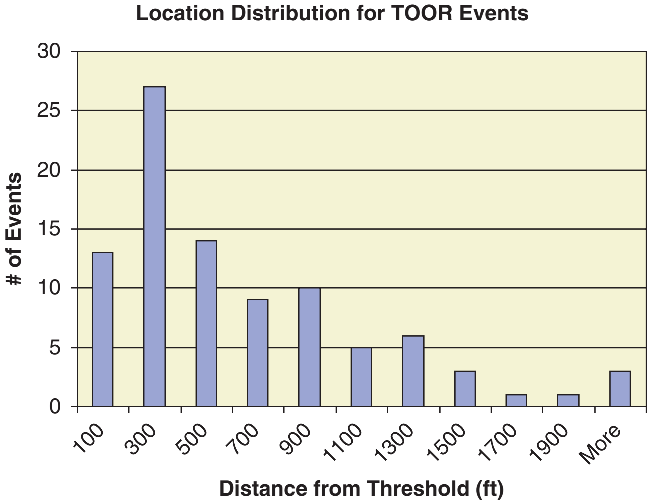


Figure 13. Location distribution for takeoff overruns.

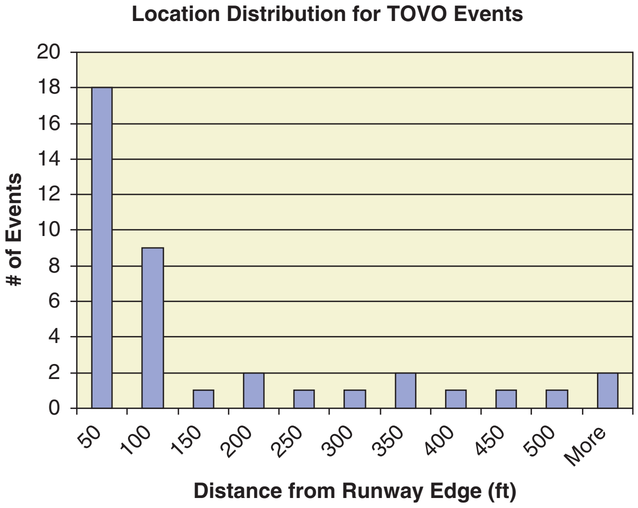


Figure 14. Location distribution for takeoff veer-offs.

deviated less than 175 feet from the runway edge. In 85% of the events, the aircraft was within 250 feet of the runway edge.

Normal Operations Data

Another key approach in this study was the use of NOD for probability modeling. In the absence of information on risk exposure, even though the occurrence of a factor (e.g., contaminated runway) could be identified as a contributor to many accidents, it is impossible to know how critical the factor is, since many other flights may have experienced the factor without incidents. With NOD, the number of operations that experience the factor benignly, singly, and in combination can be calculated; risk ratios can be generated; and the importance of risk factors can be quantified. This assessment may allow the prioritization of resource allocation for safety improvement (Enders et al. 1996).

The same NOD used in the *ACRP Report 3* study was used in this study. The data were complemented with information for GA aircraft with MTOW lower than 12,500 lb and higher than 6,000 lb. The NOD database comprises a large and representative sample of disaggregate U.S. NOD covering a range of risk factors, allowing their criticality to be quantified. The data and the information on U.S. incidents and accidents were used as a sample to develop the frequency models only. A small sample of the NOD used in this study is presented in Appendix C.

Incorporating this risk exposure information into the accident frequency model enhances its predictive power and provides the basis for formulating more risk-sensitive and responsive RSA policies. Accident frequency models need no longer rely on simple crash rates based on just aircraft, engine, or operation type. As discussed in the following pages, factors previously ignored by airport risk assessments and RSA regulations are accounted for using the models developed in this study.

Aircraft Data

One of the project goals was to incorporate a factor in the models to account for the impact of aircraft performance and available runway length on probability of incidents. When the distance available is close to the distance required, the safety margin is smaller during the aircraft landing or takeoff, and the likelihood is greater that an overrun or veer-off will occur.

Compared to the *ACRP Report 3* study, two new factors were included in the improved models: the runway distance available for the operation (takeoff or landing) and the aircraft runway distance required under the operation conditions. The runway available and required distances were gathered or estimated for each accident, incident, and normal operation, according to the procedures described in ensuing sections. The parameter introduced in the frequency models was the logarithm of the ratio between the distance required and the distance available, to address the interaction between the two parameters. When the criticality factor is close to zero, the ratio between the required and available distance is close to one.

Aircraft dimensions and performance data were gathered from various sources, including aircraft manufacturers' websites and other databases:

- FAA Aircraft Characteristics Database.
  - Source: FAA
  - Website: (http://www.faa.gov/airports/engineering/aircraft_char_database/)
- Eurocontrol Aircraft Performance Database V2.0
  - Source: Eurocontrol
  - Website: (http://elearning.ians.lu/aircraftperformance/).
- FAA Aircraft Situation Display to Industry (ASDI)—Aircraft Types.
  - Source: FAA
  - Website: (http://www.fly.faa.gov/ASDI/asdidocs/aircraft_types.txt).
- Boeing Airplane Characteristics for Airport Planning.
  - Source: The Boeing Company
  - Website: http://www.boeing.com/commercial/airports/plan_manuals.html
- Airbus Airplane Characteristics for Airport Planning.
  - Source: Airbus Industrie
  - Website: airbus.com/Support/Engineering & Maintenance/Technical data/Aircraft Characteristics
- Embraer Aircraft Characteristics for Airport Planning.
  - Source: Embraer
  - Website: http://www.embraeraviationservices.com/english/content/aeronaves/

Aircraft performance data used to develop the probability models also were incorporated into the analysis software. A summary of the aircraft database is presented in Appendix D.

CHAPTER 3

Modeling RSA Risk

The analysis of RSA risk requires three models that consider probability (frequency), location and consequences. The outcome of the analysis is the risk of accident during runway excursions and undershoots. The three model approach is represented in Figure 15.

The first model is used to estimate the probability that an event will occur given certain operational conditions. This probability does not address the likelihood that the aircraft may strike an obstacle or will stop beyond a certain distance. The model uses independent variables associated with causal and contributing factors for the incident. For example, under tailwind conditions it is more likely that an overrun will occur, and this is one of the factors used in the models for overruns. The aircraft performance is represented by the interaction between the runway distance required by the aircraft for the given conditions and the runway distance available at the airport. Although human and organizational factors are among the most important causes of aircraft accidents, it was not possible to directly incorporate these factors into the risk models. Since this model is specific for the event type, five different models are required, e.g., one for landing overruns and another one for takeoff overruns.

The second component is the location model. The analyst usually is interested in evaluating the likelihood that an aircraft will depart the runway and stop beyond the RSA or strike an obstacle. The location model is used to estimate the probability that the aircraft stops beyond a certain distance from the runway. As pointed out in *ACRP Report 3* and by Wong (2007), the probability of an accident is not equal for all locations around the airport. The probability of an accident in the proximity of the runways is higher than at larger distances from the runway. Since this model is specific for the event type, five different models are required, e.g., one for landing overruns and another one for takeoff overruns.

The last part is the consequence model. This model uses the location models to assess the likelihood that an aircraft will strike an obstacle or depart the RSA and fall into a drop in the terrain or into a water body adjacent to the RSA. In addition, it takes into consideration the type of obstacle and the estimated collision speed to cause severe consequences. For example, an aircraft colliding with a brick building may result in severe consequences even at low speeds; however, the aircraft must be at a higher speed when striking a Localizer antenna mounted on a frangible structure for a similar level of severity. The collision speed is evaluated based on the location of the obstacle and the typical aircraft deceleration for the type of RSA terrain. The ensuing sections provide details for each component of the risk model. The same model is used for all five types of events (LDUS, LDOR, LDVO, TOOR, and TOVO.)

The remainder of this chapter discusses the probability and location models. The consequence model is discussed in Chapter 4.

Event Probability (Frequency Model)

Similar to *ACRP Report 3* model development procedures, backward stepwise logistic regression was used to calibrate five frequency models, one for each type of incident: LDOR, LDUS, LDVO, TOVO, and TOOR. Various numerical techniques were evaluated to conduct the multivariate analysis, and logistic regression was the preferred statistical procedure for a number of reasons. This technique is suited to models with a dichotomous outcome (accident and non-accident) with multiple predictor variables that include a mixture of continuous and categorical parameters. Also, it is particularly appropriate for case-control studies because it allows the use of samples with different sampling fractions, depending on the outcome variable without giving biased results. Backward stepwise logistic regression was used to calibrate the frequency models because of the predictive nature of the research, and the technique is able to identify relationships missed by forward stepwise logistic regression (Hosmer and Lemeshow 2000).

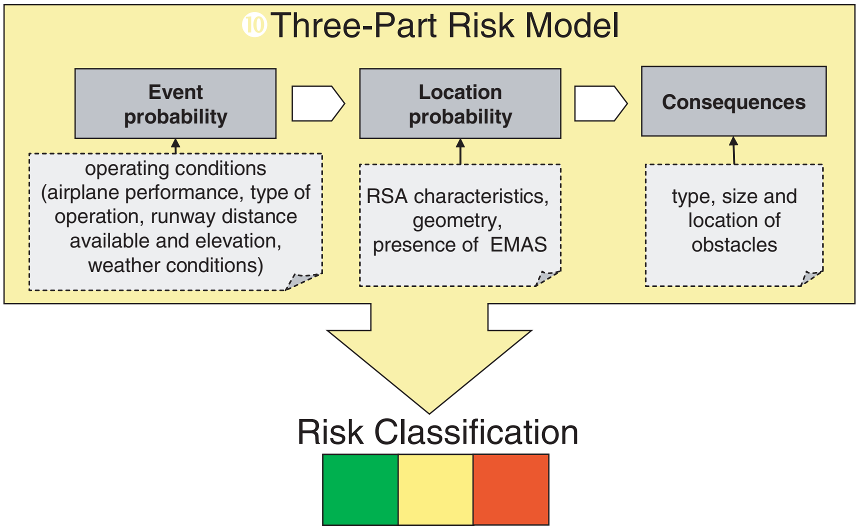


Figure 15. Modeling approach.

To avoid the negative effects of multi-co-linearity on the model, correlations between independent variables were first tested to eliminate highly correlated variables, particularly if they did not significantly contribute to explaining the variation of the probability of an accident.

The basic model structure selected is a logistic equation, as follows:

$$P\{Accident\_Occurence\} = \frac{1}{1+e^{b_0+b_1X_1+b_2X_2+b_3X_3+\dots}}$$

where

P{Accident_Occurrence} = the probability (0–100%) of an accident type occurring given certain operational conditions;
X_i = independent variables (e.g., ceiling, visibility, crosswind, precipitation, aircraft type, criticality factor); and
b_i = regression coefficients.

Several parameters were considered for inclusion in the models. The backward stepwise procedure helps identify those variables that are relevant for each type of event. Some of the independent variables are converted to binary form to avoid spurious effects of non-linear relationships in the model exponent. These binary variables are represented by only two values, 0 or 1. In this case, the presence of the factor (e.g., rain) is represented by 1, and the absence of the factor (e.g., no rain) is represented by 0.

One significant improvement relative to the models presented in *ACRP Report 3* is the use of tailwind and headwind. These variables were not present in previous models because the actual runway had not been identified for the NOD. The research team has gathered information on the runways used, and the process allowed the calculation of the head/tailwind components to be included in the model.

Another major improvement that has increased model accuracy was the inclusion of a runway criticality factor. The basic idea was to include a new parameter that could represent the interaction between the runway distance required by the aircraft and the runway distance available at the airport. The log of the ratio between the distance required and the distance available was used. Positive values represent situations when the distance available was smaller than the distance required, and in this case, risk will be higher. The greater the value is, the more critical is the operation because the safety margin decreases.

The distance required is a function of the aircraft performance under specific conditions. Therefore, every distance required under International Standards Organization (ISO) conditions (sea level, 15 degrees centigrade) was converted to actual conditions for operations. Moreover, the distances were adjusted for the runway surface condition (wet, snow, slush, or ice) and for the level of head/tailwind. The adjustment factors applied to the distance required are presented in Table 2. A correction for slope was not applied to adjust the total distance required.

The use of NOD in the accident frequency model was a major improvement introduced by Wong et al. (2006) and was maintained for this study. The analysis with NOD also adds to the understanding of cause-result relationships of the five accident types.

The technique used to develop the models is able to identify relationships missed by forward stepwise logistic regression (Hosmer and Lemeshow 2000). The predictor variables

Table 2. Adjustment factors used to correct required distances.

Local Factor	Unit	Reference	Adjustment
Elevation (E) (i)	1000 ft	E = 0 ft (sea level)	$F_e = 0.07 \times E + 1$
Temperature (T) (i)	deg C	T = 15 deg C	$F_t = 0.01 \times (T – (15 – 1.981 E) + 1$
Tailwind (TWLDJ) for Jets (iii)	knot	TWLDJ = 0 knot	$F_{TWJ} = (RD + 22 \times TWLDJ)/RD$ (ii)
Tailwind (TWLDT) for Turboprops (iii)	knot	TWLDT = 0 knot	$F_{TWJ} = (RD + 30 \times TWLDT)/RD$
Headwind (HWTOJ) for Jets (iii)	knot	HWTOJ = 0 knot	$F_{TWJ} = (RD + 6 \times HWTOJ)/RD$
Headwind (HWTOT) for Turboprops (iii)	knot	HWTOJ = 0 knot	$F_{TWJ} = (RD + 6 \times HWTOT)/RD$
Runway Surface Condition – Wet (W) (iv)	Yes/No	Dry	$F_W = 1.4$
Runway Surface Condition – Snow (S) (iv)	Yes/No	Dry	$F_S = 1.6$
Runway Surface Condition – Slush (Sl) (iv)	Yes/No	Dry	$F_{Sl} = 2.0$
Runway Surface Condition – Ice (I) (iv)	Yes/No	Dry	$F_I = 3.5$

i – RD is the runway distance required in feet
ii – temperature and elevation corrections used for runway design
iii – correction for wind are average values for aircraft type (jet or turboprop)
iv – runway contamination factors are those suggested by Flight Safety Foundation

were entered by blocks, each consisting of related factors, such that the change in the model's substantive significance could be observed as the variables were included. Table 3 summarizes the model coefficients obtained for each model.

Table 4 summarizes the parameters representing the accuracy of each model obtained. The table presents the R^2 and C-values for each model. It is important to note that relatively low R^2 values are the norm in logistic regression (Ash and Schwartz 1999) and they should not be compared with the R^2 of linear regressions (Hosmer and Lemeshow 2000). A better parameter to assess the predictive capability of a logistic model is the C-value. This parameter represents the area under the sensitivity/specificity curve for the model, which is known as Receiver Operating Characteristic (ROC) curve.

Sensitivity and specificity are statistical measures of the performance of a binary classification test. Sensitivity measures the proportion of true positives that are correctly identified as such (the percentage of accidents and incidents that are correctly identified when using the model). Specificity measures the proportion of true negatives that are correctly identified (the percentage of normal operations that the model can correctly identify as non-incident). These two measures are closely related to the concepts of Type I and Type II errors. A theoretical, optimal prediction can achieve 100% sensitivity (i.e., predict all incidents) and 100% specificity (i.e., not predict a normal operation as an incident). A perfect model has a C-value equal to 1.00.

To assess how successful the models are in classifying flights correctly as "accident" or "normal" and to find the appropriate cut-off points for the logistic regression models, the ROC curves were defined for each model to calculate the C-value. An example of this assessment is shown in Figure 16 representing the model for landing overruns. The area under the curve for this model represents the C-value and is 87.4%. The C-values for each of the five models developed were above 78% and are considered excellent models.

The cut-off point is the critical probability above which the model will class an event as an accident. The ROC curve plots all potential cut-off points according to their respective True Positive Rates and False Positive Rates. The best cut-off point has an optimally high sensitivity and specificity.

Event Location Models

The accident location models are based on historical accident data for aircraft overruns, veer-offs, and undershoots. The accident location for overruns depends on the type of terrain (paved or unpaved) and if EMAS is installed in the RSA. When EMAS is available, during landing and takeoff overruns, the aircraft will stop at shorter distances, and typical deceleration for the type of aircraft is used to assess the location probability.

Worldwide data on accidents and incidents were used to develop the location models. The model structure is similar to the one used by Eddowes et al. (2001). Based on the accident/incident location data, five sets of complementary cumulative probability distribution (CCPD) models were developed. With CCPDs, the fraction of accidents involving locations exceeding a given distance from the runway end or threshold can be estimated. When the CCPD is multiplied by the frequency of accident occurrence, a complementary cumulative frequency

Table 3. Independent variables used for frequency models.

Variable	LDOR	LDUS	LDVO	TOOR	TOVO
Adjusted Constant	-13.065	-15.378	-13.088	-14.293	-15.612
User Class F		1.693		1.266	
User Class G	1.539	1.288	1.682		2.094
User Class T/C	-0.498	0.017			
Aircraft Class A/B	-1.013	-0.778	-0.770	-1.150	-0.852
Aircraft Class D/E/F	0.935	0.138	-0.252	-2.108	-0.091
Ceiling less than 200 ft	-0.019	0.070		0.792	
Ceiling 200 to 1000 ft	-0.772	-1.144		-0.114	
Ceiling 1000 to 2500 ft	-0.345	-0.721			
Visibility less than 2 SM	2.881	3.096	2.143	1.364	2.042
Visibility from 2 to 4 SM	1.532	1.824		-0.334	0.808
Visibility from 4 to 8 SM	0.200	0.416		0.652	-1.500
Xwind from 5 to 12 kt	-0.913	-0.295	0.653	-0.695	0.102
Xwind from 2 to 5 kt	-1.342	-0.698	-0.091	-1.045	
Xwind more than 12 kt	-0.921	-1.166	2.192	0.219	0.706
Tailwind from 5 to 12 kt			0.066		
Tailwind more than 12 kt	0.786		0.98		
Temp less than 5 C	0.043	0.197	0.558	0.269	0.988
Temp from 5 to 15 C	-0.019	-0.71	-0.453	-0.544	-0.42
Temp more than 25 C	-1.067	-0.463	0.291	0.315	-0.921
Icing Conditions	2.007	2.703	2.67	3.324	
Rain		0.991	-0.126	0.355	-1.541
Snow	0.449	-0.25	0.548	0.721	0.963
Frozen Precipitation			-0.103		
Gusts		0.041	-0.036	0.006	
Fog			1.74		
Thunderstorm	-1.344				
Turboprop			-2.517	0.56	1.522
Foreign OD	0.929	1.354	-0.334		-0.236
Hub/Non-Hub Airport	1.334				-0.692
Log Criticality Factor	9.237	1.629	4.318		1.707
Night Conditions			-1.36		

Where:

	Ref:	
Equipment Class	C	Large jet of MTOW 41k-255k lb (B737, A320 etc.)
Heavy Acft	AB	Heavy jets of MTOW 255k lb+ (B777, A340, etc.)
Commuter Acft	D	Large commuter of MTOW 41k-255k lb (Regional Jets, ERJ-190, CRJ-900, ATR42, etc.)
Medium Acft	E	Medium aircraft of MTOW 12.5k-41k lb (biz jets, Embraer 120, Learjet 35 etc.)
Small Acft	F	Small aircraft of MTOW 12.5k or less (small, Beech-90, Cessna Caravan, etc.)
User Class	Ref: C = Commercial	
User Class F	Cargo	
User Class T/C	Taxi/Commuter	
User Class G	General Aviation	
Foreign OD	Foreign origin/destination (yes/no) - Ref: domestic	
Ceiling (feet)	Ref: Ceiling Height > 2500 ft	
Visibility (Statute Miles)	Ref: Visibility > 8 SM	
Crosswind (knots)	Ref: Crosswind < 2 kt	
Tailwind (knots)	Ref: Tailwind < 5 kt	
Gusts (knots)	Ref: No gusts	
Thunderstorms (yes/no)	Ref: No thunderstorms	
Icing Conditions (yes/no)	Ref: No icing conditions	
Snow (yes/no)	Ref: No snow	
Rain (yes/no)	Ref: No rain	
Fog (yes/no)	Ref: No fog	
Air Temperature (deg C)	Ref: Air temperature above 15 C and below 25C	
Non-Hub Airport (yes/no)	Ref: Hub airport	
Log Criticality Factor	If Log(CF) > 0, available runway distance is smaller than required distance	

Notes:

Ref: indicates the reference category against which the odds ratios should be interpreted.

Non-hub airport: airport having less than 0.05% of annual passenger boardings.

Table 4. Summary statistics for frequency models.

Model	R^2	C
LDOR	0.28	0.87
LDUS	0.14	0.85
LDVO	0.32	0.88
TOOR	0.11	0.78
TOVO	0.14	0.82

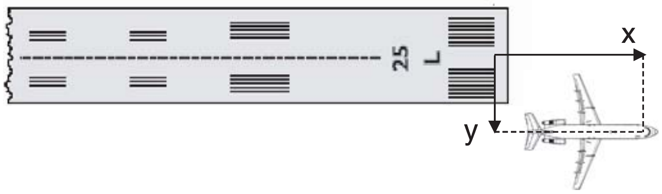


Figure 17. X-Y origin for aircraft overruns.

distribution (CCFD) is obtained. The latter quantifies the overall frequency of accidents involving locations exceeding a given distance from the runway boundaries.

Figures 17 to 19 show the axis locations used to represent each type of incident. The reference location of the aircraft is its nose wheel. For overruns and undershoots, the x-y origin is the centerline at the runway end. For veer-offs, the y-axis origin is the edge of the runway, not necessarily the edge of the paved area when the runway has shoulders.

For the longitudinal distribution, the basic model is:

$$P\{Location > x\} = e^{-ax^n}$$

where

P{Location > x} = the probability the overrun/undershoot distance along the runway centerline beyond the runway end is greater than x;

x = a given location or distance beyond the runway end; and

a, n = regression coefficients.

A typical longitudinal location distribution is presented in Figure 20.

For the transverse distribution, the same model structure was selected. However, given the accident's transverse location for aircraft overruns and undershoots, in general, is not reported if the wreckage location is within the extended runway lateral limits, it was necessary to use weight factors to reduce model bias, particularly for modeling the tail of the probability distribution. The model can be represented by the following equation:

$$P\{Location > y\} = e^{-by^m}$$

where

P{Location>y} = the probability the overrun/undershoot distance from the runway border (veer-offs) or centerline (overruns and undershoots) is greater than y;

y = a given location or distance from the extended runway centerline or runway border; and

b, m = regression coefficients.

A typical transverse location distribution is presented in Figure 21, and the model parameters are presented in Table 5.

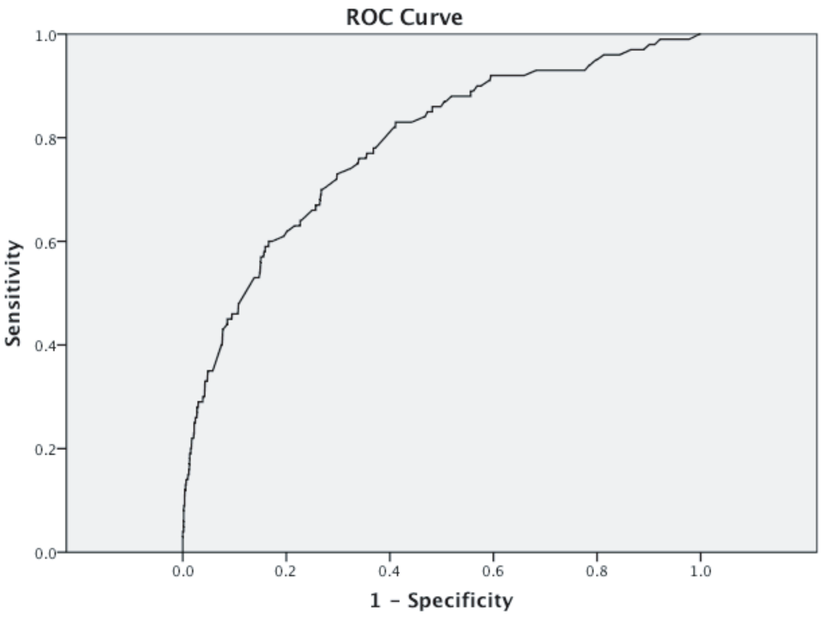


Figure 16. ROC curve for LDOR frequency model.

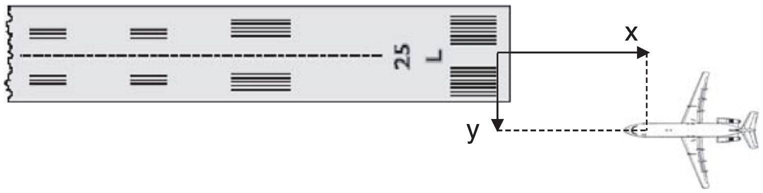


Figure 18. X-Y origin for aircraft undershoots.

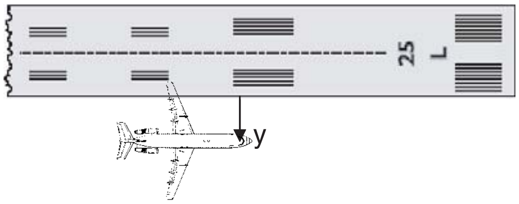


Figure 19. Y origin for aircraft veer-offs.

For Table 5, the following are the parameters represented:

d = any given distance of interest;
x = the longitudinal distance from the runway end;
P{d>x} = the probability the wreckage location exceeds distance x from the runway end;
y = the transverse distance from the extended runway centerline (overruns and undershoots) or from the runway border (veer-offs); and
P{d>y} = the probability the wreckage location exceeds distance y from the extended runway centerline (overruns and undershoots) or from the runway border (veer-offs).

Figures 22–29 illustrate the models presented in Table 5.

EMAS Deceleration Model

The analysis tool developed in this research includes the capability to evaluate RSAs with EMAS beds. The details of the development are presented in Appendix E.

The same location models for overruns are used when EMAS beds are available in the RSA. However, the bed length is adjusted for each type of aircraft according to MTOW and the EMAS bed length, according to the following steps:

1. The maximum runway exit speed to hold the aircraft within the EMAS bed is calculated according to the model presented below. The adjusted R^2 for this model is 89%.

$$v = 3.0057 - 6.8329\log(W) + 31.1482\log(S)$$

where:
v = the maximum exit speed in m/s;
W = the maximum takeoff weight of the aircraft in kg; and
S = the EMAS bed length in meters.

2. The maximum runway exit speed estimated using the previous regression equation, along with the EMAS bed length (S_{EMAS}), is input in the following equation to calculate the deceleration of the aircraft in the EMAS bed.

$$a_{EMAS} = \frac{v^2}{2S}$$

3. The runway length factor is then estimated as follows:

$$RLF = \frac{a_{EMAS}}{a^{RSA}}$$

4. The runway length factor is then estimated as follows:

$$RLF = \frac{a_{EMAS}}{a^{RSA}}$$

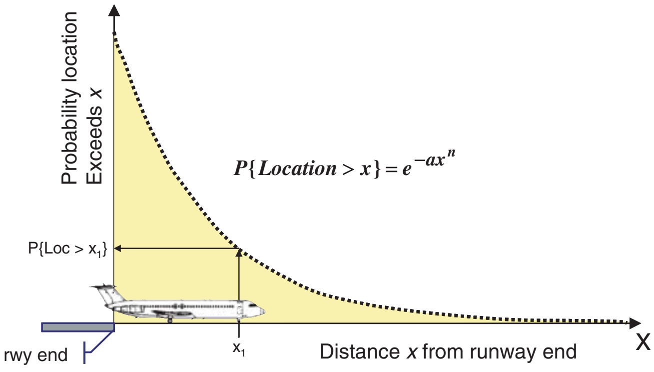


Figure 20. Typical model for aircraft overruns.

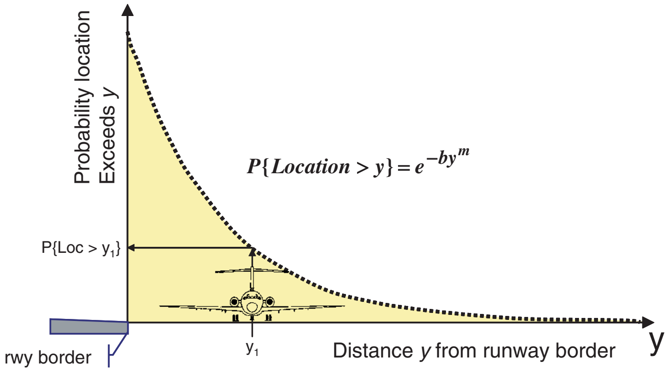


Figure 21. Typical model for aircraft veer-offs.

Table 5. Summary of location models.

Type of Accident	Type of Data	Model	R^2	# of Points
LDOR	X	$P\{d > x\} = e^{-0.00321x^{0.984941}}$	99.8%	305
	Y	$P\{d > y\} = e^{-0.20983\,y^{0.4862}}$	93.9%	225
LDUS	X	$P\{d > x\} = e^{-0.01481x^{0.751499}}$	98.7%	83
	Y	$P\{d > y\} = e^{-0.02159y^{0.773896}}$	98.6%	86
LDVO	Y	$P\{d > y\} = e^{-0.02568y^{0.803946}}$	99.5%	126
TOOR	X	$P\{d > x\} = e^{-0.00109x^{1.06764}}$	99.2%	89
	Y	$P\{d > y\} = e^{-0.04282y0.659566}$	98.7%	90
TOVO	Y	$P\{d > y\} = e^{-0.01639\,y^{0.863461}}$	94.2%	39

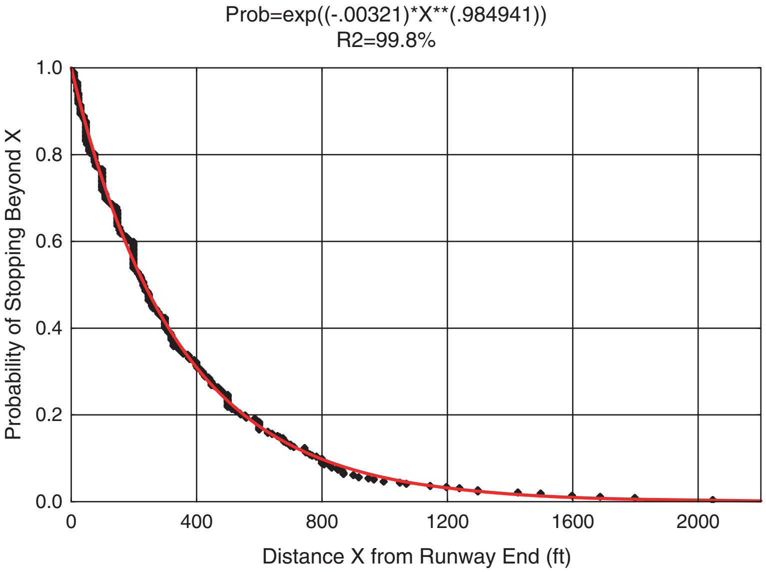


Figure 22. Longitudinal location model for landing overruns.

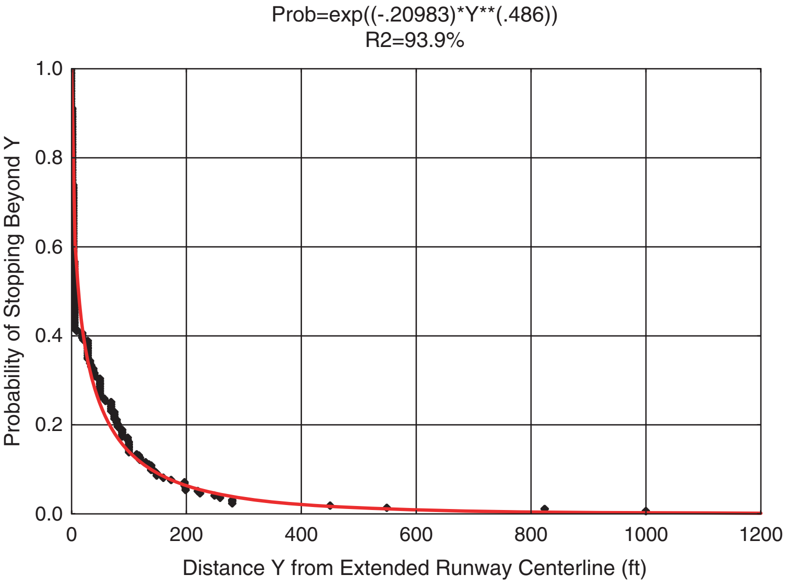


Figure 23. Transverse location model for landing overruns.

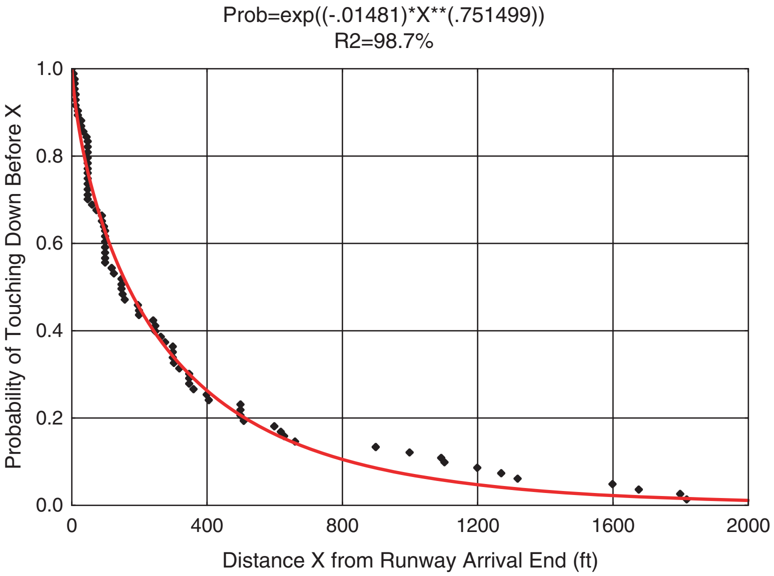


Figure 24. Longitudinal location model for landing undershoots.

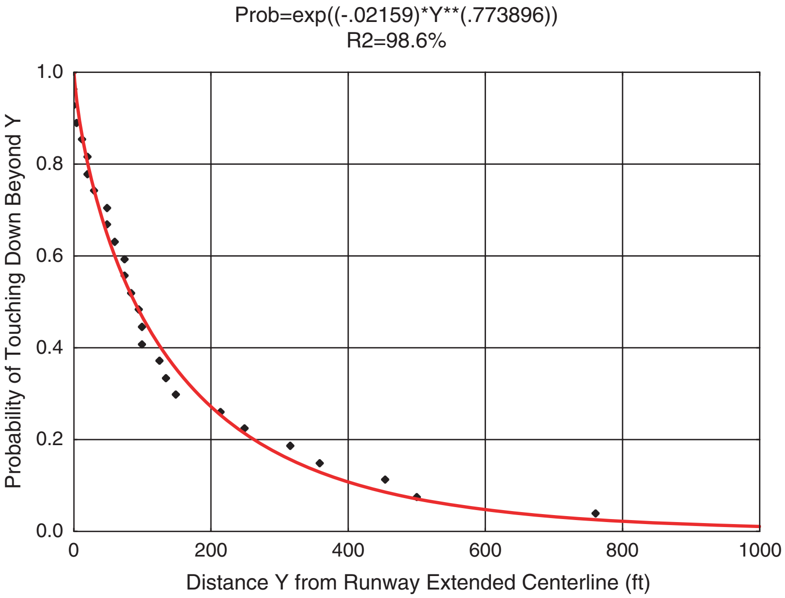


Figure 25. Transverse location model for landing undershoots.

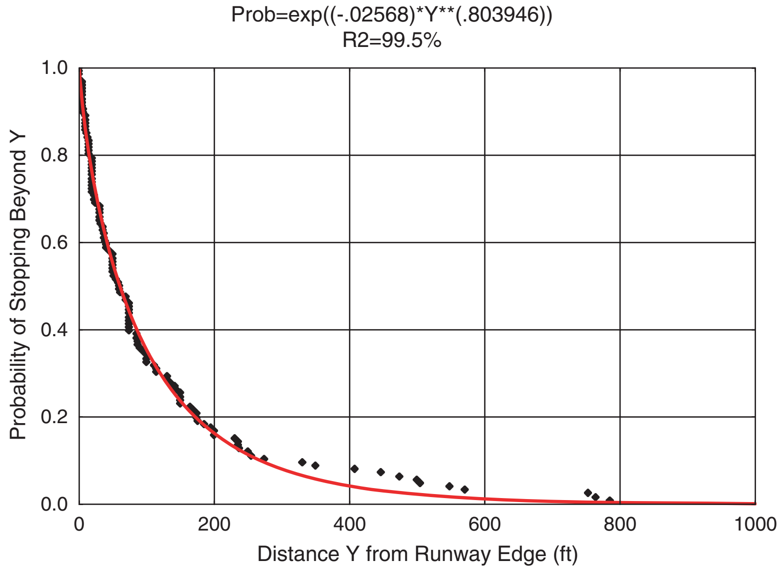


Figure 26. Lateral location model for landing veer-offs.

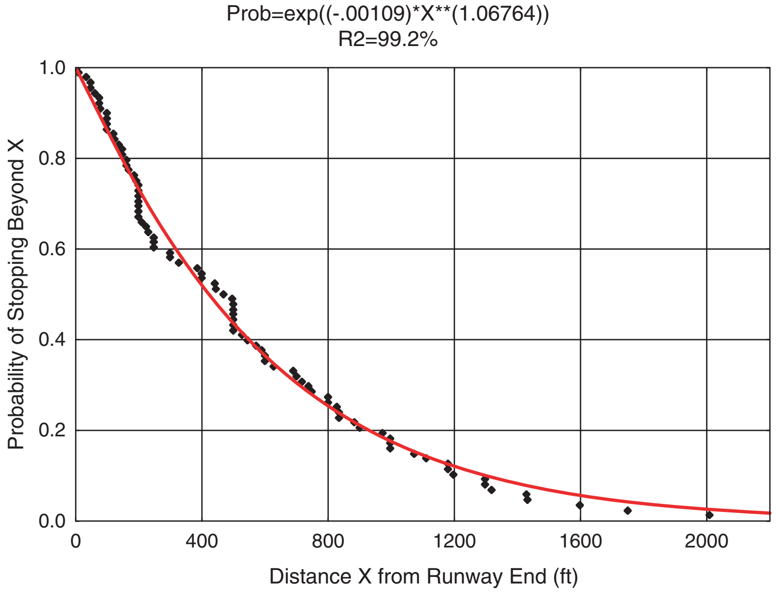


Figure 27. Longitudinal location model for takeoff overruns.

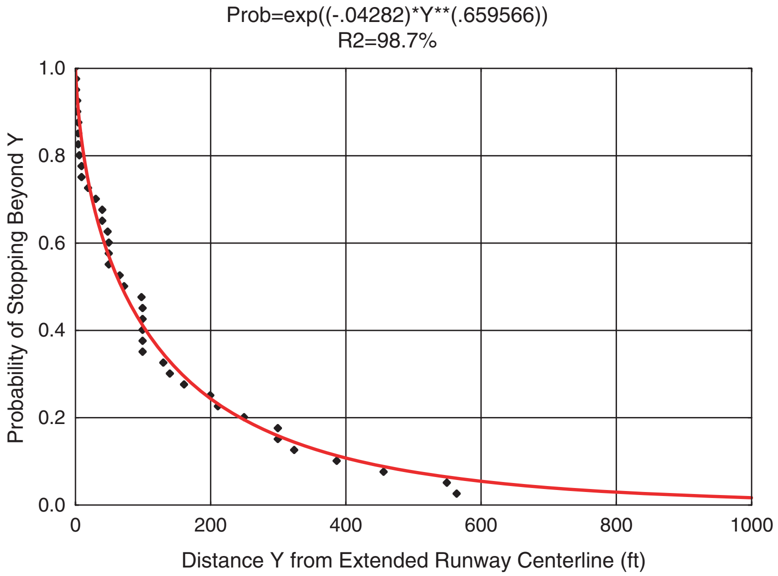


Figure 28. Transverse location model for takeoff overruns.

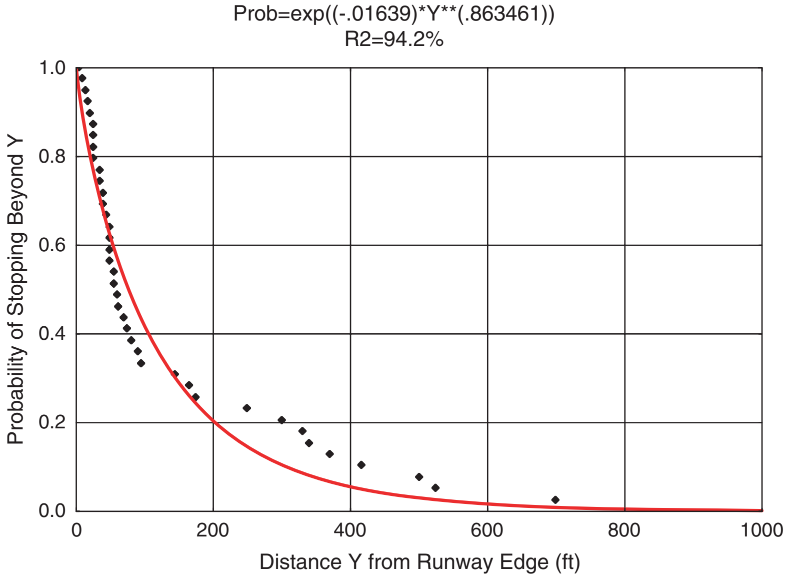


Figure 29. Lateral location model for takeoff veer-offs.

5. The equivalent length of conventional RSA is then calculated:

$$S_{RSA} = \frac{a_{EMAS}}{a_{RSA}} S_{EMAS} = RLF \quad S_{EMAS}$$

With the equivalent RSA length, the RSA is adjusted for each type of aircraft and is input into the standard location models presented in the previous section.

Accuracy of Models

There were five multivariate logistic frequency models, eight exponential location models, and one log linear deceleration model developed in this study. The accuracy of these models is considered excellent, with C-values ranging from 0.78 to 0.88 for the frequency models. The location models had R^2 values ranging from 93.9% to 99.8%, and the deceleration model for EMAS presented an adjusted R^2 of 89%.

CHAPTER 4

Consequence Approach

Risk is the likelihood of the worst credible consequence for a hazard. Many overruns, veer-offs, and undershoots have resulted in aircraft hull loss and multiple fatalities, and therefore, the worst credible level of consequences may be assumed to be catastrophic, according to the severity classification defined by the FAA and presented in Appendix F.

In some situations, a pilot may lose control of the aircraft, resulting in the destruction of the equipment with possible fatalities, even when the aircraft accident takes place inside the RSA or the runway; however, in the majority of accidents, the RSA will offer some protection to mitigate consequences. Consequences will depend on the type of structures and the level of energy during the aircraft collision. Possible obstacles may include buildings, ditches, highways, fences, pronounced drops in terrain, unprepared rough terrain, trees, and even navigational aids (NAVAID) structures, like approach lighting system (ALS) towers and Localizer antennas, particularly if mounted on sturdy structures.

The energy of the aircraft during the collision is related to its speed when it strikes the obstacle, i.e., the greater speeds are expected to result in more severe consequences. Also, the consequences will depend on the type of obstacle. An aircraft striking a brick building at 40 mph may be destroyed whereas if the obstacle is a perimeter fence less severe consequences are expected to occur.

The variables assumed to have an impact on consequences resulting from overruns, veer-offs, and undershoots are:

- Obstacle type, size, and location;
- Aircraft size (wingspan) and speed; and
- Number of obstacles and location distribution (shadowing).

The basic approach is that presented in *ACRP Report 3,* as summarized in the ensuing sections. Additional details on how it was incorporated in the analysis are provided. The approach described in *ACRP Report 3* was intended to model accident and incident consequences so that they could be combined with the probability of aircraft overruns and undershoots for an assessment of risk. The approach is rational because it is based on physical and mathematical principles.

Modeling Approach for Risk

The basic idea was to assess the effect of different obstacles at various locations in the vicinity or inside the RSA. The approach integrates the probability distributions defined by the location models with the location, size, and characteristics of existing obstacles in the RSA and its vicinity.

The implementation of the approach required some simplifying assumptions so that it could be integrated with the frequency and location models. The following are the assumptions used:

1. Aircraft overrunning, undershooting, or veering off the runway will strike the obstacle in paths parallel to the runway direction. This assumption is necessary to define the area of influence of the obstacle.
2. Four categories of obstacles are defined as functions of the maximum speed that an aircraft may collide with an obstacle, with small chances of causing hull loss and injuries to its occupants:
   a. Category 1: Maximum speed is nil (e.g., cliff at the RSA border, concrete wall).
   b. Category 2: Maximum speed is 5 knots (e.g., brick buildings).
   c. Category 3: Maximum speed is 20 knots (e.g., ditches, fences).
   d. Category 4: Maximum speed is 40 knots (e.g., frangible structures, ALS).
3. Severe damage and injuries are expected only if the aircraft collides within the central third of the wingspan and with a speed higher than the maximum for that obstacle category. The concept is explained in the ensuing section.

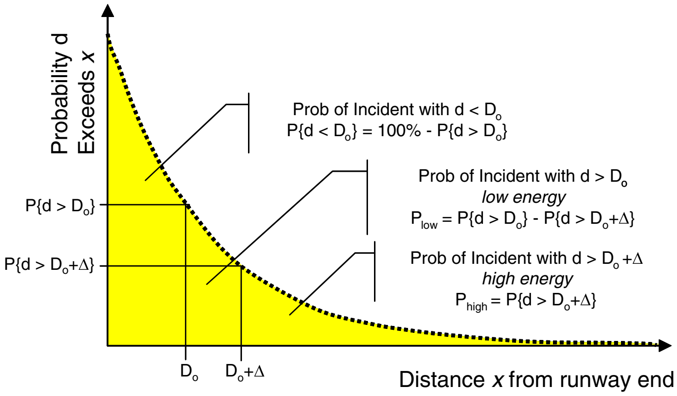
4. The lateral distribution is random and does not depend on the presence of obstacles. This is a conservative assumption because there are events when the pilot will avoid the obstacles if he has some directional control of the aircraft. The accident/incident database contains a number of cases when the pilot avoided ILS and ALS structures in the RSA.

The main purpose of modeling consequences of aircraft accidents is to obtain an assessment of risk based on the likelihood for the worst credible consequence. It was not deemed necessary to develop a consequence model for each type of accident, as was done to model frequency and location. The approach can be used to address any of the five types of incidents included in the analysis.

The basic idea is to use the location models to estimate the incident occurrences for which the aircraft will have high energy when striking an obstacle, thus resulting in serious consequences. It should be noted that neither of the models used in the approach provides an estimate of the aircraft speed; however, using the location model and the average aircraft deceleration during a runway excursion, it is possible to infer the probability that the speed is above a certain level when reaching the obstacle. Figure 30 is used to illustrate the case for overruns and help understand the principle. This approach was introduced in *ACRP Report 3.*

The x-axis represents the longitudinal location of the wreckage relative to the runway departure end. The y-axis is the probability that the wreckage location exceeds a given distance "x."

In this example, an obstacle is located at a distance D_0 from the departure end, and the example scenario being analyzed is an aircraft landing overrun incident. Figure 30 shows an exponential decay model developed for the specific accident scenario, in this case, landing overruns.



D_o is distance to Obstacle, d is distance the aircraft came to stop

Area (yellow) between D_o and $D_o+\Delta$ represents % occurrences at low speed (energy) when hitting obstacle (low consequences)

Figure 30. Approach to model consequences of overrun accidents.

There are three distinct regions in this plot. The first region (green) represents overruns that the aircraft departed the runway but the exit speed was relatively low and the aircraft came to a stop before reaching the existing obstacle. The consequences for such incidents associated with that specific obstacle are expected to be none if the x-location is smaller than D_0.

The rest of the curve represents events that the aircraft exited the runway at speeds high enough for the wreckage path to extend beyond the obstacle location. However, a portion of these accidents will have relatively higher energy and should result in more severe consequences, while for some cases the aircraft will be relatively slow when hitting the obstacle so that catastrophic consequences are less likely to happen. Using the location model, if x-location is between D_0 and $D_0+\Delta$, it may be assumed that no major consequences are expected if the obstacle is present.

The value of Δ is estimated based on aircraft deceleration over different types of terrain (paved, unpaved, or EMAS) and crashworthiness speed criteria for aircraft. It should be noted that Δ depends on the type of terrain, type and size of aircraft, and type of obstacle. Frangible objects in the RSA are less prone to causing severe consequences. It also should be noted that lighter aircraft may stop faster and the landing gear configuration also may have an effect on the aircraft deceleration in soft terrain, but these factors are not accounted for in this approach.

Using this approach, it is possible to assign three scenarios: the probability that the aircraft will not hit the obstacle (green region—resulting in none or minor consequences); the probability that the aircraft will hit the obstacle with low speed and energy (yellow region—with substantial damage to aircraft but minor injuries); and the probability that the aircraft will hit the obstacle with high energy (orange region—with substantial damage and injuries).

For those events with low energy when impacting the obstacle, it is possible to assume that, if no obstacle was present, the aircraft would stop within a distance Δ from the location of the obstacle. The problem is then to evaluate the rate of these accidents having low speeds at the obstacle location, and this is possible based on the same location model. This probability can be estimated by excluding the cases when the speed is high and the final wreckage location is significantly beyond the obstacle location.

To complement the approach it is necessary to combine the longitudinal and transverse location distribution with the presence, type, and dimensions of existing obstacles. The basic approach is represented in Figure 31 for a single and simple obstacle.

Laterally, if part of the obstacle is within the yellow zone, as shown in Figure 32a, medium consequences are expected; however, if any part of the obstacle is within the orange zone, as

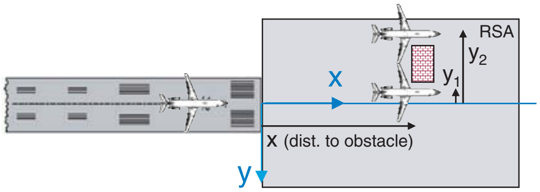


Figure 31. Modeling consequences.

shown in Figure 32b, and the speed is high, severe consequences are expected. If the obstacle is off the orange and yellow zones, no consequences related to that obstacle are expected.

In Figure 33, Obstacle 1 is located at a distance x_1, y_1 from the threshold and has dimensions $W_1 \times L_1$. When evaluating the possibility of severe consequences, it is possible to assume this will be the case if the aircraft fuselage or a section of the wing close to the fuselage strikes the obstacle at high speed. Thus, it is possible to assume the accident will have severe consequences if the y location is between y_c and y_f, as shown in the figure. Based on the location models for lateral distance, the probability the aircraft axis is within this range can be calculated as follows:

$$P_{sc} = \frac{e^{-by_c^m} - e^{-by_f^m}}{2}$$

where

P_{sc} = the probability of high consequences;
b, m = regression coefficients for the y-location model;
y_c = the critical aircraft location, relative to the obstacle, closest to the extended runway axis; and
y_f = the critical aircraft location, relative to the obstacle, farther from the extended runway axis.

Combining this approach with the longitudinal distribution approach and the possibility of multiple obstacles, the risk for accidents with severe consequences can be estimated using the following model:

$$P_{sc} = \sum_{i=1}^{N} \frac{\left(e^{-by_{ci}^m} - e^{-by_{fi}^m}\right)}{2} e^{-a(x_i+\Delta_i)^n}$$

where

N = the number of existing obstacles;
a, n = regression coefficients for the x-model; and
Δ_i = the location parameter for obstacle *i*.

Multiple obstacles may be evaluated using the same principle. A shadowing effect also is taken into account when part of obstacle *i+1* is behind obstacle *i*. Because it is assumed that aircraft will travel in paths parallel to the runway centerline, any portion of the obstacle located behind at a distance greater than Δ_i is disregarded from the analysis.

A quantitative assessment of risk likelihood will be obtained as a function of operating conditions (aircraft, weather, runway distances available) and RSA dimensions and conditions (presence of EMAS, presence, location, size, and type of obstacles, etc.). For the analysis, the user may select the alternative to evaluate the probability that an aircraft will go off the RSA or that severe consequences will take place.

Implementation of Approach

The implementation of the proposed approach is best explained using one example. Figure 34 depicts an area adjacent to the runway end with two obstacles. The area isn't necessarily the official airport RSA but any available area that can be

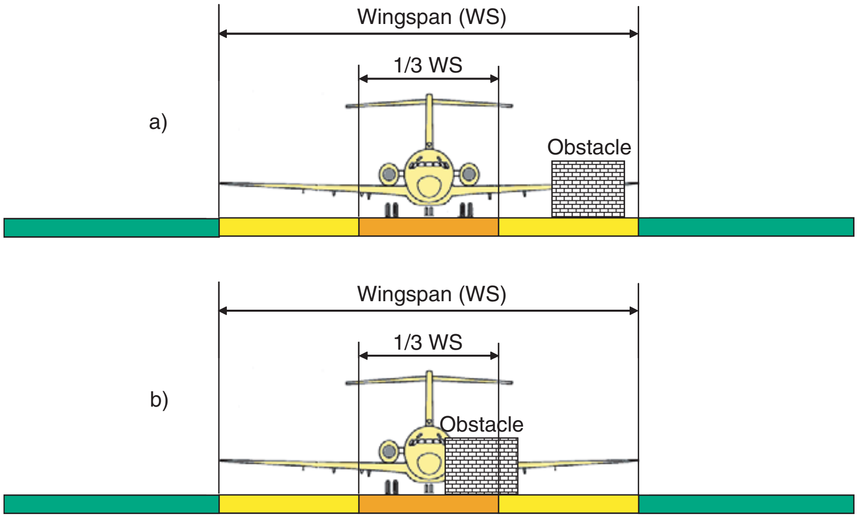


Figure 32. Lateral location versus consequences.

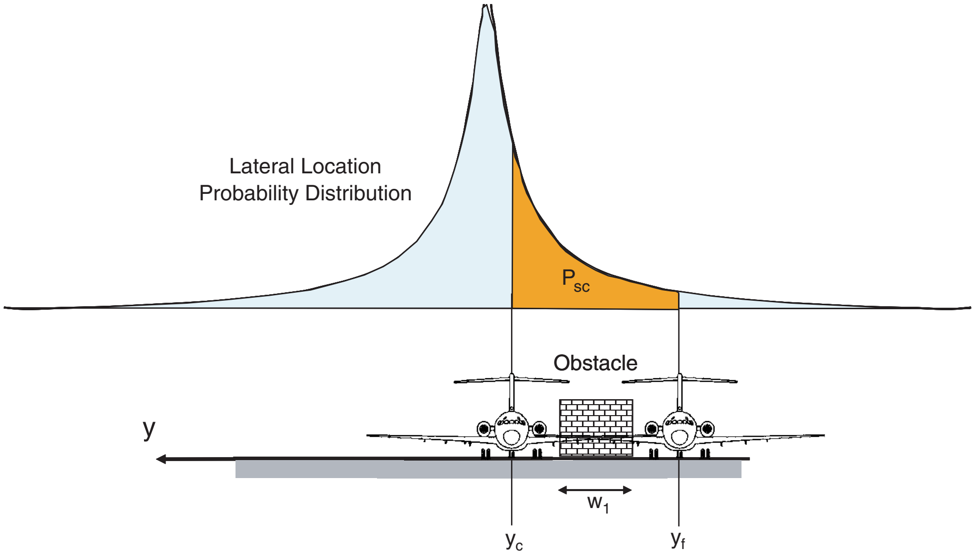


Figure 33. Modeling likelihood of striking an obstacle.

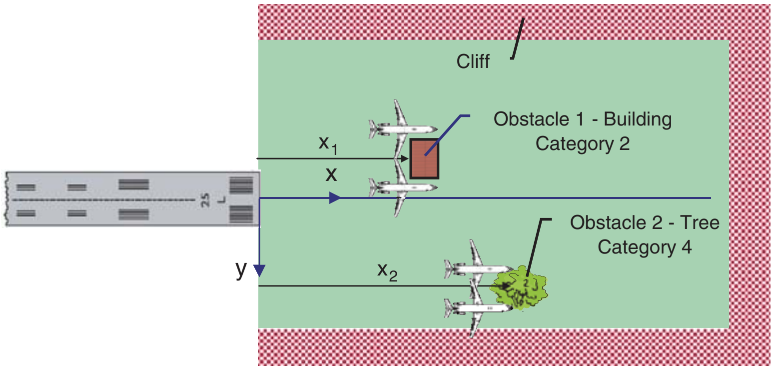


Figure 34. RSA scenario with obstacles.

used by an aircraft overrunning the runway end. The example shows the safety area surrounded by a cliff limiting its boundaries. Obstacle 1 is not frangible and is classified as a Category 2 obstacle (e.g., building), maximum collision speed of 5 knots, located at distance x_1 from the runway end. For this obstacle, the maximum speed without severe consequences is estimated to be 5 knots. A second obstacle is a small size tree classified as Category 4, maximum speed of 40 knots, and located at distance x_2 from the runway end. The remaining safety area is defined by the cliff surrounding the RSA and such boundary is classified as Category 1, maximum speed of 0 knots.

The typical aircraft deceleration in unpaved surfaces is 0.22*g*, where *g* is the acceleration due to gravity (32.2 ft/s^2). Using the relationship between acceleration, velocity, and distance, Δ can be calculated as shown in Table 6.

The Δ values presented will be used to reduce the safety area so that only the effective portion where the aircraft may stop without severe damage is considered in the analysis. To perform the analysis, the frequency and location models are combined in a manner similar to that for the analysis without obstacles; however, the safety area is transformed to account for the presence of the obstacles, as shown in Figure 35.

The area used to calculate the probability as a function of the aircraft stopping location is shown in green. It should be noted that the safety area in the shadow of Obstacle 1 is much larger than that for Obstacle 2 for three reasons:

1. Obstacle 1 is wider than Obstacle 2.
2. The maximum speed for striking Obstacle 1 (Category 2) is lower than that for Obstacle 2 (Category 4).

Table 6. Obstacle categories.

Obstacle Category	Max Speed (knots)	Δ (ft) (See Figure 30)
1	0	0
2	5	20
3	20	80
4	40	320

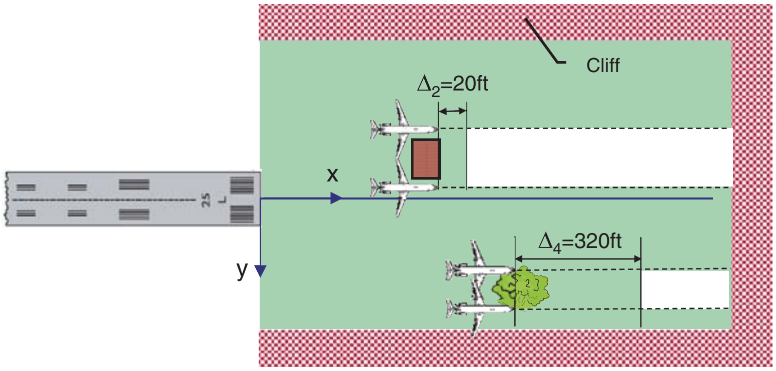


Figure 35. Effective RSA for analysis.

3. Obstacle 1 is located closer to the runway end, and aircraft speed is higher at this point than that at the location of Obstacle 2.

The analysis will provide the probability that the aircraft will overrun the runway and the incident will have severe consequences, thus providing an estimate of risk.

Additional Simplifications

Additional simplifications were necessary to implement the approach. One such simplification was the use of maximum aircraft design group (ADG) wingspan instead of the actual aircraft wingspan. Without this simplification, a different safety area configuration would be required for each aircraft, greatly increasing the time to do the analysis. Using the ADG wingspan reduced the process to six steps, one for each ADG.

A second simplification was also necessary to reduce the time to perform the analysis. Although the obstacles are categorized according to the maximum speed to cause severe consequences, each type of aircraft will have a different maximum speed. However, it would be very time-consuming to apply these differences in the calculations. Therefore, the maximum speed in the proposed approach depends only on the type of obstacle rather than the interaction between the obstacle and the aircraft.

CHAPTER 5

Analysis Software

Overview

One of the main project goals was to develop an analysis tool to incorporate the approach and the models developed in this study. The software is called Runway Safety Area Risk Analysis (RSARA). The program and the accompanying user's guide are available on the accompany CD with this report. In addition, the user's guide is available in Appendix I.

RSARA is a Windows-based system developed to facilitate characterizing analysis conditions and entering required data. The software main screen is shown in Figure 36.

Software Capabilities

RSARA was tailored to help airport stakeholders evaluate different RSA alternatives. The software has the following capabilities:

- Performs full risk assessment for multiple runways.
- Enters multiple obstacles to each RSA scenario.
- Characterizes different categories for obstacles.
- Defines and analyzes non-standard (non-rectangular) RSA geometry.
- Analyzes with standard and non-standard EMAS beds.
- Internally integrates operations and weather data from separate files.
- Automatically converts operations and weather data into parameters used by probability models.
- Includes database of aircraft with capability to add new or edit existing aircraft.
- Automatically computes runway criticality factor for each operation.
- Automatically corrects for required distances (landing and takeoff) based on elevation, temperature, wind, and runway surface condition.
- Generates analysis reports from software with summaries of following parameters:
    - Average risk for each type of incident by runway, by RSA section, and total for the airport.
    - The expected number of years to occur an accident for a user-defined annual traffic volume and growth rate.
    - Percentage of operations subject to a probability higher than a user-defined target level of safety (TLS).
    - Graphical outputs with the distribution of risk for each RSA and each type of event.

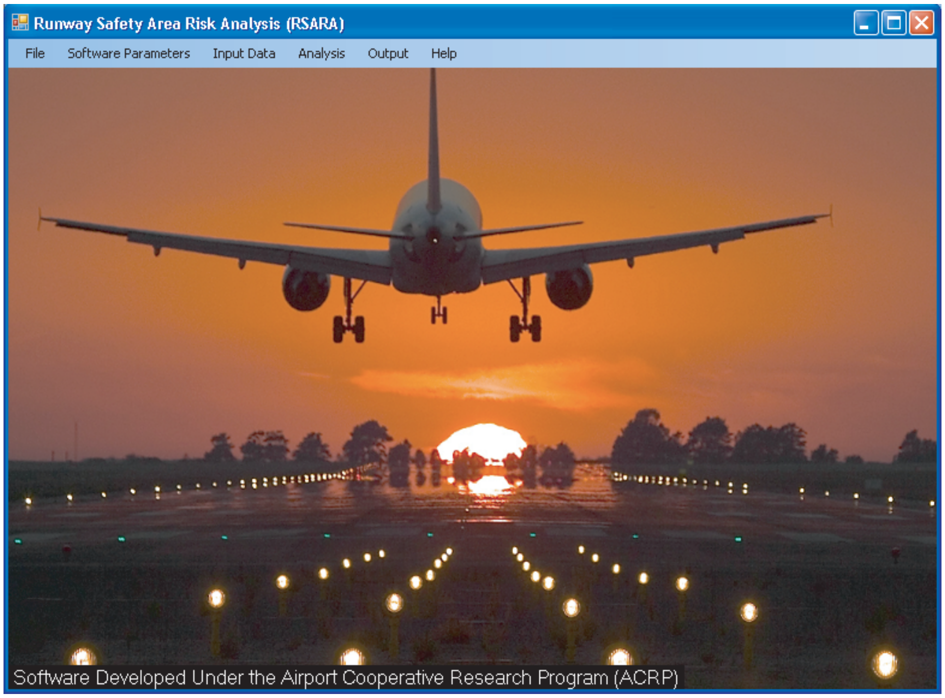
Input Data

Input data required to run the analysis include the following information:

- Sample of historical operations data (date and time, aircraft model, runway used, type of operation, etc.).
- Sample of historical weather data for the airport covering the period of sample of historical operations (wind, temperature, precipitation, visibility, etc.).
- Characteristics of runways (elevation, direction, declared distances).
- Characteristics of RSAs (geometry, type of surface, presence of EMAS, location, size and category of obstacles).
- General information (airport annual traffic volume, annual growth rate).

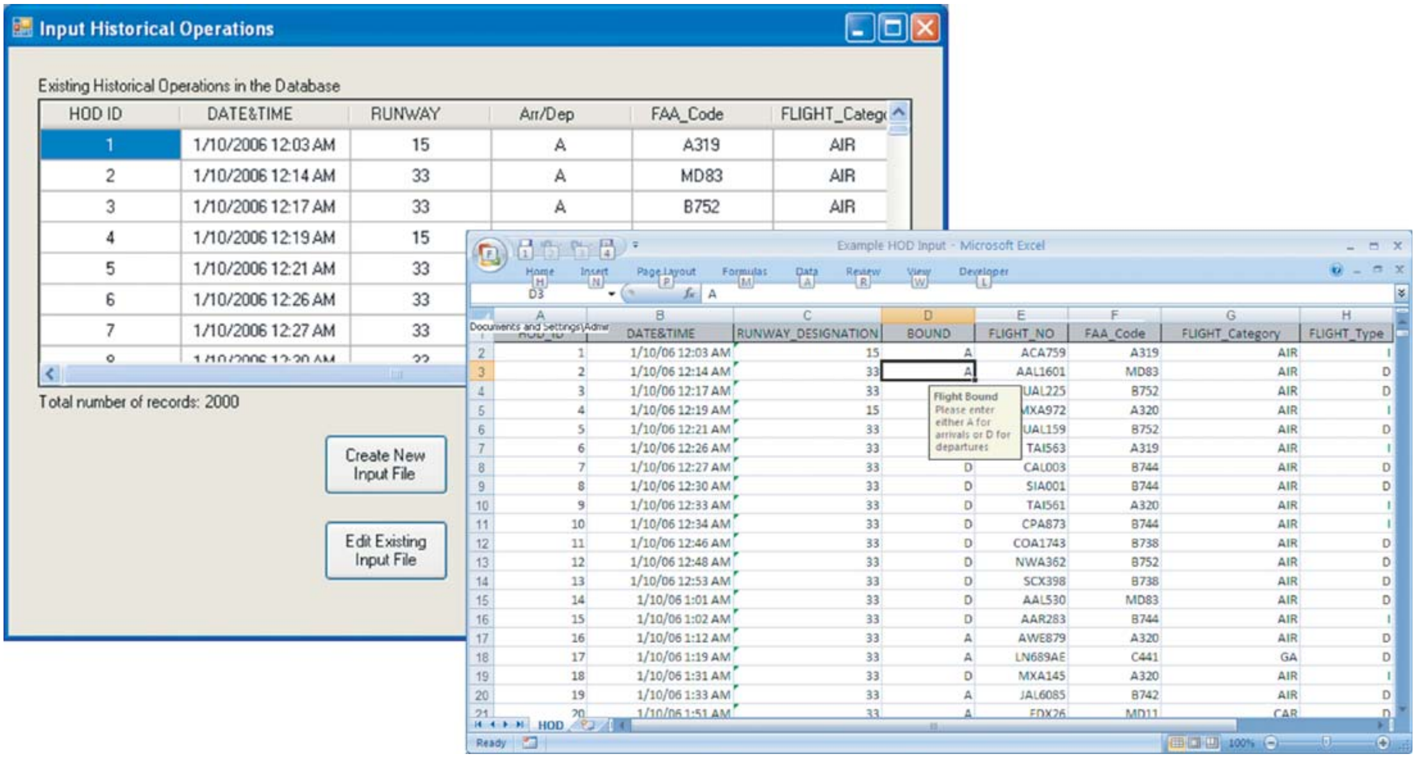
Much of the input information is arranged in table format. Operations and weather data are entered using Microsoft Excel templates with automatic checks for value ranges and data format. Figure 37 shows the program screen and template to input operations data.

The template for drawing the RSA area for overrun and undershoot was created using Microsoft Excel. It consists of a canvas area formed by a matrix of cells. Each cell corresponds to a coordinate that is referenced to the center of the runway. The default coordinate grid is set at 10 × 10 ft. If the RSA is larger than the available canvas, a new scale can be set at the top of the



Software Developed Under the Airport Cooperative Research Program (ACRP)

Figure 36. RSARA—main program screen.



Existing Historical Operations in the Database

HOD ID	DATE&TIME	RUNWAY	Arr/Dep	FAA_Code	FLIGHT_Categ
1	1/10/2006 12:03 AM	15	A	A319	AIR
2	1/10/2006 12:14 AM	33	A	MD83	AIR
3	1/10/2006 12:17 AM	33	A	B752	AIR
4	1/10/2006 12:19 AM	15			
5	1/10/2006 12:21 AM	33			
6	1/10/2006 12:26 AM	33			
7	1/10/2006 12:27 AM	33			

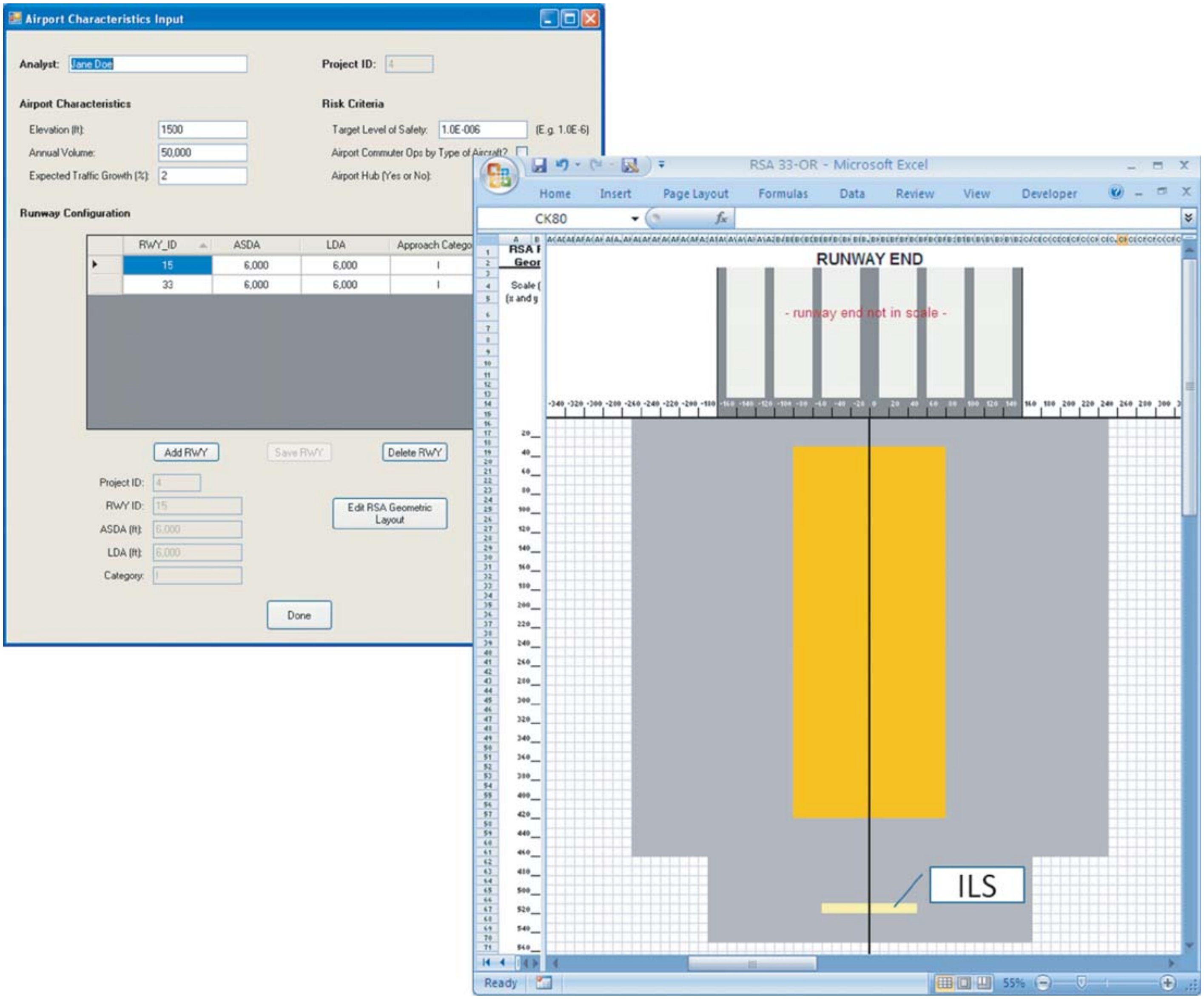
Total number of records: 2000

Documents and Settings\Admi

	A	B	C	D	E	F	G	H
1		DATE&TIME	RUNWAY_DESIGNATION	BOUND	FLIGHT_NO	FAA_Code	FLIGHT_Category	FLIGHT_Type
2	1	1/10/06 12:03 AM	15	A	ACA759	A319	AIR	I
3	2	1/10/06 12:14 AM	33	A	AAL1601	MD83	AIR	D
4	3	1/10/06 12:17 AM	33		UAL225	B752	AIR	D
5	4	1/10/06 12:19 AM	15		MXA972	A320	AIR	I
6	5	1/10/06 12:21 AM	33		UAL159	B752	AIR	D
7	6	1/10/06 12:26 AM	33		TAI563	A319	AIR	I
8	7	1/10/06 12:27 AM	33	D	CAL003	B744	AIR	D
9	8	1/10/06 12:30 AM	33	D	SIA001	B744	AIR	D
10	9	1/10/06 12:33 AM	33	D	TAI561	A320	AIR	I
11	10	1/10/06 12:34 AM	33	D	CPA873	B744	AIR	I
12	11	1/10/06 12:46 AM	33	D	COA1743	B738	AIR	D
13	12	1/10/06 12:48 AM	33	D	NWA362	B752	AIR	D
14	13	1/10/06 12:53 AM	33	D	SCX398	B738	AIR	D
15	14	1/10/06 1:01 AM	33	D	AAL530	MD83	AIR	D
16	15	1/10/06 1:02 AM	33	D	AAR283	B744	AIR	I
17	16	1/10/06 1:12 AM	33	A	AWE879	A320	AIR	D
18	17	1/10/06 1:19 AM	33	A	LN689AE	C441	GA	D
19	18	1/10/06 1:31 AM	33	D	MXA145	A320	AIR	I
20	19	1/10/06 1:33 AM	33	A	JAL6085	B742	AIR	D
21	20	1/10/06 1:51 AM	33	A	FDX26	MD11	CAR	D

Flight Bound
Please enter either A for arrivals or D for departures

Figure 37. Example of input screen and template.



Analyst: Jane Doe

Project ID: 4

Airport Characteristics

Elevation (ft): 1500

Annual Volume: 50,000

Expected Traffic Growth (%): 2

Risk Criteria

Target Level of Safety: 1.0E-006 (E.g. 1.0E-6)

Airport Commuter Ops by Type of Aircraft? ☐

Airport Hub (Yes or No):

Runway Configuration

RWY_ID	ASDA	LDA	Approach Catego
15	6,000	6,000	I
33	6,000	6,000	I

Add RWY | Save RWY | Delete RWY

Project ID: 4

RWY ID: 15

ASDA (ft): 6,000

LDA (ft): 6,000

Category: I

Edit RSA Geometric Layout

Done

Figure 38. RSA characterization using Microsoft Excel.

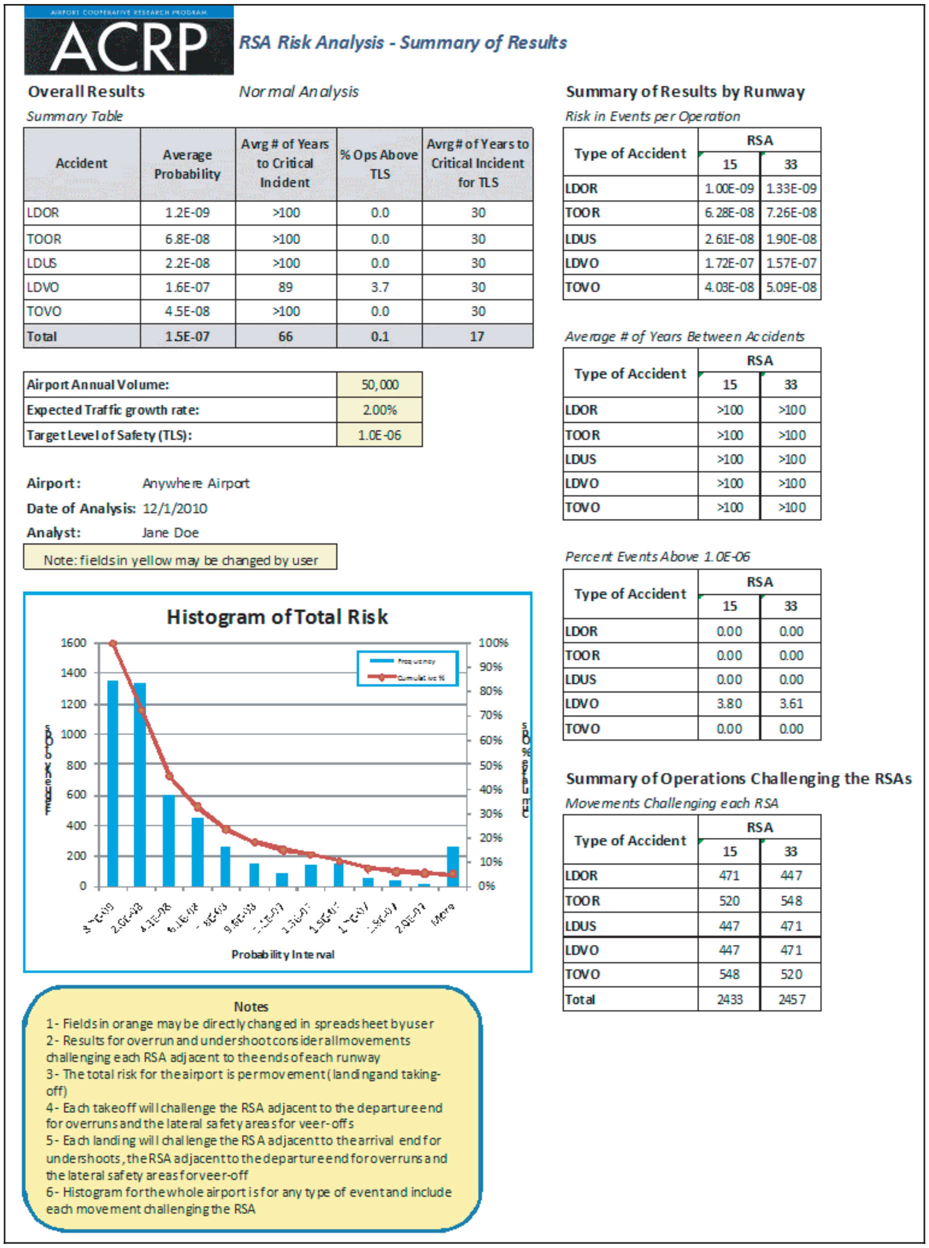
canvas template. The user assigns a letter or number to each cell to define the type of surface or category of obstacle. After entering a code, the color of the cell will change according to the surface type or obstacle entered to facilitate the visualization of the drawing. Tables with the codes describing the surface types and obstacles available are provided in the template. Figure 38 shows an example of RSA defined with the tool.

Output and Interpretation

When the analyses are completed, the user may see the results using the Output option of the main menu. There are two types of results: runways or the consolidated results for the whole airport. Within each of these options, the user can view the results for risk of events taking place outside the RSA or view the analysis output for the risk of accidents.

Each folder contains the risk estimates for each type of incident and individual operation and the total risk during landings and takeoffs. The results for each individual runway are provided in separate output Excel files. The summary table provides the average risk for each type of accident and expected number of years for an accident to occur. The accumulated risk distribution is provided in graphical form for each section of the RSA.

The results for the entire airport are provided in one output Excel file. The user must create the output files for each runway prior to creating the output file for the airport. An example presenting the summary of results for the whole airport is shown in Figure 39. The main table contains a summary of average risk levels for each type of incident and for all incidents. Risk levels are shown in terms of accident rates per number of operations and expected number of years to occur one accident. Additional



AIRPORT COOPERATIVE RESEARCH PROGRAM ACRP

RSA Risk Analysis - Summary of Results

Overall Results *Normal Analysis*

Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.2E-09	>100	0.0	30
TOOR	6.8E-08	>100	0.0	30
LDUS	2.2E-08	>100	0.0	30
LDVO	1.6E-07	89	3.7	30
TOVO	4.5E-08	>100	0.0	30
Total	**1.5E-07**	**66**	**0.1**	**17**

Airport Annual Volume:	50,000
Expected Traffic growth rate:	2.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Anywhere Airport
Date of Analysis: 12/1/2010
Analyst: Jane Doe

Note: fields in yellow may be changed by user

Histogram of Total Risk

Notes

1- Fields in orange may be directly changed in spreadsheet by user
2- Results for overrun and undershoot consider all movements challenging each RSA adjacent to the ends of each runway
3- The total risk for the airport is per movement (landing and taking-off)
4- Each takeoff will challenge the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-offs
5- Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6- Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA	
	15	33
LDOR	1.00E-09	1.33E-09
TOOR	6.28E-08	7.26E-08
LDUS	2.61E-08	1.90E-08
LDVO	1.72E-07	1.57E-07
TOVO	4.03E-08	5.09E-08

Average # of Years Between Accidents

Type of Accident	RSA	
	15	33
LDOR	>100	>100
TOOR	>100	>100
LDUS	>100	>100
LDVO	>100	>100
TOVO	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA	
	15	33
LDOR	0.00	0.00
TOOR	0.00	0.00
LDUS	0.00	0.00
LDVO	3.80	3.61
TOVO	0.00	0.00

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA	
	15	33
LDOR	471	447
TOOR	520	548
LDUS	447	471
LDVO	447	471
TOVO	548	520
Total	2433	2457

Figure 39. Example output summary.

tables are presented showing the average risk for each RSA section, the percentage of movements with higher risk, and the number of operations challenging each RSA section.

The first table contains three user-defined fields: the airport annual traffic volume, the expected annual traffic growth rate, and the TLS. These values reflect the options entered during the analysis input phase and may be modified by the user directly in the output spreadsheet. When these parameters are changed, the average number of years between incidents will change to reflect the new traffic volume estimated for future years. If the TLS is modified, the percentage of movements above the TLS will change automatically to reflect the new TLS value.

Software Field Test

Appendix G provides details of the plan to field test RSARA. The plan involved testing by eight volunteers from FAA staff, airport operators, university professors, industry representatives, and consultants. The volunteers received the installation software with the user's guide to perform analysis and recommend changes.

A questionnaire was prepared to gather comments from the volunteers, and their notes were used to improve the beta version of the software. During the trial period, the research team provided technical support by answering questions, solving installation problems, and fixing bugs.

CHAPTER 6

Model Validation

The improved risk models were validated by comparing the results of the analysis for a sample of airports to their associated historical accident rates. The eight airports listed in Table 7 were selected using random stratified sampling techniques to run the analysis with the new models and analysis software; the results are compared to the actual rate of accidents at the selected airports. None of the selected airports were part of the NOD used to develop the risk models.

The analysis runs with the eight airports also served to test the software. To run the risk analysis, one year of historical operations data were obtained for each airport. Data for airports were collected and consolidated. Operations data were retrieved from the FAA Operations & Performance Data and Aeronautical Information Management Laboratory. The weather data were obtained from the National Oceanic and Atmospheric Administration (NOAA) database for the meteorological stations serving each airport.

Historical accident and incident information for the airport was obtained from the NTSB, AIDS, and ASRS databases. Although the analysis was conducted to obtain risk assessment estimates, information on frequency calculated in the analysis also was used to compare expected and actual frequency rates for each type of incident. Similarly, actual and estimated accident rates were compared to evaluate the need to make adjustments to the models. Table 8 presents the relevant accidents and incidents identified for the eight airports selected. RSA's and obstacles were characterized using satellite pictures from Google Earth, and RSA files were created for each runway.

Relevant traffic volume information from 1981 to 2009 was estimated from information available in the FAA Air Traffic Activity Data System (ATADS). Part of the annual air traffic volume was extrapolated to estimate the total volume for the sample period. An average annual growth rate of 5% was assumed for air traffic in the period between 1981 and 1999 when air traffic information was not available online. The volumes were adjusted to remove operations of aircraft with less than 5600 lb and other movements non-relevant to this study. The volume and the number of accidents and incidents were used to estimate the frequency rates and accident rates for each airport and type of event.

The analysis software proved to work well for each case study. There were no bugs identified during the software runs, and the results looked rational and within expected ranges for the individual airports.

Table 8 contains the events for each airport occurring during the analysis period. Figure 40 summarizes the total number of accidents and incidents occurring at the eight airports since 1981. The majority of the cases were landing veer-offs, and, for most types of events, the number of incidents was larger than the number of accidents. One notable exception was the case for TOORs. It is true that the number of cases is quite small for a sample of eight airports; however it is notable that there were fewer TOOR incidents compared to accidents. Approximately 50% of TOOR in the accident/incident database developed for this study were incidents, and it may be an indication of higher severity for TOOR. When comparing the location models for TOOR and LDOR, the percentage of aircraft stopping at any given distance is larger during the takeoff, compared to landing overruns.

A summary of analysis results is presented in Table 9. More details on the analysis and additional results are presented in Appendix H. It is important to note that the RSA configurations used for the analysis at Yeager Airport were representative of conditions prior to the recent improvements that included the extension of RSA's and implementing EMAS. The main reason for using these data for Yeager is that the plan was to compare the analysis results with historical accident/incident rates. As expected, risk for Yeager was the highest because its RSAs before the recent improvements were considerably smaller than current FAA standards.

For simplicity, all analyses were conducted using the average annual operations during the past 10 years. The expected number of years between critical events is based

Table 7. List of airports for model/software validation.

State	Airport Name	Location ID	City	Hub
FL	Miami International	MIA	Miami	L
AK	Ted Stevens Anchorage International	ANC	Anchorage	M
MO	Lambert-St Louis International	STL	St Louis	M
WA	Spokane International	GEG	Spokane	S
SD	Joe Foss Field	FSD	Sioux Falls	N
WV	Yeager	CRW	Charleston	N
AZ	Deer Valley International	DVT	Phoenix	GA
FL	Ft Lauderdale Executive	FXE	Ft Lauderdale	GA

Table 8. Accidents and incidents at selected airports.

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code
07/01/1981	US	Saint Louis, MO	NTSB	LDVO	Incident	DC6	STL
07/24/1981	US	Charleston	NTSB	LDUS	Accident	BE60	CRW
10/15/1981	US	Saint Louis, MO	AIDS	LDVO	Incident	DC6	STL
2/24/1983	US	Anchorage, AK	AIDS	LDVO	Incident	LJ24	ANC
10/26/1983	US	Saint Louis, MO	NTSB	LDUS	Accident	CV3	STL
12/23/1983	US	Anchorage, AK	NTSB	TOOR	Accident	DC10	ANC
9/28/1987	US	Saint Louis, MO	AIDS	LDUS	Incident	MD80	STL
12/26/1987	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	AC11	FXE
10/14/1988	US	Anchorage, AK	AIDS	LDVO	Incident	YS11	ANC
10/23/1989	US	Anchorage, AK	MITRE	LDOR	Incident	B741	ANC
1/6/1990	US	Miami, FL	4-01NTSB	TOOR	Accident	L29A	MIA
02/17/1991	US	Spokane, WA	NTSB	LDVO	Accident	MU2B	GEG
03/11/1993	US	Saint Louis, MO	NTSB	LDVO	Accident	DC93	STL
8/28/1993	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	LJ23	FXE
08/29/1993	US	Charleston	NTSB	LDOR	Accident	MU2B	CRW
7/27/1994	US	Sioux Falls, SD	AIDS	LDVO	Incident	T18	FSD
11/29/1994	US	Spokane, WA	AIDS	TOVO	Incident	B731	GEG
06/23/1995	US	Miami, FL	NTSB	LDVO	Accident	C402	MIA
11/19/1995	US	Anchorage, AK	AIDS	LDUS	Incident	C441	ANC
12/19/1995	US	Saint Louis, MO	AIDS	LDVO	Incident	DC91	STL
9/17/1996	US	Miami, FL	AIDS	TOVO	Incident	BE18	MIA
11/15/1996	US	Sioux Falls, SD	MITRE	LDOR	Incident	DC91	FSD
8/7/1997	US	Miami, FL	4-01NTSB	TOOR	Accident	DC85	MIA
2/19/1999	US	Miami, FL	4-01ASRS	LDUS	Incident	A30B	MIA
10/15/2000	US	Anchorage, AK	NTSB	TOOR	Incident	B741	ANC
10/16/2000	US	Saint Louis, MO	AIDS	LDVO	Incident	MD80	STL
10/20/2000	US	Saint Louis, MO	ASRS	LDOR	Incident	MD82	STL
04/07/2001	US	Anchorage, AK	AIDS	TOVO	Incident	B190	ANC
01/01/2002	US	Miami, FL	4-01NTSB	LDOR	Incident	MD83	MIA
06/15/2002	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SW3	FXE
12/01/2002	US	Spokane, WA	AIDS	LDOR	Incident	DH8A	GEG
12/20/2002	US	Spokane, WA	4-01ASRS	LDOR	Incident	DH8A	GEG
8/16/1999	US	Fort Lauderdale, FL	MITRE	LDVO	Accident	CL60	FXE
4/17/2003	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SBR1	FXE
6/12/2003	US	Fort Lauderdale, FL	AIDS	TOOR	Incident	LJ24	FXE
8/9/2003	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SBR1	FXE
2/20/2004	US	Fort Lauderdale, FL	4-01NTSB	LDOR	Accident	LJ25	FXE
3/31/2004	US	Fort Lauderdale, FL	NTSB	LDVO	Accident	C402	FXE
7/19/2004	US	Fort Lauderdale, FL	4-01NTSB	LDOR	Accident	LJ55	FXE
09/08/2004	US	Charleston	NTSB	TOOR	Accident	C402	CRW
12/1/2005	US	Sioux Falls, SD	AIDS	LDVO	Incident	SW4	FSD
6/6/2006	US	Fort Lauderdale, FL	AIDS	TOVO	Incident	SW3	FXE
2/4/2007	US	Miami, FL	NTSB	LDVO	Incident	DC87	MIA
11/1/2007	US	Fort Lauderdale, FL	AIDS	LDOR	Incident	GLF2	FXE
1/27/2008	US	Spokane, WA	AIDS	LDOR	Incident	B731	GEG
5/23/2008	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SBR1	FXE
01/19/2010	US	Charleston	NTSB	TOOR	Accident	CRJ2	CRW

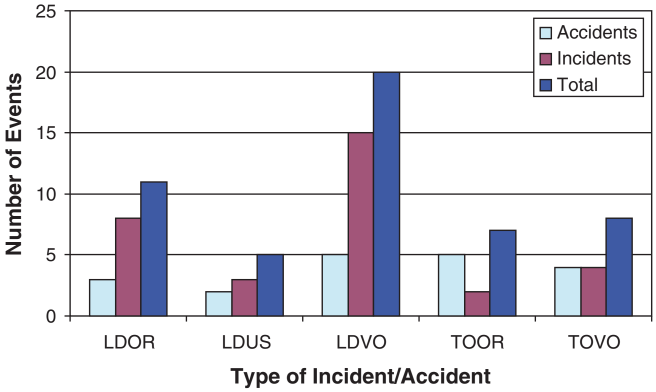


Figure 40. Summary of accidents and incidents at surveyed airports since 1981.

on the average annual volume of operations during the past 10 years and the average level of risk for the entire airport, as shown in column 5 of Table 9. A "critical event" is the focus of the analysis, and it may be an incident or an accident. When running the analysis for risk, a critical event is considered a single accident or an event in which substantial damage to the aircraft and/or injury to passengers is the consequence.

The most critical runway end is identified based on the risk of overruns and undershoots only. This risk is associated with the operations challenging the RSA adjacent to the runway end. The runway end is identified based on the approach end of the runway. The last two columns of Table 9 contain the incident type with the highest chance of occurring and the associated runway.

The validation effort was divided in two steps. The first step was to determine that the eight airports selected were representative of conditions across the United States. Although this is not an analysis required for validating the approach, the comparison helped gain confidence of the applicability of the risk assessment to other airports. Also, the estimated frequency rates of the airport sample were compared to the actual frequency for the eight airports. The second step was to compare the risk levels estimated from the analysis with the actual risk rates for the sample of airports.

Validation of Frequency Models

Figure 41 presents incident frequency rates for each type of incident and for three different estimates: the historical frequency rate in the United States, the actual incident rate for the sample of eight airports, and the estimated frequency rate for the sample of airports. The rates for the sample were calculated based on the weighted average for the eight airports. The actual rate represents the total number of incidents from 1981 to 2009 divided by the total volume of operations during the same period. The figure shows these results in both graphical and tabular format. Some differences were expected given the small sample size of eight airports surveyed.

The results presented in Figure 41 demonstrate excellent agreement between the accident rates for the sample of airports and the historical rate for all the airports in the United States. The results concur that the sample of airports is representative of conditions for the population of airports in the United States. The largest difference was found for landing veer-offs; however, the incident rate, particularly for Fort Lauderdale Executive Airport, was unusually high during the analysis period.

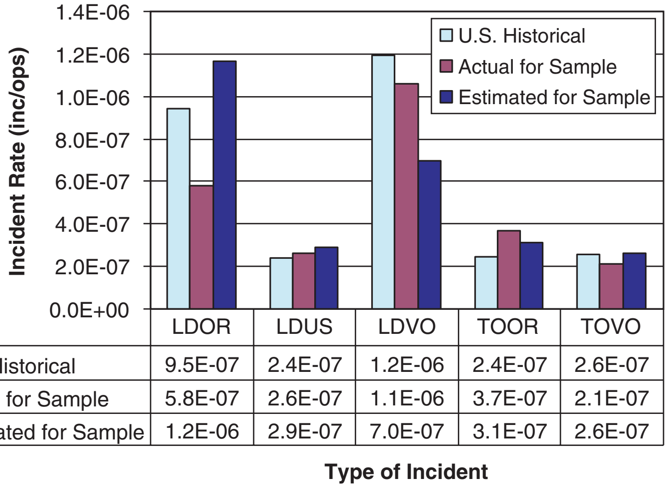
The second conclusion drawn from these results is that the actual frequency rates for the eight airports agreed with the estimated frequency rates for this sample. It is important to note that frequency rates involve both accidents and incidents, with no distinction for the level of severity.

The plot in Figure 41 also shows excellent agreement between actual and estimated frequency values for each type of incident. Therefore, there is no need to recalibrate the frequency models or to apply adjustment factors.

Table 9. Summary of analysis results for airports selected for validation.

Airport	State	Average Annual Volume of Ops for Past 10 yrs (in 2009)	No. of Runways	Avrg Airport Risk	Avrg # of Years for One Accident to Occur	Highest Risk Runway End**	Airport Most Frequent Incident and Associated Runway ***	
							Incident Type	Rwy
ANC	AK	293K (290K)	3	2.1E-07	16	14	LDVO	14/32
CRW*	WV	50K (71K)	2	5.5E-06	17	15	LDOR	15
FSD	SD	69K (86K)	2	3.1E-07	38	15	LDOR	15
FXE	FL	169K (261K)	2	8.3E-07	13	31	LDOR	31
GEG	WA	82K (81K)	2	4.1E-07	33	21	LDVO	03/21
STL	MP	209K (226K)	4	1.8E-07	28	24	LDVO	06/24
DVT	AZ	153K (376K)	2	3.7E-07	15	07L	TOVO	07L/25R
MIA	FL	380K (384K)	4	1.4E-07	19	30	LDVO	12/30

* Risk estimated for condition before RSA improvements completed in 2007.
** Runway end with highest probability of overruns and undershoots only.
*** Incident with highest probability of occurrence.



	LDOR	LDUS	LDVO	TOOR	TOVO
□ U.S. Historical	9.5E-07	2.4E-07	1.2E-06	2.4E-07	2.6E-07
■ Actual for Sample	5.8E-07	2.6E-07	1.1E-06	3.7E-07	2.1E-07
■ Estimated for Sample	1.2E-06	2.9E-07	7.0E-07	3.1E-07	2.6E-07

Figure 41. Actual frequency of incidents for sample of airports compared to historical rates.

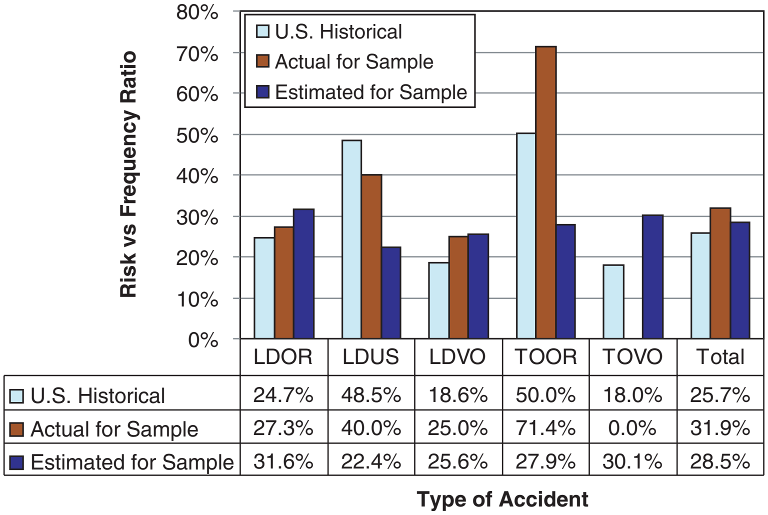
Validation of Risk Model

The second part of the validation effort consisted of the comparison of actual risk rates with those estimated for the sample of eight airports. The estimated risk is associated with the likelihood of an accident, rather than an incident. According to NTSB, accident is defined as an occurrence associated with the operation of an aircraft where as a result of the operation, any person receives fatal or serious injury or any aircraft receives substantial damage. This is also the definition used in this report to characterize an aircraft accident.

Data presented in Table 8 contain the accidents that took place at the eight sample airports from 1981 to 2009. The ratio between the actual number of accidents in that period divided by the volume of landings or takeoffs at the airport provides the actual rate for each type of event. The total number of accidents of any type divided by the total number of operations in the period evaluated is the actual accident rate for the airport.

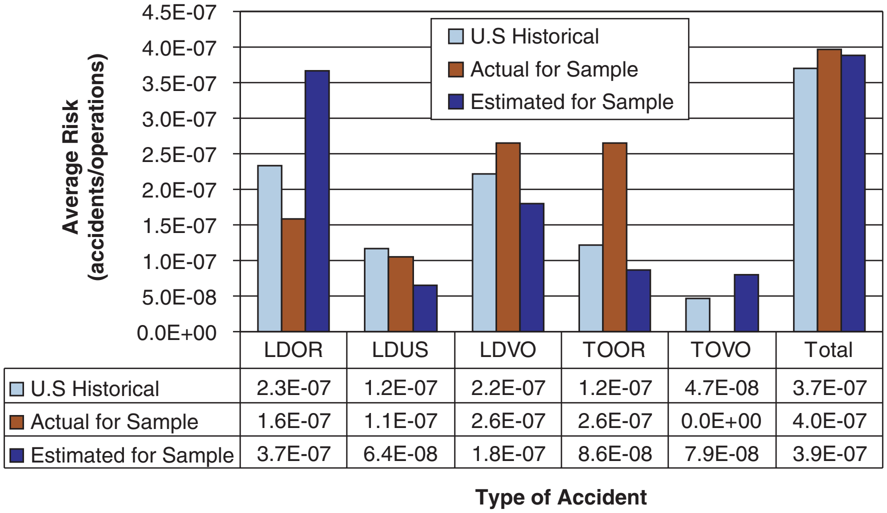
Comparison of the actual rate for each type of accident at each airport is not very helpful because the number of events is relatively low, given the sample size of airports used in the validation. Therefore, the analysis consisted of comparing the rates for the whole sample of eight airports. The comparison is made for each type of accident and for the total accident rate.

The first analysis compared the proportion between accidents and the total number of incidents. This was an important analysis to validate the consequence approach developed in this study. Three types of ratios were calculated for each type of accident: the estimated ratio for the sample of eight airports, the actual ratio for the sample, and the historical ratio in the United States. The results are shown in Figure 42 in both graphical and tabular form.



	LDOR	LDUS	LDVO	TOOR	TOVO	Total
□ U.S. Historical	24.7%	48.5%	18.6%	50.0%	18.0%	25.7%
■ Actual for Sample	27.3%	40.0%	25.0%	71.4%	0.0%	31.9%
■ Estimated for Sample	31.6%	22.4%	25.6%	27.9%	30.1%	28.5%

Figure 42. Percentage of accidents to the total number of incidents.



	LDOR	LDUS	LDVO	TOOR	TOVO	Total
U.S Historical	2.3E-07	1.2E-07	2.2E-07	1.2E-07	4.7E-08	3.7E-07
Actual for Sample	1.6E-07	1.1E-07	2.6E-07	2.6E-07	0.0E+00	4.0E-07
Estimated for Sample	3.7E-07	6.4E-08	1.8E-07	8.6E-08	7.9E-08	3.9E-07

Figure 43. Percentage of accidents to the total number of incidents.

Again, the results are in excellent agreement with the exception of the ratio for TOVO since none of the airports included in the sample had this type of incident. This can be attributed to chance, since the estimate is in good agreement with the historical level in the United States. The number of accidents is very low when using only eight airports, and larger variations were expected when comparing the parameters based on the number of accidents for the sample. The last analysis for validation was the comparison of actual and estimated risk levels for the sample of airports. The results are presented in Figure 43.

Again, the results between estimated and actual values are in excellent agreement. The validation study demonstrates the applicability of the approach and the models developed in this study.

CHAPTER 7

Conclusions and Recommendations for Further Research

RSA standards have changed over the years to improve safety, but many existing airports were built under older, less demanding standards. To comply with the current standards, some airports face enormous challenges due to physical, economical, and environmental restrictions.

Safety levels associated with the protection provided by RSA's can be different from airport to airport. Two airports with similar runway lengths and RSA configurations may have very different conditions related to operations and weather. Factors like aircraft model, runway elevation, visibility conditions, and availability of NAVAID's also have an impact on the risk of each operation.

When airports do not comply with the RSA standards and there is a need to improve existing conditions, it is necessary to evaluate the alternatives that can be most effective to reduce risk and compare the safety levels achieved and the associated costs for each option.

The objective of this study was to develop a software tool that can be used for risk assessments associated with incidents occurring in the RSA.

The basis of the approach used in this study was presented in *ACRP Report 3.* Analysis capabilities were enhanced by improving the risk models to address the analysis of runway declared distances, the use of EMAS, and incorporating the approach to evaluate the presence of obstacles in or in the vicinity of the RSA. In addition, it is now possible to evaluate the risk of aircraft veer-off in the lateral sections of the RSA. The result is a powerful tool to help the aviation industry perform risk assessments.

The major goals of this study can be summarized as follows:

1. Update the *ACRP Report 3* accident/incident database to incorporate aircraft overrun and undershoot accidents and incidents occurring after 2006 and include runway veer-off events occurring since 1980.
2. Develop risk models for frequency and location for each type of incident.
3. Develop a practical approach to assess the impact of: runway distance available on the probability of overruns, undershoots, and veer-offs; the availability of EMAS as an alternative to standard RSAs; the use of declared distances; and the presence of obstacles in the RSA or its vicinity.
4. Develop user-friendly software that incorporates the methodology and models developed as a practical tool that airport stakeholders may use to evaluate RSA alternatives.
5. Field test the software developed and validate the new tool and models based on data gathered according to an airport survey plan.

Each of these goals was accomplished, and the major achievements are presented below.

Major Achievements

Extended Database of Accidents and Incidents

The database developed under the study presented in *ACRP Report 3* included 459 aircraft overrun and undershoot accidents and incidents occurring from 1980 to 2006. The database was expanded significantly to 1414 events with the inclusion of overruns and undershoots occurring from 2006 to 2009, and the addition of veer-off events and information provided by MITRE.

Additional events were identified using a manual search of the FAA incident databases and the accidents and incidents involving GA aircraft with MTOW between 5,600 and 12,000 lb, which had been excluded from the *ACRP Report 3* study.

The comprehensive database is organized with editing and querying capabilities, and information is available according to different categories including synopsis of the event, aircraft involved, airport and weather characteristics, level of consequences, wreckage location, and major causal and contributing factors.

Development of Improved Risk Models

The models presented in *ACRP Report 3* were improved, and new ones to address veer-offs were developed. Five sets of frequency and location models were developed, including models for LDOVs, LDVOs, LDUSs, TOORs, and TOVOs. These types of events constitute the great majority of aircraft incidents that challenge the runway RSA.

New data and new factors were incorporated into the new models. Two of the most important ones were the runway criticality factor and the tail/head wind component. The runway criticality factor was defined as the ratio between the runway distance required and the runway distance available for the operation. The higher this value is, the smaller is the safety margin for the operation, and it represents the relationship between the runway and aircraft performance.

Development of Approach to Evaluate EMAS

EMAS has proved to be a successful alternative when the RSA area available at the runway ends is shorter than the standard. The improved deceleration capability provided by EMAS is an important consideration when performing an RSA analysis.

The approach presented in *ACRP Report 3* did not address the possibility of using EMAS; ACRP 04-08 filled this gap. A simplified approach based on data provided by Engineered Arresting Systems Corporation (ESCO), the manufacturer of EMAS, was developed and incorporated into the software. The approach used can help airport stakeholders verify the safety benefits of using EMAS beds, even when non-standard configurations are used.

Development of Approach to Assess Impact of Declared Distances

Statistics were used to demonstrate that the likelihood of landing and takeoff incidents may depend on the safety margin available for the operation relative to the runway distance required by the aircraft.

In this project, the estimate of frequency of incidents incorporates a runway criticality factor defined as the ratio between the runway distance required and the distance available. Although the runway distance can only be calculated using the actual aircraft weight, and this information is difficult to obtain, other factors may be used for modeling. Some of these factors include the basic distance required for standard conditions, the runway elevation, the air temperature, the wind, and the runway surface conditions. In this project, the landing distance required is estimated based on each of those factors for the specific type of aircraft.

The incorporation of these factors into the frequency models is used to help assess the impact of the declared runway distances on risk of overruns, veer-offs, and undershoots.

Development of Software Tool

The approach and the improved models were integrated into analysis software for risk assessment of RSA. The tool, called RSARA, is user-friendly and practical, and allows the user to consider each of the factors impacting RSA risk.

The software works as a simulation tool to estimate risk for each operation from an annual sample of operations for an airport. The historical sample data include flight operations data, like aircraft model, runway used, and the type of operation, as well as the weather conditions to which each of these operations was subjected.

Within the software, the definition of RSA areas is a very simple process based on Microsoft Excel spreadsheets. The procedure is as easy as drawing the RSA in a plan view and defining the RSA surface type: unpaved, paved, or EMAS.

The output is comprehensive, and risk estimates are provided by type of incident, runway, and RSA section challenged. Risk results are provided in terms of accidents per number of operations or the expected number of years to occur an accident, and are compatible with the criteria set by the FAA.

Histograms of risk help users identify the percentage of operations subject to risk levels higher than a desired TLS.

Model and Software Validation

The risk models were developed and calibrated based on a worldwide dataset of accidents and incidents. A second effort was conducted to verify and validate the models using NOD and RSA conditions for eight airports that were not used to create the NOD used to develop the models.

The verification was a key step to demonstrate the applicability of the innovative approach and models developed in this research. The comparison between estimated and actual frequency and risk rates showed excellent agreement, despite the small sample of airports used in this study. Analysis output for the eight airports and their historical records of accidents and incidents helped to prove the validity of the approach and analysis software.

The volunteers selected to test the models provided feedback to the research team that was used to improve software and eliminate bugs.

Limitations

Although an intensive effort was made to develop a very comprehensive tool, there are some limitations that users should be aware of. Some of those limitations are related to data availability, and some are related to the computer time to perform an analysis.

One important limitation is that the tool is helpful for planning purposes only. Neither the models nor the software should be used to estimate risk during real-time operations.

Only aircraft manufacturers can use actual aircraft data during operations to estimate actual aircraft performance.

The models and the approach were developed using actual data from accident and incident reports, and the models are simply based on evidence gathered from that type of information. For example, to estimate the runway distance required, a basic distance for the type of aircraft and model was used and corrected for temperature, elevation, wind, and surface characteristics. Wind corrections are considered to be average adjustments, and surface conditions are estimated based on weather conditions only, rather than relying on actual runway friction.

It was not possible to incorporate the touchdown location or the approach speed during landing. These are important factors that may lead to accident, but there are no means to account for these factors, except for assuming average values with a certain probability distribution that will lead to some level of model uncertainty.

Additional simplifications were necessary to address the interaction of incidents with existing obstacles. In many cases, the pilot is able to have some directional control of the aircraft and avoid some obstacles. The approach simply assumes that the aircraft location is a random process and the deviation from the runway centerline follows a normal probability distribution and that, during overruns and undershoots, the aircraft follows a path that is parallel to the runway centerline.

One major limitation to obtain more accurate models and estimates is the difficulty in accounting for human factors. Some type of human error was present in the majority of the events reported, and this factor is reflected as a component of the model error.

Also, obstacle categories were defined according to the maximum speed to avoid an accident with substantial damage to the aircraft and possibly injuries to its occupants. The classification was defined in this project using engineering judgment and assuming that consequences depend only on the collision speed and the area of the aircraft that has collided with the obstacle. Again, only engineering judgment was used to classify different types of obstacles according to the categories.

Recommendations for Future Work

Extend Analysis for Non-RSA Areas

Even with its limitations, the approach presented in this report is quite robust for the analysis of RSA. It takes into consideration many local factors and specific conditions to provide estimates of risk.

Still, the analysis presented can only cover the areas in the immediate vicinity of the runway. The development of a risk-based methodology to evaluate land use compatibility and third-party risk could be very helpful to support State requirements and planning efforts. The approach can be similar to the one presented in this study—using evidence of aircraft accidents in the vicinities of airports to develop risk models based on causal and contributing factors to aircraft accidents. The study should address the risk of accidents in areas within a 10-mile radius of the runway.

The methodology should consider local factors, historical operation conditions for the airport, and the type of land use for specific regions near the airport runways. The recommended study would improve the capability of land use committees and airport operators to assess third-party risk associated with aircraft accidents in the vicinity of airports.

The approach should be rational, non-prescriptive, and provide a quantitative assessment of third-party risk associated with aircraft operations at a specific airport. The study should associate aircraft operations with existing runway and environmental conditions, and aircraft type for a specific airport. Thus, the results of such a study would help decision makers to evaluate alternatives and associated safety benefits.

Development of Risk Tool for Airspace Analysis in Vicinity of Runways

The RSA analysis methodology and software presented in this study can only address the ground roll phase of operation; however, aircraft have both lateral and vertical deviations from their nominal flight path during landing and takeoff operations.

Currently, the aviation industry still relies on the Collision Risk Model (CRM) developed in the 1960s with very limited data to evaluate risk during instrument approaches during the non-visual segment and missed approach phases. The CRM has many limitations and does not cover all phases of the flight and types of approach. Only data for precision approach Categories I and II can be evaluated using the existing model. There is a need to have an updated CRM that can be used to prioritize risk mitigation actions associated with obstacles in the vicinity of the runway.

Currently, the FAA is developing a tool called Airspace Simulation and Analysis Tool (ASAT) that has comprehensive capabilities and accounts for aircraft performance, NAVAIDs, environmental conditions, terrain, wake turbulence, and human factors. However, the tool is not available to other airport stakeholders.

The improved tool should have the capability to assess risk associated with fixed or movable obstacles when they are very close to the runway. It should address all types of approach (visual, non-precision, precision, and possibly global positioning system [GPS] approach technology). Many airports would benefit from such a tool for safety management associated with the presence of obstacles.

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Abbreviations and Acronyms

AAIB	UK Air Accidents Investigation Branch
AAIU	Ireland Air Accident Investigation Unit
ACRP	Airport Cooperative Research Program
ADG	Airplane Design Group
ADREP	ICAO Accident/Incident Data Reporting
ASDI	Aircraft Situation Display to Industry
AIDS	FAA Accident/Incident Data System
AIP	Airport Improvement Program
ALS	Approach Lighting System
ASAT	Airspace Simulation and Analysis Tool
ASPM	Aviation System Performance Metrics
ASRS	FAA/NASA Aviation Safety Reporting System
ATADS	Air Traffic Activity Data System
ATC	Air Traffic Control
ATSB	Australian Transport Safety Bureau
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CCFD	Complementary Cumulative Frequency Distribution
CCPD	Complementary Cumulative Probability Distribution
CFR	Code of Federal Regulations
CIAIAC	Comisión de Investigación de Accidentes e Incidentes de Aviación Civil
CRM	Collision Risk Model
EMAS	Engineered Material Arresting System
ESCO	Engineered Arresting Systems Corporation
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FHA	Functional Hazard Analysis
GA	General Aviation
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ISO	International Standards Organization
LDOR	Landing Overrun
LDUS	Landing Undershoot

LDVO	Landing Veer-off
MTOW	Maximum Takeoff Weight
NASA	National Aeronautics and Space Administration
NASB	Netherlands Aviation Safety Board
NAVAID	Navigational Aids
NOAA	National Oceanic and Atmospheric Administration
NOD	Normal Operations Data
NTSB	National Transportation Safety Board
NTSC	Indonesia National Transportation Safety Committee
RLF	Runway Length Factor
ROC	Receiver Operating Characteristic
ROFA	Runway Object Free Area
RSA	Runway Safety Area
RSARA	Runway Safety Area Risk Assessment (software tool)
TAIC	New Zealand Transport Accident Investigation Commission
TOOR	Takeoff Overrun
TLS	Target Level of Safety
TOVO	Takeoff Veer-off
TRB	Transportation Research Board
TSB	Transportation Safety Board of Canada

Definitions

Acceptable Level of Risk: likelihood of an event when probability of occurrence is small, whose consequences are so slight, or whose benefits (perceived or real) are so great, that individuals or groups in society are willing to take or be subjected to the risk that the event might occur.

Accident: an unplanned event or series of events that results in death, injury, or damage to, or loss of, equipment or property.

Consequence: the direct effect of an event, incident, or accident. In this study it is expressed as a health effect (e.g., death, injury, exposure) or property loss.

Fatal Injury: any injury that results in death within 30 days of the accident.

Hazard: the inherent characteristic of a material, condition, or activity that has the potential to cause harm to people, property, or the environment.

Hazard Analysis: the identification of system elements, events or material properties that lead to harm or loss. Hazard analysis may also include evaluation of consequences from an event or incident.

Hull Loss: airplane totally destroyed or damaged and not repaired.

Incident: a near miss episode, malfunction, or failure without accident-level consequences that has a significant chance of resulting in accident-level consequences.

Likelihood: expressed as either a frequency or a probability. Frequency is a measure of the rate at which events occur over time (e.g., events/year, incidents/year, deaths/year). Probability is a measure of the rate of a possible event expressed as a fraction of the total number of events (e.g., one-in-ten-million, 1/10,000,000, or 1 × 10-7).

Major Accident: an accident in which any of three conditions is met: the airplane was destroyed; or there were multiple fatalities; or there was one fatality and the airplane was substantially damaged.

METAR: aviation routine weather report.

Nonconformity: non-fulfillment of a requirement. This includes but is not limited to non-compliance with Federal regulations. It also includes an organization's requirements, policies, and procedures, as well as requirements of safety risk controls developed by the organization.

Overrun or Overshoot: a departure of the aircraft from the end of the intended landing runway surface.

Quantitative Risk Analysis: incorporates numerical estimates of frequency or probability and consequence.

Risk: the combination of the likelihood and the consequence of a specified hazard being realized. It is a measure of harm or loss associated with an activity.

Risk Analysis: the study of risk in order to understand and quantify risk so it can be managed.

Risk Assessment: determination of risk context and acceptability, often by comparison to similar risks.

Runway Criticality: term introduced in this study to represent the relationship between the runway distance required by a given aircraft and specific operational conditions, and the runway distance available for that operation (landing or takeoff). Runway criticality is represented mathematically by the ratio between the runway distance required and the runway distance available. A higher ratio means a lower safety margin and greater operation criticality.

Safety: absence of risk. Safety often is equated with meeting a measurable goal, such as an accident rate that is less than an acceptable target. However, the absence of accidents does not ensure a safe system. To remain vigilant regarding safety, it is necessary to recognize that just because an accident has not happened, it does not mean that it cannot or will not happen.

Safety Management System: the formal, top-down businesslike approach to managing safety risk. It includes systematic procedures, practices, and policies for the management of safety (including safety risk management, safety policy, safety assurance, and safety promotion).

Safety Risk Management: the systematic application of policies, practices, and resources to the assessment and control of risk affecting human health and safety and the environment. Hazard, risk, and cost/benefit analysis are used to support development of risk reduction options, program objectives, and prioritization of issues and resources.

Substantial Damage: damage or failure that adversely affects the structural strength, performance, or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected component.

Target Level of Safety (TLS): the degree to which safety is to be pursued in a given context, assessed with reference to an acceptable or tolerable risk.

Undershoot: an event when the aircraft lands short of a runway or planned landing spot.

Veer-off: an aircraft running off the side of the runway during takeoff or landing roll.

Worst Credible Condition: the most unfavorable conditions or combination of conditions that it is reasonable to expect will occur.

APPENDIX A

Functional Hazard Analysis Results

Introduction

As described in the body of this report, one of the subtasks of this project was to carry out a functional hazard analysis (FHA) for aircraft overruns, undershoots, and veer-offs based on information gathered in the literature review. The objective of this subtask was to identify the most relevant factors associated with such events to support the data collection effort for accidents and incidents. Identifying such factors causing or contributing to such events was also part of the modeling process involved in this study.

FHAs often are conducted in the form of a brainstorming workshop involving a multi-disciplinary team, for example including pilots, air traffic controllers, airside operations personnel, and specialist risk assessors. The objective of the workshop is to explore all relevant operational scenarios and identify hazards associated with them. The output of the FHA is a "hazard log," including all hazards identified and preliminary information about them that can be provided by the workshop team.

Summary of Relevant Factors Identified

Table A1 summarizes the factors that are believed to lead to overrun, undershoot, and veer-off accidents and incidents based on FHA studies and literature review. Most of these factors were identified in *ACRP Report 3* and other studies, but some were added based on available reports from other sources.

Table A1. Summary of factors causing or contributing to aircraft overrun, undershoot, and veer-off occurrences.

Event	Category	Factor
Landing Overrun (LDOR)	Weather	Tail Wind
		Cross Wind
		Wind variations (gusts, shear)
		Visibility
		Ceiling
		Temperature
	Airfield	Surface contaminants and friction (water, snow, ice, slush, rubber deposits)
		Landing Distance Available (LDA)
		Slopes (longitudinal and transverse)
		Altitude
		Runway profile
		System faults
	Pilot	Landing long
		Unstabilized approach
		Landing fast
		High threshold crossing height
		"Pressonits"
		Incorrect (delay) application of thrust reverse (if available) and spoilers
		Incorrect (delay) application of brakes
		Delayed nose-wheel lowering
		'Over-consideration' for comfort
		Incorrect interpretation of reported operation conditions
		Landing on the wrong runway
	Aircraft	Landing Distance Required (LDR)
		Weight
		System faults (e.g. brake systems failure)

(continued on next page)

Table A1. (Continued).

Event	Category	Factor
Takeoff Overrun (TOOR)	Weather	Tail Wind
		Wind variations (gusts, shear)
		Cross wind
		Temperature
	Airfield	Accelerate-Stop Distance Available (ASDA)
		Surface contaminants and friction (water, snow, ice, rubber deposits) in case of aborted takeoff
		Slopes (longitudinal and transverse) in case of aborted takeoff
		Altitude
	Pilot	Delay to abort takeoff when required
		Incorrect (delay) application of thrust reverse (if available) and spoilers, in case takeoff is aborted
		Incorrect (delay) application of brakes, in case takeoff is aborted
		Incorrect interpretation of reported operation conditions
		Selection of wrong runway
	Aircraft	System or component malfunction require to abort takeoff
		Accelerate-Stop Distance Required (ASDR)
Landing Undershoot (LDUS)	Weather	Visibility
		Ceiling
		Wind variations (gusts, shear)
		Temperature
		Crosswind
	Airfield	System faults
		Availability of navigational aids
		Altitude
	Pilot	Approach too low
		Attempt to land too close to arrival end of the runway
		Misinterpretation of approach procedures
		Visual illusion resulting incorrect pilot response
	Aircraft	System faults
		Stall speed
		Approach speed
Takeoff Veer-Off (TOVO)	Weather	Crosswind
		Wind gusts
		Heavy rain
	Airfield	Runway contamination (water, snow, ice, rubber)
		Bird strike
		Runway undulation
		Construction work
	Pilot/Crew	Abort takeoff above V1
		Incorrect performance calculation
		Incorrect CG
		Incorrect runway distance available
	Aircraft	Engine power loss
		Blown tire
		Undercarriage collapse
		Loss of directional control
Landing Veer-Off (LDVO)	Weather	Cross wind
		Wind gusts
		Tailwind
		Turbulence
		Windshear
	Airfield	Runway contamination (water, snow, ice, slush, rubber)
		Snow banks
	Pilot	Hard landing with landing gear failure
		Unstabilized approach
		Go around not conducted
		Touchdown long
		Touchdown hard/bounce
	Aircraft	Spontaneous collapse of undercarriage
		Asymmetric forces due to thrust reverse problem
		Asymmetric forces due to braking problem
		Steering control system malfunction

APPENDIX B

Summary of Accidents and Incidents

The following table presents a summary of the overrun, veer-off, and undershoot accidents and incidents identified in the databases screened. Some events are reported in more than one database, and to avoid repeating the events during the consolidation of records, the reported event date, event type, aircraft type, and location were used to eliminate the repeated records.

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
7/18/1971	Australia	Sydney	Australia Civil Aviation	LDOR	Incident	B741	YSSY	325	60	N/A
1/17/1978	US	Tyler, TX	AIDS	LDOR	Incident	AC68	TYR	N/R	N/R	N/A
5/2/1978	US	Lake Charles, LA	AIDS	LDOR	Incident	CVLP	CWF	N/R	N/R	N/A
8/16/1978	US	Soda Springs, ID	AIDS	LDOR	Incident		U78	N/R	N/R	N/A
2/15/1979	US	Waukegan, IL	AIDS	LDOR	Incident	G159	UGN	N/R	N/R	N/A
8/1/1979	US	Mattoon, IL	AIDS	LDOR	Incident	SBR1	MTO	N/R	N/R	N/A
8/10/1979	US	Hayward, CA	AIDS	LDOR	Incident		HWD	N/R	N/R	N/A
9/11/1979	US	Fayetteville, AR	AIDS	LDOR	Incident	SW3	FYV	N/R	N/R	N/A
11/21/1979	US	Carlsbad, CA	AIDS	LDOR	Incident	LJ24	CRQ	100	0	N/A
4/7/1980	Canada	Athabasca, AB	Canada TSB	LDOR	Accident	MU2	CYWM	N/R	N/R	N/A
7/29/1980	US	Houma, LA	AIDS	LDOR	Incident	AC11	HUM	N/R	N/R	N/A
8/7/1980	UK	Leeds Bradford	UK AAIB	LDOR	Incident	VISC	LBA	N/R	N/R	N/A
9/6/1980	Canada	North Seal River, MB	Canada TSB	LDOR	Incident	DHC6	CEG8	N/R	N/R	N/A
12/20/1980	US	Teterboro, NJ	AIDS	LDOR	Incident	FA20	TEB	N/R	N/R	N/A
2/1/1981	US	Pontiac, MI	AIDS	LDOR	Incident	C550	PTK	N/R	N/R	N/A
3/29/1981	England	Bedfordshire	AAIB	LDOR	Accident	L29A	EGGW	152	0	N/A
5/1/1981	US	Little Rock, AR	AIDS	LDOR	Incident	AC68	LIT	N/R	N/R	N/A
5/6/1981	US	New Castle, DE	AIDS	LDOR	Incident	MU2	ILG	N/R	N/R	N/A
7/2/1981	US	Cleveland, OH	AIDS	LDOR	Incident	CL60	CGF	N/R	N/R	N/A
7/17/1981	US	Lincoln, NE	AIDS	LDOR	Incident	LJ25	LNK	N/R	N/R	N/A
8/1/1981	Canada	Salluit, QC	Canada TSB	LDOR	Incident	DHC6	YZG	N/R	N/R	N/A
9/13/1981	US	Boston, MA	AIDS	LDOR	Incident	DC10	BOS	50	0	N/A
12/9/1981	US	Albuquerque, NM	AIDS	LDOR	Incident	AC6L	ABQ	N/R	N/R	N/A

12/11/1981	Puerto Rico	San Juan	AIDS	LDOR	Incident	DC10	JSJ	300	0	N/A
1/1/1982	UK	Cambridge	UK AAIB	LDOR	Incident		CBG	N/R	N/R	N/A
1/12/1982	US	Dallas, TX	AIDS	LDOR	Incident	H25A	ADS	N/R	N/R	N/A
1/12/1982	US	Dallas, TX	MITRE	LDOR	Incident	H25A	ADS	1241	0	N/A
2/15/1982	US	Los Angeles, CA	NTSB	LDOR	Incident	B731	LAX	N/R	N/R	N/A
2/19/1982	US	Harlingen, TX	NTSB	LDOR	Incident	B721	HRL	299	0	N/A
2/19/1982	US	Oakland, CA	AIDS	LDOR	Incident	FA20	OAK	N/R	N/R	N/A
2/26/1982	US	Atlanta, GA	NTSB	LDOR	Incident	BE9L	PDK	600	280	N/A
10/1/1982	UK	Scatsa	UK AAIB	LDOR	Incident	A748	SCS	N/R	N/R	N/A
11/11/1982	US	San Juan, PR	MITRE	LDOR	Incident	L101	SJU	N/R	N/R	N/A
11/20/1982	US	Atlanta, GA	NTSB	LDOR	Accident	AC80	ATL	450	0	N/A
12/18/1982	US	Pellston, MI	NTSB	LDOR	Incident	DC91	PLN	80	0	N/A
12/27/1982	US	Dubuque, IA	MITRE	LDOR	Incident	E110	DBQ	110	0	N/A
4/19/1983	Canada	Gaspe Airport, QC	Canada TSB	LDOR	Accident	H25A	YGP	N/R	N/R	N/A
6/24/1983	US	Kailua/Kona, HI	MITRE	LDOR	Incident	YS11	KOA	N/R	N/R	N/A
7/15/1983	US	Blountville, TN	NTSB	LDOR	Accident	GLF2	TRI	N/R	N/R	N/A
7/20/1983	US	Chicago, IL	NTSB	LDOR	Incident	DC85	ORD	100	0	N/A
9/10/1983	US	Burlington, CO	NTSB	LDOR	Accident	BE9L	ITR	225	0	N/A
9/20/1983	US	Massena, NY	NTSB	LDOR	Accident	LJ35	MSS	587	30	N/A
10/21/1983	US	Bloomington, IL	MITRE	LDOR	Incident	F27	BMI	N/R	N/R	N/A
10/25/1983	US	Norfolk, VA	NTSB	LDOR	Accident	DC85	NGU	7	129	N/A
11/29/1983	UK	Sumburgh	UK AAIB	LDOR	Incident	A748	LSI	131	70	N/A
12/22/1983	US	Eagle, CO	MITRE	LDOR	Accident	LJ25	EGE	N/R	N/R	N/A
1/30/1984	US	Avalon, CA	NTSB	LDOR	Accident	LJ24	AVX	N/R	N/R	N/A
2/12/1984	US	Oshkosh, WI	MITRE	LDOR	Incident	DC93	OSH	N/R	N/R	N/A
2/28/1984	US	New York, NY	NTSB	LDOR	Accident	DC10	JFK	660	35	N/A
3/30/1984	US	Kailua/Kona, HI	MITRE	LDOR	Incident		KOA	N/R	N/R	N/A
4/2/1984	US	Little Rock, AR	NTSB	LDOR	Accident	CL60	LIT	50	60	N/A
6/23/1984	US	Chicago, IL	NTSB	LDOR	Incident	B701	ORD	600	0	N/A
7/6/1984	Canada	Blanc-Sablon, QC	Canada TSB	LDOR	Accident	A748	YBX	30	0	N/A
11/1/1984	UK	Bristol	UK AAIB	LDOR	Incident	A30B	BRS	N/R	N/R	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
12/15/1984	Canada	Sioux Lookout, ON	Canada TSB	LDOR	Accident	C500	YXL	502	0	N/A
1/5/1985	US	Oklahoma City, OK	NTSB	LDOR	Accident	LJ25	OK15	N/R	N/R	N/A
1/31/1985	US	London, KY	NTSB	LDOR	Accident	SW4	LOZ	380	0	N/A
5/8/1985	US	Chicago, IL	AIDS	LDOR	Incident	LJ24	Unknown	N/R	N/R	N/A
5/27/1985	UK	Leeds Bradford	UK AAIB	LDOR	Incident	L101	LBA	538	33	N/A
6/11/1985	US	Van Nuys, CA	NTSB	LDOR	Accident	AC11	VNY	1300	0	N/A
6/27/1985	England	Leeds	AAIB	LDOR	Accident	L101	EGNM	147	0	N/A
7/12/1985	US	Fort Worth, TX	NTSB	LDOR	Accident	LJ35	FTW	459	100	N/A
8/28/1985	US	Green Bay, WI	MITRE	LDOR	Incident	BA11	GRB	N/R	N/R	N/A
9/23/1985	US	Chicago, IL	NTSB	LDOR	Accident	FA10	DPA	1200	1100	N/A
10/19/1985	US	Bloomington, IN	NTSB	LDOR	Accident	VISC	BMG	320	75	N/A
11/7/1985	US	Sparta, TN	NTSB	LDOR	Accident	H25A	SRB	359	20	N/A
1/2/1986	US	Detroit, MI	NTSB	LDOR	Incident	DC10	DTW	100	0	N/A
1/31/1986	US	Lancaster, CA	AIDS	LDOR	Incident	C550	WJF	N/R	N/R	N/A
2/8/1986	US	Carlsbad, CA	NTSB	LDOR	Accident	MU30	CRQ	100	119	N/A
2/21/1986	US	Erie, PA	NTSB	LDOR	Accident	DC91	ERI	180	70	N/A
2/27/1986	US	Coatesville, PA	NTSB	LDOR	Accident	FA10	40N	400	250	N/A
3/13/1986	US	Charleston, SC	NTSB	LDOR	Incident	DC91	CHS	870	200	N/A
5/7/1986	US	Hollywood, FL	NTSB	LDOR	Accident	LJ24	HWO	N/R	N/R	N/A
8/2/1986	US	Bedford, IN	NTSB	LDOR	Accident	H25A	BFR	677	0	N/A
10/14/1986	US	Beverly, MA	MITRE	LDOR	Accident	BE9L	BVY	N/R	N/R	N/A
10/25/1986	US	Charlotte, NC	NTSB	LDOR	Accident	B731	CLT	516	75	N/A
1/5/1987	US	Lebanon, NH	MITRE	LDOR	Incident	LJ35	LEB	N/R	N/R	N/A
1/29/1987	US	Chicago, IL	MITRE	LDOR	Incident	DC91	MDW	N/R	N/R	N/A
3/12/1987	US	Des Moines, IA	AIDS	LDOR	Incident	DC85	DSM	50	0	N/A
9/9/1987	US	Tulsa, OK	AIDS	LDOR	Incident	LJ35	TUL	N/R	N/R	N/A
10/6/1987	US	Kennewick, WA	NTSB	LDOR	Accident	JS31	S98	450	0	N/A
10/21/1987	US	San Luis Obispo, CA	MITRE	LDOR	Incident	SW4	SBP	N/R	N/R	N/A
10/28/1987	US	Bartlesville, OK	NTSB	LDOR	Accident	CVLT	BVO	918	0	N/A
11/4/1987	US	Williamsport, PA	MITRE	LDOR	Incident	BE9L	IPT	100	0	N/A
11/23/1987	US	Nashville, TN	AIDS	LDOR	Incident	B721	BNA	50	0	N/A

2/3/1988	US	Denver, CO	MITRE	LDOR	Incident	DC85	DEN	30	0	N/A
6/17/1988	US	West Palm Beach, FL	NTSB	LDOR	Incident	LJ24	PBI	30	0	N/A
7/15/1988	US	San Diego, CA	MITRE	LDOR	Accident	MU2	MYF	N/R	N/R	N/A
8/1/1988	US	Pensacola, FL	NTSB	LDOR	Incident	MD88	PNS	320	90	N/A
8/19/1988	US	Pensacola, FL	ASRS	LDOR	Incident		PNS	78	0	N/A
9/19/1988	US	Paducah, KY	ASRS	LDOR	Incident		PAH	N/R	N/R	N/A
9/22/1988	US	Fremont, MI	NTSB	LDOR	Accident	C550	3FM	644	150	N/A
9/23/1988	US	Paducah, KY	MITRE	LDOR	Incident	SW4	PAH	200	0	N/A
10/14/1988	US	Seattle, WA	MITRE	LDOR	Incident	B721	SEA	50	0	N/A
10/19/1988	US	Columbus, GA	ASRS	LDOR	Incident		LSF	400	0	N/A
10/21/1988	Canada	Happy Lake, NT	Canada TSB	LDOR	Incident	DHC6		N/R	N/R	N/A
11/10/1988	US	Burbank, CA	MITRE	LDOR	Incident	B17	BUR	470	0	N/A
11/13/1988	US	Nashville, TN	MITRE	LDOR	Incident	SW4	BNA	N/R	N/R	N/A
11/17/1988	US	Bend, OR	NTSB	LDOR	Accident	LJ25	BDN	200	0	N/A
12/19/1988	US	Charleston, SC	ASRS	LDOR	Incident		CHS	150	0	N/A
12/30/1988	US	San Jose, CA	MITRE	LDOR	Incident	LJ35	SJC	N/R	N/R	N/A
1/9/1989	US	Baton Rouge, LA	NTSB	LDOR	Incident	DC91	BTR	300	0	N/A
1/12/1989	US	Crossville, TN	AIDS	LDOR	Incident	C500	CSV	N/R	N/R	N/A
1/19/1989	US	Baton Rouge, LA	ASRS	LDOR	Incident		BTR	200	0	N/A
2/15/1989	US	Binghamton, NY	NTSB	LDOR	Accident		BGM	200	80	N/A
2/19/1989	US	Covington, OH	ASRS	LDOR	Incident		CVG	60	-140	N/A
2/20/1989	US	Bloomington, IL	MITRE	LDOR	Incident	SH36	BMI	N/R	N/R	N/A
2/27/1989	US	Poughkeepsie, NY	NTSB	LDOR	Accident	C550	POU	700	100	N/A
3/19/1989	US	Chicago, IL	ASRS	LDOR	Incident		ORD	500	30	N/A
3/19/1989	US	Daytona Beach, FL	ASRS	LDOR	Incident		DAB	50	0	N/A
3/19/1989	US	Washington, DC	ASRS	LDOR	Incident		DCA	150	0	N/A
3/23/1989	US	Roanoke, VA	NTSB	LDOR	Accident	LJ25	ROA	200	10	N/A
3/29/1989	US	Owensboro, KY	MITRE	LDOR	Incident	MU30	OWB	N/R	N/R	N/A
4/1/1989	UK	Leeds Bradford	UK AAIB	LDOR	Incident	SH36	LBA	N/R	N/R	N/A
4/12/1989	US	San Diego, CA	MITRE	LDOR	Incident	B752	SAN	N/R	N/R	N/A
4/19/1989	US	San Diego, CA	ASRS	LDOR	Incident		SAN	280	50	N/A
5/4/1989	US	El Monte, CA	AIDS	LDOR	Incident	C500	EMT	N/R	N/R	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
5/18/1989	US	Jackson, MS	MITRE	LDOR	Incident	MU30	JAN	N/R	N/R	N/A
6/5/1989	US	Greensboro, NC	MITRE	LDOR	Incident	BE20	GSO	N/R	N/R	N/A
7/18/1989	US	Chicago, IL	NTSB	LDOR	Incident	DC10	ORD	N/R	N/R	N/A
7/27/1989	US	Jackson, WY	MITRE	LDOR	Incident	B731	JAC	N/R	N/R	N/A
10/18/1989	US	Monte Vista, CO	NTSB	LDOR	Incident	DC91	MVI	N/R	N/R	N/A
10/19/1989	US	Dover, DE	ASRS	LDOR	Incident		DOV	200	0	N/A
10/23/1989	US	Anchorage, AK	MITRE	LDOR	Incident	B741	ANC	N/R	N/R	N/A
12/13/1989	US	Chicago, IL	NTSB	LDOR	Incident	DC91	MDW	304	30	N/A
12/30/1989	US	Tucson, AZ	NTSB	LDOR	Accident	B731	TUS	3803	175	N/A
1/19/1990	US	Denver, CO	ASRS	LDOR	Incident		DEN	100	0	N/A
4/5/1990	US	Pensacola, FL	MITRE	LDOR	Incident	F86	PNS	N/R	N/R	N/A
4/22/1990	Australia	Lord Howe Island	ASN	LDOR	Accident	C501	LDH	250	0	N/A
4/28/1990	New Zealand	Queenstown	TAIC	LDOR	Incident	B461	ZQN	318	82	N/A
7/18/1990	US	Milwaukee, WI	NTSB	LDOR	Accident	MU30	MWC	N/R	N/R	N/A
7/19/1990	US	Jackson, WY	ASRS	LDOR	Incident		JAC	310	0	N/A
7/29/1990	US	Jackson, WY	MITRE	LDOR	Incident	B731	JAC	N/R	N/R	N/A
8/19/1990	US	Santa Ana, CA	ASRS	LDOR	Incident		SNA	75	0	N/A
10/4/1990	US	Dallas, TX	MITRE	LDOR	Incident	GNAT	ADS	N/R	N/R	N/A
2/14/1991	US	Cleveland, OH	NTSB	LDOR	Accident	GLF2	BKL	250	150	N/A
3/12/1991	US	Alexandria, MN	AIDS	LDOR	Incident	MU30	AXN	N/R	N/R	N/A
3/19/1991	US	Raleigh, NC	ASRS	LDOR	Incident		RDU	150	0	N/A
3/29/1991	US	Sioux City, IA	MITRE	LDOR	Incident	AC11	SUX	N/R	N/R	N/A
6/19/1991	US	Kansas City, MO	ASRS	LDOR	Incident		MCI	500	0	N/A
6/26/1991	US	Kansas City, MO	MITRE	LDOR	Incident	B721	MCI	N/R	N/R	N/A
7/2/1991	US	Columbia, TN	NTSB	LDOR	Accident	LJ23	MRC	543	38	N/A
8/10/1991	US	Charlotte, NC	AIDS	LDOR	Incident	B762	CLT	50	0	N/A
8/19/1991	US	Seattle, WA	ASRS	LDOR	Incident		SEA	25	30	N/A
8/19/1991	US	Charlotte, NC	ASRS	LDOR	Incident		CLT	80	0	N/A
10/6/1991	US	Augusta, ME	NTSB	LDOR	Accident	SW4	AUG	20	0	N/A
11/19/1991	US	Los Angeles, CA	ASRS	LDOR	Incident		LAX	150	0	N/A
11/26/1991	US	Los Angeles, CA	MITRE	LDOR	Incident	B731	LAX	N/R	N/R	N/A

12/23/1991	US	Carlsbad, CA	NTSB	LDOR	Accident	LJ25	CRQ	50	75	N/A
3/31/1992	UK	Aberdeen	UK AAIB	LDOR	Accident	B461	ABZ	479	43	N/A
4/19/1992	US	Fort Lauderdale, FL	MITRE	LDOR	Incident	ASTR	FLL	N/R	N/R	N/A
4/23/1992	US	Detroit, MI	NTSB	LDOR	Accident	DC85	YIP	N/R	N/R	N/A
5/19/1992	US	Bozeman, MT	ASRS	LDOR	Incident		BZN	150	0	N/A
6/17/1992	US	Cedar Rapids, IA	NTSB	LDOR	Accident	SBR1	CID	212	0	N/A
7/1/1992	US	Chicago, IL	AIDS	LDOR	Incident	B752	ORD	25	0	N/A
7/11/1992	US	Cheyenne, WY	MITRE	LDOR	Incident	B190	CYS	N/R	N/R	N/A
7/19/1992	US	Chicago, IL	ASRS	LDOR	Incident		ORD	30	0	N/A
7/19/1992	N Mariana	Rota Island	ASRS	LDOR	Incident		ROP	10	0	N/A
7/29/1992	US	Jackson, WY	MITRE	LDOR	Incident	B752	JAC	N/R	N/R	N/A
8/7/1992	US	Milwaukee, WI	MITRE	LDOR	Incident	B721	MKE	N/R	N/R	N/A
8/19/1992	US	Milwaukee, WI	ASRS	LDOR	Incident		MKE	250	0	N/A
8/23/1992	US	Louisville, KY	MITRE	LDOR	Incident	MD88	SDF	N/R	N/R	N/A
9/8/1992	US	Wilmington, NC	MITRE	LDOR	Incident	MU30	ILM	N/R	N/R	N/A
11/7/1992	US	Phoenix, AZ	NTSB	LDOR	Accident	SBR1	PHX	1500	120	N/A
11/22/1992	US	Cleveland, OH	NTSB	LDOR	Accident	LJ25	CLE	200	0	N/A
11/27/1992	UK	Southampton	UK AAIB	LDOR	Accident		SOU	246	0	N/A
2/13/1993	US	Portland, ME	NTSB	LDOR	Incident	B731	PWM	330	50	N/A
2/19/1993	US	Portland, ME	ASRS	LDOR	Incident		PWM	260	0	N/A
4/27/1993	US	Denver, CO	NTSB	LDOR	Accident	DC91	DEN	1	30	N/A
4/29/1993	US	Pine Bluff, AR	NTSB	LDOR	Accident	E120	PBF	687	50	N/A
5/24/1993	US	Killeen, TX	AIDS	LDOR	Incident	FA10	ILE	N/R	N/R	N/A
5/26/1993	England	Southampton	UK AAIB	LDOR	Accident	C550	SOU	630	0	N/A
6/4/1993	US	Springfield, MO	MITRE	LDOR	Incident	FA10	SGF	N/R	N/R	N/A
7/21/1993	Canada	Tofino, BC	TSB	LDOR	Incident	CVLT	YAZ	152	20	N/A
8/26/1993	US	Hailey, ID	NTSB	LDOR	Accident	FA10	SUN	850	260	N/A
9/12/1993	French Polynesia	Papeete	France BEA	LDOR	Accident	B741	PPT	230	197	N/A
9/19/1993	US	Washington, DC	ASRS	LDOR	Incident		DCA	50	0	N/A
9/29/1993	England	Norwich	UK AAIB	LDOR	Incident	BA11	NWI	89	0	N/A
12/4/1993	US	Corvallis, OR	AIDS	LDOR	Incident	L29B	CVO	N/R	N/R	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
1/19/1994	US	Windsor Locks, CT	MITRE	LDOR	Incident	DC91	BDL	N/R	N/R	N/A
1/19/1994	US	Wilmington, OH	ASRS	LDOR	Incident		ILN	10	0	N/A
1/20/1994	US	Teterboro, NJ	NTSB	LDOR	Accident	MU30	TEB	N/R	N/R	N/A
1/21/1994	Canada	Terrace, BC	Canada TSB	LDOR	Incident	B461	YXT	415	39	N/A
1/27/1994	US	Chicago, IL	MITRE	LDOR	Incident	DC85	ORD	59	0	N/A
1/27/1994	US	Pontiac, MI	MITRE	LDOR	Incident	LJ35	PTK	30	0	N/A
2/1/1994	US	New Roads, LA	NTSB	LDOR	Accident	SF34	HZR	420	20	N/A
2/8/1994	US	Washington, DC	AIDS	LDOR	Incident	MD80	DCA	50	50	N/A
2/19/1994	US	Rifle, CO	ASRS	LDOR	Incident	B461	RIL	630	70	N/A
2/19/1994	US	Washington, DC	ASRS	LDOR	Incident		DCA	250	50	N/A
3/19/1994	US	State College, PA	ASRS	LDOR	Incident	JS32	UNV	20	0	N/A
3/19/1994	US	Columbus, OH	ASRS	LDOR	Incident		CMH	260	0	N/A
4/26/1994	US	Anderson, IN	AIDS	LDOR	Incident	CVLP	AID	N/R	N/R	N/A
6/13/1994	US	Lewisburg, WV	MITRE	LDOR	Incident	LJ35	LWB	130	0	N/A
7/22/1994	US	Jackson, WY	MITRE	LDOR	Incident	B731	JAC	61	0	N/A
8/10/1994	S Korea	Jeju	ADREP	LDOR	Accident	A30B	CJU	1427	3278	N/A
8/19/1994	US	Savannah, GA	ASRS	LDOR	Incident		SAV	2	30	N/A
10/8/1994	US	Pittsburgh, PA	MITRE	LDOR	Incident	B190	PIT	N/R	N/R	N/A
10/10/1994	US	San Antonio, TX	AIDS	LDOR	Accident	LJ35	SAT	N/R	N/R	N/A
11/4/1994	US	Little Rock, AR	MITRE	LDOR	Incident	DC91	LIT	N/R	N/R	N/A
11/17/1994	US	Bozeman, MT	AIDS	LDOR	Incident	DC91	BZN	290	0	N/A
12/7/1994	US	Batavia, NY	AIDS	LDOR	Incident	C550	GVQ	N/R	N/R	N/A
1/19/1995	US	Atlanta, GA	NTSB	LDOR	Incident	B731	ATL	250	0	N/A
1/24/1995	US	Milwaukee, WI	AIDS	LDOR	Incident		MKE	100	0	N/A
2/1/1995	US	Atlanta, GA	ASRS	LDOR	Incident	DC85	ATL	470	90	N/A
2/17/1995	US	Atlanta, GA	MITRE	LDOR	Incident	DC85	ATL	N/R	N/R	N/A
2/19/1995	US	Chicago, IL	ASRS	LDOR	Incident		ORD	200	-70	N/A
2/19/1995	US	Chicago, IL	ASRS	LDOR	Incident	DC10	ORD	10	0	N/A
2/22/1995	US	Chicago, IL	MITRE	LDOR	Incident	DC10	ORD	N/R	N/R	N/A
3/1/1995	Canada	Jasper Hinton, AB	TSB	LDOR	Incident	MU30	CEC4	256	0	N/A
3/19/1995	US	Honolulu, HI	ASRS	LDOR	Incident	DC10	HNL	100	70	N/A
4/29/1995	US	Chicago, IL	MITRE	LDOR	Incident	DC85	ORD	N/R	N/R	N/A

5/11/1995	Canada	Wabush, NL	TSB	LDOR	Incident	B721	YWK	299	21	N/A
6/7/1995	US	Hyannis, MA	AIDS	LDOR	Incident	C500	HYA	300	0	N/A
7/26/1995	US	Minneapolis, MN	NTSB	LDOR	Accident	C550	FCM	800	0	N/A
8/21/1995	US	Mesa, AZ	MITRE	LDOR	Incident	LJ23	FFZ	N/R	N/R	N/A
9/19/1995	US	Fayetteville, AR	ASRS	LDOR	Incident		FYV	52	0	N/A
9/19/1995	US	Charleston, SC	ASRS	LDOR	Incident	MD88	CHS	50	160	N/A
12/8/1995	US	Chicago, IL	MITRE	LDOR	Incident	B721	ORD	40	0	N/A
12/9/1995	US	Jackson, WY	AIDS	LDOR	Incident	MU30	JAC	N/R	N/R	N/A
12/14/1995	US	Detroit, MI	AIDS	LDOR	Incident	LJ55	DET	485	0	N/A
12/19/1995	US	Los Angeles, CA	ASRS	LDOR	Incident	B731	LAX	160	100	N/A
1/1/1996	England	Leicestershire	UK AAIB	LDOR	Incident	F70	EMA	377	30	N/A
1/2/1996	Australia	Bankstown	ATSB	LDOR	Incident	A37	BWU	N/R	N/R	N/A
1/5/1996	England	Leicestershire	AAIB	LDOR	Incident	DC85	EMA	N/R	N/R	N/A
1/19/1996	US	Jackson, WY	MITRE	LDOR	Incident	E120	JAC	N/R	N/R	N/A
1/26/1996	US	Sparta, TN	AIDS	LDOR	Incident	FA20	SRB	279	0	N/A
2/7/1996	US	Bradford, PA	NTSB	LDOR	Accident	B190	BFD	870	825	N/A
2/7/1996	US	Mammoth Lakes, CA	AIDS	LDOR	Incident	SW2	MMH	20	0	N/A
2/19/1996	US	Houston, TX	NTSB	LDOR	Accident	DC91	IAH	51	140	N/A
2/19/1996	US	Savannah, GA	ASRS	LDOR	Incident		SAV	300	50	N/A
2/20/1996	US	Washington, DC	NTSB	LDOR	Incident	B731	DCA	250	0	N/A
2/20/1996	US	Washington, DC	AIDS	LDOR	Incident	B731	DCA	150	75	N/A
2/20/1996	US	Rifle, CO	NTSB	LDOR	Incident	H25B	RIL	1000	80	N/A
2/28/1996	US	Savannah, GA	NTSB	LDOR	Incident	DC91	SAV	201	0	N/A
3/25/1996	US	Hailey, ID	AIDS	LDOR	Incident	C500	SUN	40	0	N/A
4/3/1996	US	Traverse City, MI	AIDS	LDOR	Incident	AT43	TVC	N/R	N/R	N/A
4/3/1996	Canada	Moncton, NB	Canada TSB	LDOR	Incident	B721	YQM	154	0	N/A
8/13/1996	UK	Northolt	UK AAIB	LDOR	Accident	LJ25	NHT	748	115	N/A
9/28/1996	US	Chillicothe, OH	NTSB	LDOR	Accident	MU2	RZT	15	147	N/A
10/6/1996	US	Salinas, CA	MITRE	LDOR	Incident	F86	SNS	N/R	N/R	N/A
10/14/1996	US	Las Vegas, NV	AIDS	LDOR	Incident	AC68	VGT	400	0	N/A
10/29/1996	US	Waukegan, IL	MITRE	LDOR	Incident	CL60	UGN	N/R	N/R	N/A
11/1/1996	US	Cleveland, OH	ASRS	LDOR	Incident	MD88	CLE	285	0	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
11/11/1996	US	Cleveland, OH	AIDS	LDOR	Incident	MD80	CLE	200	0	N/A
11/11/1996	US	Cleveland, OH	NTSB	LDOR	Incident	MD88	CLE	530	35	N/A
11/15/1996	US	Sioux Falls, SD	MITRE	LDOR	Incident	DC91	FSD	N/R	N/R	N/A
11/19/1996	US	Honolulu, HI	ASRS	LDOR	Incident	DC10	HNL	25	0	N/A
12/6/1996	US	Bedford, MA	AIDS	LDOR	Incident	GLF2	BED	N/R	N/R	N/A
12/22/1996	US	Hailey, ID	AIDS	LDOR	Incident	CL60	SUN	N/R	N/R	N/A
1/1/1997	US	Kansas City, MO	NTSB	LDOR	Accident	LJ35	MKC	105	1000	N/A
1/3/1997	US	Jackson, WY	AIDS	LDOR	Incident	WW24	JAC	60	0	N/A
1/21/1997	US	Bloomington, IN	NTSB	LDOR	Accident	BE30	BMG	600	0	N/A
1/25/1997	US	Provincetown, MA	NTSB	LDOR	Incident	C402	PVC	80	0	N/A
2/19/1997	US	Chicago, IL	ASRS	LDOR	Incident	B731	ORD	10	0	N/A
2/27/1997	US	Greenville, SC	NTSB	LDOR	Accident	LJ35	GMU	350	0	N/A
3/12/1997	US	Houston, TX	AIDS	LDOR	Incident	MU30	SGR	145	0	N/A
4/10/1997	US	Bloomington, IL	MITRE	LDOR	Incident	JS41	BMI	N/R	N/R	N/A
5/21/1997	US	San Diego, CA	NTSB	LDOR	Accident	E120	NKX	1300	0	N/A
6/25/1997	England	London	AAIB	LDOR	Incident	B461	EGLC	99	10	N/A
7/3/1997	US	Pensacola, FL	AIDS	LDOR	Incident	B190	PNS	N/R	N/R	N/A
7/5/1997	US	Ardmore, OK	NTSB	LDOR	Accident	SBR1	ADM	60	0	N/A
7/15/1997	US	Avon Park, FL	NTSB	LDOR	Accident	LJ35	AVO	1800	550	N/A
7/30/1997	Italy	Florence	ADREP	LDOR	Accident	AT43	FLR	394	0	N/A
8/3/1997	US	East Hampton, NY	AIDS	LDOR	Incident	C560	HTO	330	30	N/A
8/19/1997	US	Des Moines, IA	NTSB	LDOR	Accident	SW3	DSM	867	0	N/A
11/29/1997	Wales	Fairwood Common	AAIB	LDOR	Incident	VAMP	EGFH	N/R	N/R	N/A
12/7/1997	England	Channel Islands	AAIB	LDOR	Accident	F27	EGJB	130	30	N/A
12/19/1997	US	Savannah, GA	ASRS	LDOR	Incident	B721	SAV	20	0	N/A
12/19/1997	US	Memphis, TN	ASRS	LDOR	Incident	DC10	MEM	75	0	N/A
1/6/1998	US	Pittsburgh, PA	NTSB	LDOR	Accident	C500	AGC	375	75	N/A
1/7/1998	UK	London City	AAIB	LDOR	Incident	B461	LCY	144	0	N/A
1/16/1998	US	Van Nuys, CA	AIDS	LDOR	Incident	GLF4	VNY	N/R	N/R	N/A
1/19/1998	US	Portland, ME	ASRS	LDOR	Incident	B721	PWM	215	0	N/A
1/19/1998	US	Mekoryuk, AK	ASRS	LDOR	Incident		MYU	355	40	N/A
1/22/1998	US	Denver, CO	MITRE	LDOR	Incident	DC85	DEN	N/R	N/R	N/A

1/22/1998	US	Denver, CO	AIDS	LDOR	Incident	DC85	DEN	N/R	N/R	N/A
2/3/1998	US	Omaha, NE	AIDS	LDOR	Incident	C414	OMA	100	0	N/A
2/18/1998	Canada	Peterborough, ON	TSB	LDOR	Incident	FA10	YPQ	236	0	N/A
2/23/1998	US	Van Nuys, CA	AIDS	LDOR	Incident	LJ35	VNY	50	0	N/A
2/26/1998	US	Pittsburgh, PA	AIDS	LDOR	Incident	WW24	AGC	24	0	N/A
3/4/1998	US	Manistee, MI	NTSB	LDOR	Accident	C650	MBL	150	0	N/A
3/11/1998	US	Aspen, CO	MITRE	LDOR	Incident	B461	ASE	N/R	N/R	N/A
3/14/1998	US	Portland, ME	MITRE	LDOR	Incident	MD81	PWM	600	0	N/A
3/14/1998	US	Portland, ME	AIDS	LDOR	Incident	MD80	PWM	600	15	N/A
3/25/1998	US	Columbus, OH	AIDS	LDOR	Incident	CL60	OSU	N/R	N/R	N/A
3/31/1998	US	Des Moines, IA	MITRE	LDOR	Incident	B721	DSM	N/R	N/R	N/A
4/1/1998	US	Chinle, AZ	AIDS	LDOR	Incident	C421	E91	N/R	N/R	N/A
4/19/1998	US	Lincoln, NE	AIDS	LDOR	Incident	C650	LNK	N/R	N/R	N/A
5/19/1998	US	Atlanta, GA	ASRS	LDOR	Incident	DC91	ATL	200	0	N/A
5/23/1998	US	Orlando, FL	NTSB	LDOR	Accident	LJ24	ORL	500	0	N/A
6/19/1998	US	Fishers Island, NY	NTSB	LDOR	Accident	C500	0B8	115	0	N/A
6/21/1998	Spain	Ibiza	Spain TSB	LDOR	Accident	A320	LEIB	250	150	N/A
7/14/1998	US	Pittsburgh, PA	AIDS	LDOR	Incident	B731	PIT	N/R	N/R	N/A
7/14/1998	US	Pittsburgh, PA	MITRE	LDOR	Incident	B731	PIT	N/R	N/R	N/A
7/22/1998	UK	Belfast	UK AAIB	LDOR	Incident	B461	BHD	23	0	N/A
8/6/1998	Canada	Kasabonika, ON	Canada TSB	LDOR	Accident	A748	XKS	449	0	N/A
8/28/1998	US	Minneapolis, MN	AIDS	LDOR	Incident	BE30	FCM	N/R	N/R	N/A
9/26/1998	England	Fairoaks	UK AAIB	LDOR	Accident	C560	FRK	765	140	N/A
10/24/1998	UK	Southampton	UK AAIB	LDOR	Incident	F100	SOU	262	0	N/A
11/19/1998	US	Atlanta, GA	ASRS	LDOR	Incident	DC85	ATL	85	0	N/A
12/18/1998	US	Rochester, NY	AIDS	LDOR	Incident	B721	ROC	600	0	N/A
12/18/1998	US	Rochester, NY	MITRE	LDOR	Incident	B721	ROC	600	110	N/A
12/24/1998	US	Providence, RI	AIDS	LDOR	Incident	MD80	PVD	N/R	N/R	N/A
12/26/1998	US	Jackson, WY	MITRE	LDOR	Incident	B731	JAC	N/R	N/R	N/A
12/29/1998	US	Jackson, WY	AIDS	LDOR	Incident	BE30	JAC	46	0	N/A
1/19/1999	US	Wilmington, OH	ASRS	LDOR	Incident	DC85	ILN	800	100	N/A
1/20/1999	US	Chino, CA	AIDS	LDOR	Incident	GLF2	CNO	150	0	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
2/8/1999	Netherlands	Amsterdam	Netherland TSB	LDOR	Incident	B741	EHAM	100	0	N/A
2/16/1999	US	Van Nuys, CA	NTSB	LDOR	Accident	GLF2	VNY	1072	451	N/A
2/18/1999	US	Columbus, NE	NTSB	LDOR	Accident	MU30	OLU	150	0	N/A
3/9/1999	US	Indianapolis, IN	MITRE	LDOR	Incident	DC85	IND	30	0	N/A
4/17/1999	US	Beckley, WV	NTSB	LDOR	Accident	BE40	BKW	216	0	N/A
4/28/1999	US	Crossville, TN	AIDS	LDOR	Incident	FA10	CSV	N/R	N/R	N/A
5/4/1999	US	Sparta, TN	AIDS	LDOR	Incident	FA20	SRB	140	0	N/A
5/8/1999	US	New York, NY	NTSB	LDOR	Accident	SF34	JFK	350	0	N/A
6/1/1999	US	Little Rock, AR	NTSB	LDOR	Accident	MD82	LIT	800	20	N/A
6/19/1999	Philippines	Manila	ASRS	LDOR	Incident		XCN	N/R	N/R	N/A
7/1/1999	US	Hyannis, MA	NTSB	LDOR	Accident	LJ60	HYA	745	0	N/A
7/19/1999	US	Minneapolis, MN	ASRS	LDOR	Incident	B721	MSP	125	0	N/A
7/30/1999	US	Minneapolis, MN	AIDS	LDOR	Incident	B721	MSP	100	0	N/A
7/30/1999	US	Minneapolis, MN	MITRE	LDOR	Incident	B721	MSP	100	0	N/A
8/1/1999	Canada	St. John's, NL	Canada TSB	LDOR	Accident	F28	YYT	420	90	N/A
8/5/1999	US	Mineral Point, WI	AIDS	LDOR	Incident	BE99	MRJ	N/R	N/R	N/A
8/9/1999	US	Minneapolis, MN	AIDS	LDOR	Incident	DC10	MSP	200	0	N/A
8/14/1999	US	Saranac Lake, NY	AIDS	LDOR	Incident	B721	SLK	30	0	N/A
8/19/1999	US	Minneapolis, MN	ASRS	LDOR	Incident	DC10	MSP	200	30	N/A
9/6/1999	Scotland	Shetland	AAIB	LDOR	Accident	C208	EGPB	135	0	N/A
9/19/1999	US	Minneapolis, MN	ASRS	LDOR	Incident	DC91	MSP	25	0	N/A
9/19/1999	Ireland	Shannon	ASRS	LDOR	Incident	MD11	SNN	N/R	N/R	N/A
9/23/1999	Thailand	Bangkok	ATSB	LDOR	Accident	B741	BKK	1049	59	N/A
9/26/1999	US	Gainesville, GA	NTSB	LDOR	Accident	LJ24	GVL	274	100	N/A
10/19/1999	France	Paris	ASRS	LDOR	Incident	MD11	CDG	190	50	N/A
11/22/1999	Canada	Dryden, ON	Canada TSB	LDOR	Accident	SW4	YHD	300	0	N/A
12/13/1999	US	Atlanta, GA	MITRE	LDOR	Incident	C550	PDK	20	0	N/A
12/29/1999	US	Traverse City, MI	MITRE	LDOR	Accident	DC91	TVC	N/R	N/R	N/A
1/1/2000	US	Charlotte, NC	ASRS	LDOR	Incident	DC91	CLT	225	0	N/A
1/19/2000	US	Gary, IN	MITRE	LDOR	Incident	B721	GYY	N/R	N/R	N/A
1/20/2000	US	Sparta, TN	ASRS	LDOR	Incident	FA10	SRB	N/R	N/R	N/A

1/27/2000	US	Dallas, TX	NTSB	LDOR	Accident	MU30	DAL	N/R	N/R	N/A
2/16/2000	Japan	Sapporo	ADREP	LDOR	Accident	YS11	OKD	N/R	N/R	N/A
2/29/2000	US	Houston, TX	MITRE	LDOR	Incident	B731	IAH	N/R	N/R	N/A
3/5/2000	US	Burbank, CA	NTSB	LDOR	Accident	B731	BUR	200	200	N/A
3/12/2000	US	Jackson, WY	NTSB	LDOR	Accident	LJ60	JAC	160	0	N/A
3/17/2000	US	Hyannis, MA	NTSB	LDOR	Accident	F900	HYA	667	0	N/A
3/21/2000	US	Killeen, TX	NTSB	LDOR	Accident	SF34	ILE	175	3	N/A
4/1/2000	US	Eagle, CO	AIDS	LDOR	Incident	H25A	EGE	9	0	N/A
5/18/2000	US	Milwaukee, WI	AIDS	LDOR	Incident	AC56	MWC	228	0	N/A
6/29/2000	US	Joliet, IL	NTSB	LDOR	Accident	BE20	JOT	170	0	N/A
7/1/2000	England	Coventry	UK AAIB	LDOR	Accident	F27	CVT	852	98	N/A
7/23/2000	Canada	Dorval, QC	Canada TSB	LDOR	Incident	B741	YUL	700	0	N/A
8/9/2000	US	Portland, OR	AIDS	LDOR	Incident	C402	PDX	250	0	N/A
9/1/2000	Canada	Ottawa, ON	ASRS	LDOR	Incident	B721	YOW	100	0	N/A
9/15/2000	Canada	Ottawa, ON	Canada TSB	LDOR	Incident	B721	YOW	234	0	N/A
10/20/2000	US	Saint Louis, MO	ASRS	LDOR	Incident	MD82	STL	807	225	N/A
11/28/2000	Canada	Fredericton, NB	Canada TSB	LDOR	Incident	F28	YFC	320	0	N/A
12/18/2000	Canada	Windsor, ON	Canada TSB	LDOR	Incident	A124	YQG	340	0	N/A
12/24/2000	French Polynesia	Papeete	France BEA	LDOR	Accident	DC10	PPT	230	82	N/A
12/29/2000	US	Charlottesville, VA	NTSB	LDOR	Accident	JS41	CHO	60	0	N/A
1/1/2001	US	Glasgow, KY	ASRS	LDOR	Incident	BE9L	GLW	N/R	N/R	N/A
2/4/2001	US	Ft. Pierce, FL	NTSB	LDOR	Accident	LJ25	FPR	N/R	N/R	N/A
2/13/2001	US	Olympia, WA	NTSB	LDOR	Accident	BE20	OLM	442	0	N/A
3/4/2001	US	Phoenix, AZ	NTSB	LDOR	Incident	B731	PHX	75	0	N/A
3/9/2001	US	Bridgeport, CT	NTSB	LDOR	Accident	H25A	BDR	22	0	N/A
3/12/2001	US	Telluride, CO	AIDS	LDOR	Incident	LJ35	TEX	N/R	N/R	N/A
3/17/2001	France	Lyon	France BEA	LDOR	Incident	B731	LYS	279	197	N/A
3/20/2001	US	Shreveport, LA	ASRS	LDOR	Incident	E110	SHV	110	0	N/A
3/20/2001	US	El Paso, TX	ASRS	LDOR	Incident		ELP	150	0	N/A
4/4/2001	Canada	St. John's, NL	Canada TSB	LDOR	Accident	B731	YYT	75	53	N/A
5/28/2001	US	Chicago, IL	MITRE	LDOR	Incident	B731	ORD	205	0	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
6/14/2001	US	Van Nuys, CA	AIDS	LDOR	Incident	C550	VNY	N/R	N/R	N/A
7/20/2001	US	Portland, ME	ASRS	LDOR	Incident	SF34	PWM	50	0	N/A
8/16/2001	US	Saint Paul, MN	AIDS	LDOR	Incident	C404	STP	N/R	N/R	N/A
8/28/2001	US	Detroit, MI	NTSB	LDOR	Accident	FA10	DET	679	120	N/A
8/30/2001	US	Olathe, KS	AIDS	LDOR	Incident	GLF5	OJC	200	0	N/A
11/19/2001	Unknown	Unknown	AIDS	LDOR	Incident	MU30	Unknown	N/R	N/R	N/A
12/1/2001	US	Philadelphia, PA	ASRS	LDOR	Incident	C550	PHL	250	0	N/A
12/13/2001	US	Telluride, CO	AIDS	LDOR	Incident	SW3	TEX	N/R	N/R	N/A
12/14/2001	US	Philadelphia, PA	AIDS	LDOR	Incident	C560	PHL	N/R	N/R	N/A
1/1/2002	US	Miami, FL	NTSB	LDOR	Incident	MD83	MIA	590	135	N/A
1/19/2002	US	Atlanta, GA	AIDS	LDOR	Incident	MU30	PDK	440	0	N/A
1/22/2002	US	Elberta, AL	AIDS	LDOR	Incident	BE40	4AL7	N/R	N/R	N/A
2/10/2002	US	Cleveland, OH	NTSB	LDOR	Accident	MU30	CGF	106	0	N/A
3/25/2002	US	Anderson, IN	NTSB	LDOR	Accident	MU30	AID	30	50	N/A
3/26/2002	US	Erie, PA	MITRE	LDOR	Incident	DC91	ERI	40	0	N/A
5/1/2002	US	Baltimore, MD	NTSB	LDOR	Accident	BE40	BWI	680	0	N/A
5/2/2002	US	Leakey, TX	NTSB	LDOR	Accident	C560	49R	560	50	N/A
5/23/2002	US	Olathe, KS	AIDS	LDOR	Incident	C500	OJC	N/R	N/R	N/A
6/1/2002	Australia	Darwin	ATSB	LDOR	Incident	B731	YPDN	44	0	N/A
6/20/2002	Dominican Republic	Santo Domingo	ASRS	LDOR	Incident	B721	SDQ	200	0	N/A
7/12/2002	Ireland	Dublin	AAIU	LDOR	Incident	SH36	EIDW	47	0	N/A
8/13/2002	US	Big Bear City, CA	NTSB	LDOR	Accident	C550	L35	406	30	N/A
8/30/2002	US	Lexington, KY	NTSB	LDOR	Accident	LJ25	LEX	410	10	N/A
9/10/2002	Canada	Gander, NL	Canada TSB	LDOR	Accident	DC85	YQX	900	0	N/A
9/15/2002	US	La Porte, TX	AIDS	LDOR	Incident	C550	PPO	100	0	N/A
11/2/2002	Ireland	Sligo	AAIU	LDOR	Accident	F27	SXL	328	98	N/A
11/22/2002	US	Soldotna, AK	AIDS	LDOR	Incident	ASTR	SXQ	N/R	N/R	N/A
12/1/2002	US	Spokane, WA	AIDS	LDOR	Incident	DH8A	GEG	N/R	N/R	N/A
12/13/2002	Singapore	Singapore	AAIB Singapore	LDOR	Incident	DC85	SIN	968	197	N/A
12/20/2002	US	Spokane, WA	ASRS	LDOR	Incident	DH8A	GEG	100	0	N/A
12/20/2002	US	White Plains, NY	ASRS	LDOR	Incident	H25A	HPN	200	0	N/A

1/6/2003	US	Cleveland, OH	NTSB	LDOR	Accident	E145	CLE	785	0	N/A
1/6/2003	US	Rifle, CO	AIDS	LDOR	Incident	GLF4	RIL	160	0	N/A
1/17/2003	Spain	Melilla	CIAIAC	LDOR	Accident	F50	MLN	710	90	N/A
1/30/2003	England	Norwich	UK AAIB	LDOR	Incident	E135	NWI	426	33	N/A
2/8/2003	US	Bethel, AK	MITRE	LDOR	Incident	LJ25	BET	N/R	N/R	N/A
2/15/2003	Italy	Florence	AIDS	LDOR	Incident	B741	FLR	770	0	N/A
2/15/2003	US	Rifle, CO	AIDS	LDOR	Incident	CL60	RIL	27	0	N/A
2/17/2003	US	Eagle, CO	MITRE	LDOR	Incident	LJ60	EGE	N/R	N/R	N/A
2/17/2003	US	Eagle, CO	AIDS	LDOR	Incident	LJ60	EGE	N/R	N/R	N/A
2/20/2003	Italy	Sigonella	ASRS	LDOR	Incident	B741	NSY	800	0	N/A
2/27/2003	US	Lewisburg, TN	AIDS	LDOR	Incident	FA20	LUG	150	0	N/A
3/4/2003	US	Stockton, CA	AIDS	LDOR	Incident	GLF5	SCK	N/R	N/R	N/A
3/27/2003	US	Waukegan, IL	MITRE	LDOR	Incident	MU2	UGN	N/R	N/R	N/A
5/18/2003	US	Houston, TX	NTSB	LDOR	Accident	BE30	IWS	20	0	N/A
5/20/2003	US	Minneapolis, MN	ASRS	LDOR	Incident	B731	MSP	200	0	N/A
5/28/2003	England	Leeds	UK AAIB	LDOR	Incident	C560	LBA	525	86	N/A
5/30/2003	US	New York, NY	NTSB	LDOR	Incident	MD11	JFK	238	0	N/A
7/1/2003	Unknown	Unknown	ASRS	LDOR	Incident	FA10	Unknown	N/R	N/R	N/A
7/13/2003	US	Evansville, IN	AIDS	LDOR	Incident	LJ60	EVV	150	0	N/A
9/19/2003	US	Del Rio, TX	NTSB	LDOR	Accident	LJ25	DRT	1600	100	N/A
10/1/2003	Belgium	Liège	ASN	LDOR	Accident	B741	LGG	260	0	N/A
11/5/2003	US	Naples, FL	AIDS	LDOR	Incident	C650	APF	N/R	N/R	N/A
11/17/2003	US	Tulsa, OK	AIDS	LDOR	Incident	LJ24	RVS	183	0	N/A
1/2/2004	US	Pensacola, FL	AIDS	LDOR	Incident	MD80	PNS	100	0	N/A
1/3/2004	US	Minocqua, WI	AIDS	LDOR	Incident	C500	ARV	N/R	N/R	N/A
1/25/2004	US	Greensboro, NC	AIDS	LDOR	Incident	JS41	GSO	N/R	N/R	N/A
2/20/2004	US	Fort Lauderdale, FL	NTSB	LDOR	Accident	LJ25	FXE	1689	220	N/A
2/29/2004	US	San Diego, CA	AIDS	LDOR	Incident	AC68	MYF	N/R	N/R	N/A
3/1/2004	US	Mobile, AL	AIDS	LDOR	Incident	C500	BFM	N/R	N/R	N/A
3/19/2004	US	Pueblo, CO	AIDS	LDOR	Incident	E120	PUB	N/R	N/R	N/A
3/20/2004	Unknown	Unknown	ASRS	LDOR	Incident	B190	Unknown	25	0	N/A
3/26/2004	US	Watertown, NY	AIDS	LDOR	Accident	B190	ART	N/R	N/R	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
4/19/2004	Canada	Chibougamau, QC	Canada TSB	LDOR	Accident	BE10	YMT	500	0	N/A
4/20/2004	US	New Orleans, LA	ASRS	LDOR	Incident	B731	MSY	200	0	N/A
5/12/2004	US	Mesa, AZ	AIDS	LDOR	Incident	FA10	FFZ	N/R	N/R	N/A
5/20/2004	US	Honolulu, HI	ASRS	LDOR	Incident	B762	HNL	75	0	N/A
6/3/2004	US	Lexington, KY	AIDS	LDOR	Incident	LJ55	LEX	N/R	N/R	N/A
6/23/2004	US	Houston, TX	AIDS	LDOR	Incident	E145	IAH	50	30	N/A
7/14/2004	Canada	Ottawa, ON	Canada TSB	LDOR	Incident	E145	YOW	300	0	N/A
7/19/2004	US	Fort Lauderdale, FL	NTSB	LDOR	Accident	LJ55	FXE	950	280	N/A
7/20/2004	US	Tallahassee, FL	ASRS	LDOR	Incident	DC91	TLH	400	0	N/A
8/5/2004	US	Watertown, NY	AIDS	LDOR	Incident	CL60	ART	23	55	N/A
8/5/2004	US	Oxford, NC	AIDS	LDOR	Incident	LJ25	HNZ	N/R	N/R	N/A
8/20/2004	Unknown	Unknown	ASRS	LDOR	Incident	B731	Unknown	25	0	N/A
10/1/2004	US	Panama City, FL	ASRS	LDOR	Incident		PFN	50	0	N/A
11/10/2004	US	Panama City, FL	AIDS	LDOR	Incident	BE20	PFN	N/R	N/R	N/A
12/1/2004	US	Teterboro, NJ	NTSB	LDOR	Accident	GLF4	TEB	100	490	N/A
12/5/2004	US	Pine Bluff, AR	NTSB	LDOR	Accident	FA10	PBF	240	0	N/A
12/16/2004	Canada	Oshawa, ON	Canada TSB	LDOR	Accident	SH36	YOO	600	0	N/A
1/1/2005	US	Madison, WI	AIDS	LDOR	Incident	CL60	MSN	N/R	N/R	N/A
1/3/2005	US	San Diego, CA	AIDS	LDOR	Incident	PA31	MYF	255	0	N/A
1/12/2005	US	Jacksonville, FL	NTSB	LDOR	Accident	B350	CRG	557	20	N/A
1/24/2005	Germany	Düsseldorf	ASN	LDOR	Accident	B741	DUS	2050	50	N/A
2/28/2005	US	Lincolnton, NC	AIDS	LDOR	Incident	LJ35	IPJ	300	0	N/A
3/8/2005	US	Teterboro, NJ	NTSB	LDOR	Incident	H25B	TEB	230	0	N/A
5/20/2005	US	Wallace, NC	AIDS	LDOR	Incident	C500	ACZ	220	0	N/A
6/14/2005	US	Norwood, MA	AIDS	LDOR	Incident	FA10	OWD	400	0	N/A
8/2/2005	Canada	Toronto, ON	Canada TSB	LDOR	Accident	A342	YYZ	1000	30	N/A
8/13/2005	US	Portsmouth, VA	AIDS	LDOR	Incident	L18	PVG	N/R	N/R	N/A
9/23/2005	US	San Diego, CA	AIDS	LDOR	Incident	BE40	MYF	200	0	N/A
10/5/2005	US	Jacksonville, FL	NTSB	LDOR	Incident	BE58	JAX	N/R	N/R	N/A
10/29/2005	US	Nashville, TN	AIDS	LDOR	Incident	BE20	JWN	700	0	N/A
11/15/2005	Canada	Hamilton, ON	Canada TSB	LDOR	Accident	ASTR	CYHM	272	100	N/A

12/8/2005	US	Chicago, IL	NTSB	LDOR	Accident	B737	MDW	500	5	N/A
12/29/2005	US	Indianapolis, IN	AIDS	LDOR	Incident	LJ25	EYE	20	0	N/A
2/5/2006	England	Bedfordshire	AAIB	LDOR	Incident	CL60	EGGW	98	0	N/A
2/11/2006	Kuwait	Kuwait City	AIDS	LDOR	Incident	MD11	OKBK	80	0	N/A
2/20/2006	Unknown	Unknown	ASRS	LDOR	Incident	MD11	Unknown	220	0	N/A
2/28/2006	US	Albuquerque, NM	AIDS	LDOR	Incident	LJ25	AEG	N/R	N/R	N/A
3/3/2006	US	Teterboro, NJ	AIDS	LDOR	Incident	F900	TEB	N/R	N/R	N/A
3/8/2006	Canada	Powell River, BC	Canada TSB	LDOR	Accident	PA31	CYPW	113	0	N/A
5/30/2006	US	Mosinee, WI	AIDS	LDOR	Incident	CL60	CWI	400	0	N/A
6/22/2006	Scotland	Aberdeen	UK AAIB	LDOR	Incident	D328	ABZ	1148	40	N/A
10/6/2006	US	Las Vegas, NV	AIDS	LDOR	Incident	B190	VGT	N/R	N/R	N/A
10/10/2006	Norway	Sørstokken	ASN	LDOR	Accident	B461	SRP	500	0	N/A
10/10/2006	England	Hampshire	AAIB	LDOR	Incident	SW4	EGHL	34	0	N/A
10/13/2006	US	Burbank, CA	AIDS	LDOR	Incident	GLF2	BUR	N/R	N/R	N/A
12/2/2006	US	Seattle, WA	AIDS	LDOR	Incident	DH8A	SEA	N/R	N/R	N/A
12/12/2006	US	Great Bend, KS	AIDS	LDOR	Incident	PA31	GBD	N/R	N/R	N/A
1/26/2007	US	Pontiac, MI	AIDS	LDOR	Incident	CL60	PTK	N/R	N/R	N/A
2/18/2007	US	Cleveland, OH	NTSB	LDOR	Accident	E170	CLE	310	160	N/A
2/20/2007	England	London	AAIB	LDOR	Incident	B461	EGLC	33	0	N/A
3/7/2007	Indonesia	Yogyakarta	NTSC Indonesia	LDOR	Accident	B731	WARJ	252	30	N/A
3/29/2007	US	Oklahoma City, OK	AIDS	LDOR	Incident	GALX	PWA	500	0	N/A
4/12/2007	US	Traverse City, MI	NTSB	LDOR	Accident	CL60	TVC	500	0	N/A
5/1/2007	US	Philadelphia, PA	AIDS	LDOR	Incident	C560	PHL	100	0	N/A
6/20/2007	US	Laramie, WY	NTSB	LDOR	Accident	B190	LAR	160	481	N/A
7/18/2007	US	Minneapolis, MN	AIDS	LDOR	Incident	B731	MSP	120	0	N/A
11/1/2007	US	Fort Lauderdale, FL	AIDS	LDOR	Incident	GLF2	FXE	500	0	N/A
12/1/2007	US	Madison, WI	AIDS	LDOR	Incident	CL60	MSN	45	0	N/A
12/10/2007	US	Idaho Falls, ID	AIDS	LDOR	Incident	MD80	IDA	N/R	N/R	N/A
1/27/2008	US	Spokane, WA	AIDS	LDOR	Incident	B731	GEG	500	0	N/A
1/30/2008	US	Decatur, IL	AIDS	LDOR	Incident	B752	DEC	N/R	N/R	N/A
2/25/2008	US	Jackson, WY	NTSB	LDOR	Incident	A320	JAC	116	140	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
3/7/2008	US	Columbus, OH	AIDS	LDOR	Incident	B731	CMH	267	0	N/A
3/15/2008	US	San Antonio, TX	AIDS	LDOR	Incident	LJ35	SAT	240	0	N/A
5/4/2008	US	Fort Collins/Loveland, CO	AIDS	LDOR	Incident	MD80	FNL	10	0	N/A
6/24/2008	US	Nantucket, MA	AIDS	LDOR	Incident	SW3	ACK	N/R	N/R	N/A
12/28/2008	US	Houston, TX	AIDS	LDOR	Incident		BPT	50	0	N/A
1/4/2009	US	Syracuse, NY	AIDS	LDOR	Incident	E145	SYR	N/R	N/R	N/A
2/28/2009	US	Savannah, GA	AIDS	LDOR	Incident	CL60	SAV	750	0	N/A
4/3/1978	US	Detroit, MI	AIDS	LDUS	Incident	DC10	DTW	-50	0	N/A
5/31/1978	US	Lewistown, MT	AIDS	LDUS	Incident	MU2	LWT	N/R	N/R	N/A
6/29/1978	US	Ebensburg, PA	AIDS	LDUS	Incident	MU2	9G8	N/R	N/R	N/A
1/10/1979	US	Lubbock, TX	AIDS	LDUS	Incident	LJ24	LBB	-120	0	N/A
1/27/1979	US	Agana, GU	AIDS	LDUS	Incident	B721	GUM	-278	0	N/A
8/17/1979	US	Oklahoma City, OK	AIDS	LDUS	Accident	FA20	PWA	-200	0	N/A
8/28/1979	US	Saipan, MP	AIDS	LDUS	Incident	B721	GSN	N/R	N/R	N/A
12/21/1979	US	Burlington, VT	AIDS	LDUS	Incident	BA11	BTV	-100	0	N/A
12/22/1979	US	Denver, CO	AIDS	LDUS	Incident	B721	DEN	-50	0	N/A
7/25/1980	US	Tampa, FL	AIDS	LDUS	Incident	B721	TPA	-50	0	N/A
10/19/1980	US	Phoenix, AZ	AIDS	LDUS	Incident	B721	PHX	-500	0	N/A
10/22/1980	US	Phoenix, AZ	AIDS	LDUS	Incident	DC91	PHX	-500	0	N/A
3/12/1981	US	Cincinnati, OH	AIDS	LDUS	Incident	SBR1	LUK	-50	0	N/A
4/18/1981	US	Sand Point, AK	AIDS	LDUS	Incident	YS11	SDP	-300	0	N/A
11/26/1981	US	Augusta, GA	AIDS	LDUS	Incident	B721	AGS	-300	0	N/A
1/19/1982	US	Rockport, TX	NTSB	LDUS	Accident	SW3	RKP	-1821	317	N/A
5/16/1982	US	Hooper Bay, AK	NTSB	LDUS	Accident	DHC6	HPB	-1270	50	N/A
1/23/1983	US	New York, NY	AIDS	LDUS	Incident	DC85	JFK	-200	0	N/A
3/20/1983	US	Chicago, IL	AIDS	LDUS	Incident	SBR1	ORD	N/R	N/R	N/A
7/7/1983	US	Rochelle, IL	AIDS	LDUS	Incident	BE20	RPJ	N/R	N/R	N/A
12/12/1983	US	Coatesville, PA	NTSB	LDUS	Accident	SBR1	40N	-20	250	N/A
12/21/1983	US	Detroit, MI	NTSB	LDUS	Accident	BE20	DET	-125	0	N/A
1/5/1984	US	Seattle, WA	NTSB	LDUS	Incident	B721	SEA	-360	0	N/A
4/8/1984	US	Austin, TX	AIDS	LDUS	Incident	LJ25	AUS	-50	0	N/A

7/12/1984	US	Mcalester, OK	NTSB	LDUS	Accident	BE18	MLC	N/R	N/R	N/A
5/12/1985	US	Lake Geneva, WI	NTSB	LDUS	Accident	FA10	C02	-13	5	N/A
6/28/1985	US	Charlotte, NC	NTSB	LDUS	Accident	PAY3	CLT	-1800	0	N/A
8/2/1985	US	Dallas, TX	NTSB	LDUS	Accident	L101	DFW	-6336	360	N/A
9/25/1985	US	Dutch Harbor, AK	NTSB	LDUS	Accident	B731	DUT	N/R	N/R	N/A
2/7/1986	US	Mekoryuk, AK	NTSB	LDUS	Accident	DHC6	MYU	N/R	N/R	N/A
2/8/1986	US	Harlingen, TX	AIDS	LDUS	Accident	B721	HRL	-250	0	N/A
5/20/1986	US	Hutchinson, KS	NTSB	LDUS	Incident	SW3	HUT	-3	0	N/A
7/1/1986	US	Lincoln, NE	NTSB	LDUS	Accident	SW4	LNK	-243	0	N/A
9/29/1986	US	Liberal, KS	NTSB	LDUS	Accident	SBR1	LBL	-21	0	N/A
1/4/1987	US	Hudson, NY	AIDS	LDUS	Incident	LJ55	1B1	-100	0	N/A
2/11/1987	US	Oneonta, NY	NTSB	LDUS	Accident	BE99	N66	-10	100	N/A
6/22/1987	US	Atlanta, GA	AIDS	LDUS	Incident	DH8A	ATL	N/R	N/R	N/A
9/28/1987	US	Saint Louis, MO	AIDS	LDUS	Incident	MD80	STL	-30	0	N/A
11/23/1987	US	Homer, AK	NTSB	LDUS	Accident	B190	HOM	-159	0	N/A
12/5/1987	US	Lexington, KY	NTSB	LDUS	Accident	H25A	LEX	N/R	N/R	N/A
2/16/1988	US	Groton, CT	AIDS	LDUS	Incident	SF34	GON	-150	0	N/A
6/1/1988	US	New York, NY	NTSB	LDUS	Incident	B741	JFK	N/R	N/R	N/A
7/26/1988	US	Morristown, NJ	NTSB	LDUS	Accident	LJ35	MMU	-660	75	N/A
9/19/1988	US	San Diego, CA	ASRS	LDUS	Incident		SAN	-50	0	N/A
12/19/1988	US	Sandusky, OH	ASRS	LDUS	Incident		SKY	-60	0	N/A
3/15/1989	US	Lafayette, IN	NTSB	LDUS	Accident	YS11	LAF	-510	13	N/A
4/13/1989	US	Scottsdale, AZ	NTSB	LDUS	Accident	H25B	SCF	-10	0	N/A
5/6/1989	US	Columbia, TN	NTSB	LDUS	Accident	E110	MRC	-2350	20	N/A
7/19/1989	US	Sioux City, IA	NTSB	LDUS	Accident	DC10	SUX	-198	761	N/A
8/21/1989	US	Gold Beach, OR	NTSB	LDUS	Accident	BE9L	4S1	-50	150	N/A
12/26/1989	US	Pasco, WA	NTSB	LDUS	Accident	JS31	PSC	-1200	20	N/A
1/17/1990	US	West Point, MS	NTSB	LDUS	Accident	BE40	M83	-6	0	N/A
1/19/1990	US	Little Rock, AR	NTSB	LDUS	Accident	GLF2	LIT	-1600	0	N/A
5/4/1990	US	Wilmington, NC	NTSB	LDUS	Accident	NOMA	ILM	-600	0	N/A
11/29/1990	US	Sebring, FL	NTSB	LDUS	Accident	C550	SEF	-100	60	N/A
12/16/1990	US	Marshfield, WI	AIDS	LDUS	Incident	C500	MFI	N/R	N/R	N/A

(continued on next page)

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12/20/1990	US	Mcminnville, OR	AIDS	LDUS	Incident	FA10	MMV	N/R	N/R	N/A
5/15/1991	US	Nashville, TN	NTSB	LDUS	Incident	B721	BNA	-408	0	N/A
10/19/1991	US	Allakaket, AK	NTSB	LDUS	Accident	BE99	AET	-100	30	N/A
11/15/1991	US	Brigham City, UT	AIDS	LDUS	Incident	H25A	BMC	N/R	N/R	N/A
6/16/1992	US	New Castle, DE	NTSB	LDUS	Accident	BE20	ILG	-1320	0	N/A
8/8/1992	US	Nuiqsut, AK	NTSB	LDUS	Accident	BE99	AQT	-50	0	N/A
11/5/1992	US	San Antonio, TX	AIDS	LDUS	Incident	SW4	SAT	N/R	N/R	N/A
7/19/1993	US	Nantucket, MA	ASRS	LDUS	Incident		ACK	-150	0	N/A
7/30/1993	US	Nantucket, MA	AIDS	LDUS	Incident	B731	ACK	-50	0	N/A
12/8/1993	US	Dallas, TX	NTSB	LDUS	Incident	B731	DFW	-1095	0	N/A
1/24/1994	US	Key Largo, FL	NTSB	LDUS	Incident	LJ35	07FA	-35	0	N/A
2/19/1995	US	Portland, OR	ASRS	LDUS	Incident	B721	PDX	-350	0	N/A
3/3/1995	US	Gillette, WY	NTSB	LDUS	Accident	WW24	GCC	-50	0	N/A
6/19/1995	Panama	Panama City	ASRS	LDUS	Incident	B741	PTY	-350	0	N/A
9/18/1995	US	Chino, CA	NTSB	LDUS	Accident	SW3	CNO	-1000	75	N/A
10/12/1995	US	Cleveland, OH	NTSB	LDUS	Accident	GLF2	CLE	N/R	N/R	N/A
11/19/1995	US	Anchorage, AK	AIDS	LDUS	Incident	C441	ANC	N/R	N/R	N/A
1/7/1996	US	Nashville, TN	NTSB	LDUS	Accident	DC91	BNA	-90	0	N/A
8/31/1996	US	Lubbock, TX	AIDS	LDUS	Incident	B721	LBB	-10	0	N/A
10/19/1996	US	Flushing, NY	NTSB	LDUS	Accident	MD88	LGA	-303	95	N/A
4/7/1997	US	Stebbins, AK	NTSB	LDUS	Accident	PA31	WBB	-153	0	N/A
8/13/1997	US	Lexington, KY	NTSB	LDUS	Accident	FA20	LEX	-13	215	N/A
8/14/1997	US	Dalton, GA	NTSB	LDUS	Accident	BE20	DNN	-1105	135	N/A
10/19/1997	Hong Kong	Hong Kong	ASRS	LDUS	Incident	B741	HKG	-150	0	N/A
11/13/1997	US	Wheeling, WV	NTSB	LDUS	Accident	BE65	HLG	-90	125	N/A
2/9/1998	US	Chicago, IL	NTSB	LDUS	Accident	B721	ORD	-300	500	N/A
2/19/1998	Hong Kong	Hong Kong	ASRS	LDUS	Incident	B741	HKG	-900	0	N/A
2/11/1999	US	Grand Island, NE	AIDS	LDUS	Incident	GLF5	GRI	N/R	N/R	N/A
2/19/1999	US	Miami, FL	ASRS	LDUS	Incident	A30B	MIA	-75	0	N/A
3/30/1999	England	Newquay	AAIB	LDUS	Incident	C550	EGHQ	-266	0	N/A
3/30/1999	US	Rogers, AR	NTSB	LDUS	Accident	LJ35	ROG	-12	100	N/A

5/19/1999	US	New York, NY	ASRS	LDUS	Incident	B762	JFK	-100	0	N/A
9/24/1999	Canada	St. John's, NL	Canada TSB	LDUS	Accident	A320	YYT	-250	0	N/A
12/30/2000	US	Salt Lake City, UT	AIDS	LDUS	Incident	MD90	SLC	-400	0	N/A
5/25/2001	French Guiana	Cayenne	France BEA	LDUS	Incident	A343	CAY	-98	0	N/A
6/12/2001	US	Salina, KS	NTSB	LDUS	Accident	LJ25	SLN	-2254	85	N/A
9/19/2001	US	Indianapolis, IN	NTSB	LDUS	Accident	BE20	IND	-621	0	N/A
10/20/2001	US	Houston, TX	ASRS	LDUS	Incident	B731	IAH	-100	0	N/A
1/15/2002	US	Kings Ford, MI	AIDS	LDUS	Incident	SW3	IMT	N/R	N/R	N/A
7/26/2002	US	Tallahassee, FL	NTSB	LDUS	Accident	B721	TLH	-1677	454	N/A
10/15/2002	Canada	Ontario, ON	AIDS	LDUS	Incident	B741	ONT	-50	0	N/A
10/20/2002	US	Ontario, CA	ASRS	LDUS	Incident	B741	ONT	-45	0	N/A
1/5/2003	US	Oklahoma City, OK	AIDS	LDUS	Incident	SBR1	PWA	N/R	N/R	N/A
4/9/2003	US	Du Bois, PA	NTSB	LDUS	Accident	SH33	DUJ	-500	-50	N/A
6/28/2003	US	Goodnews, AK	NTSB	LDUS	Accident	SW3	GNU	-100	0	N/A
10/9/2003	US	Montague, CA	AIDS	LDUS	Incident	BE99	1O5	N/R	N/R	N/A
11/18/2003	US	Dallas, TX	NTSB	LDUS	Accident	C550	DFW	-350	0	N/A
1/26/2004	US	Prescott, AZ	AIDS	LDUS	Incident	C560	PRC	N/R	N/R	N/A
6/6/2004	US	San Jose, CA	AIDS	LDUS	Incident	H25A	SJC	N/R	N/R	N/A
8/25/2004	US	Venice, FL	NTSB	LDUS	Accident	C550	VNC	-30	0	N/A
1/9/2007	Canada	Fort St. John, BC	Canada TSB	LDUS	Incident	JS31	CYXJ	-320	0	N/A
12/17/2007	US	Vernal, UT	AIDS	LDUS	Incident	BE99	VEL	-50	0	N/A
7/13/2008	US	Saratoga Springs, NY	AIDS	LDUS	Incident	LJ45	5B2	N/R	N/R	N/A
9/15/2008	US	Nantucket, MA	AIDS	LDUS	Incident	C414	ACK	N/R	N/R	N/A
1/27/2009	US	Lubbock, TX	NTSB	LDUS	Accident	AT43	LBB	-630	0	N/A
1/10/1978	US	White Plains, NY	AIDS	LDVO	Incident	SBR1	HPN	N/A	N/A	N/R
1/25/1978	US	Owensboro, KY	AIDS	LDVO	Incident	FA10	OWB	N/A	N/A	N/R
1/26/1978	US	Flint, MI	AIDS	LDVO	Incident	LJ25	FNT	N/A	N/A	N/R
9/4/1978	US	Angier, NC	AIDS	LDVO	Incident		78NC	N/A	N/A	N/R
9/5/1978	US	Lafayette, IN	AIDS	LDVO	Incident	C500	LAF	N/A	N/A	N/R
1/29/1979	US	Independence, KS	AIDS	LDVO	Incident	SW3	IDP	N/A	N/A	N/R
2/2/1979	US	Grand Rapids, MI	AIDS	LDVO	Incident	LJ24	GRR	N/A	N/A	N/R

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
2/7/1979	US	Elko, NV	AIDS	LDVO	Incident		EKO	N/A	N/A	N/R
2/28/1979	US	Morristown, TN	AIDS	LDVO	Incident	SW2	MOR	N/A	N/A	N/R
4/4/1979	US	Dayton, OH	AIDS	LDVO	Incident	LJ23	DAY	N/A	N/A	N/R
4/29/1979	US	Fairbanks, AK	AIDS	LDVO	Incident	GLF5	PAFA	N/A	N/A	N/R
7/28/1979	US	Downey, ID	AIDS	LDVO	Incident	AC68	U58	N/A	N/A	N/R
8/15/1979	US	Campbellton, TX	AIDS	LDVO	Incident	C500	0XA5	N/A	N/A	N/R
12/29/1979	US	Van Nuys, CA	AIDS	LDVO	Incident	GLF5	VNY	N/A	N/A	N/R
1/6/1980	US	Chicago, IL	AIDS	LDVO	Incident	WW24	Unknown	N/A	N/A	N/R
1/16/1980	US	Clarksburg, WV	AIDS	LDVO	Incident	GA7	CKB	N/A	N/A	N/R
3/11/1980	US	Islip, NY	AIDS	LDVO	Incident	SW3	ISP	N/A	N/A	N/R
3/13/1980	US	Hagerstown, MD	AIDS	LDVO	Incident	SW4	HGR	N/A	N/A	N/R
10/1/1980	England	Saint Peter	AAIB	LDVO	Accident	C500	EGJJ	N/A	N/A	548
10/2/1980	US	Cleveland, OH	AIDS	LDVO	Incident	FA10	CLE	N/A	N/A	N/R
10/26/1980	US	Flushing, NY	AIDS	LDVO	Incident	SW3	LGA	N/A	N/A	N/R
11/18/1980	US	New Castle, DE	AIDS	LDVO	Incident	SW2	ILG	N/A	N/A	N/R
12/5/1980	US	Islip, NY	AIDS	LDVO	Incident	AC90	ISP	N/A	N/A	N/R
1/13/1981	US	Savoy, IL	AIDS	LDVO	Incident	AC68	CMI	N/A	N/A	N/R
2/11/1981	US	Indianapolis, IN	AIDS	LDVO	Incident	AC90	IND	N/A	N/A	N/R
3/17/1981	US	Tucson, AZ	AIDS	LDVO	Incident	LJ24	TUS	N/A	N/A	N/R
9/6/1981	US	Denver, CO	AIDS	LDVO	Incident	GLF2	DEN	N/A	N/A	N/R
10/2/1981	US	Lexington, KY	AIDS	LDVO	Incident	SW2	LEX	N/A	N/A	N/R
10/15/1981	US	Saint Louis, MO	AIDS	LDVO	Incident	DC6	STL	N/A	N/A	N/R
10/31/1981	US	Jackson, MS	AIDS	LDVO	Incident	BE20	JAN	N/A	N/A	N/R
11/23/1981	US	Saint Paul, MN	AIDS	LDVO	Incident	FA10	STP	N/A	N/A	N/R
12/17/1981	US	Van Nuys, CA	AIDS	LDVO	Incident	LJ24	VNY	N/A	N/A	N/R
1/2/1982	US	Cedar City, UT	AIDS	LDVO	Incident	BE20	CDC	N/A	N/A	N/R
1/6/1982	US	Atlanta, GA	AIDS	LDVO	Incident	SW2	PDK	N/A	N/A	N/R
1/15/1982	US	Atlanta, GA	AIDS	LDVO	Incident	SW2	Unknown	N/A	N/A	N/R
2/2/1982	US	Port Clinton, OH	AIDS	LDVO	Incident	BE20	PCW	N/A	N/A	N/R
2/24/1982	US	Chicago, IL	NTSB	LDVO	Incident	SW4	ORD	N/A	N/A	N/R
4/8/1982	US	Teterboro, NJ	AIDS	LDVO	Incident	LJ35	TEB	N/A	N/A	N/R
5/18/1982	US	Gillette, WY	NTSB	LDVO	Incident	G159	GCC	N/A	N/A	20

5/21/1982	US	Dayton, OH	NTSB	LDVO	Incident	BA11	DAY	N/A	N/A	N/R
6/8/1982	US	Gillette, WY	NTSB	LDVO	Incident	G159	GCC	N/A	N/A	N/R
6/16/1982	US	Scottsbluff, NE	AIDS	LDVO	Incident	SW4	BFF	N/A	N/A	N/R
9/5/1982	England	Stansted Mountfitchet	AAIB	LDVO	Incident	DC85	EGSS	N/A	N/A	238
10/13/1982	US	Atlanta, GA	AIDS	LDVO	Incident	H25A	Unknown	N/A	N/A	N/R
1/3/1983	US	Sacramento, CA	AIDS	LDVO	Incident	SW3	SAC	N/A	N/A	N/R
2/5/1983	US	Atlanta, GA	AIDS	LDVO	Incident	MU30	PDK	N/A	N/A	N/R
2/6/1983	US	Saint Paul Island, AK	AIDS	LDVO	Incident	LJ24	SNP	N/A	N/A	N/R
2/16/1983	US	Manchester, NH	AIDS	LDVO	Incident	WW24	MHT	N/A	N/A	N/R
2/24/1983	US	Anchorage, AK	AIDS	LDVO	Incident	LJ24	ANC	N/A	N/A	N/R
3/1/1983	US	Houston, TX	AIDS	LDVO	Incident	AC11	HOU	N/A	N/A	N/R
3/1/1983	US	Corpus Christi, TX	AIDS	LDVO	Incident	SW3	CRP	N/A	N/A	N/R
3/17/1983	US	Denver, CO	AIDS	LDVO	Incident	AC90	DEN	N/A	N/A	N/R
3/22/1983	US	Ulysses, KS	AIDS	LDVO	Incident	BE20	ULS	N/A	N/A	N/R
3/27/1983	US	Chicago, IL	AIDS	LDVO	Incident	LJ55	PWK	N/A	N/A	N/R
4/5/1983	US	Hutchinson, KS	NTSB	LDVO	Accident	AC50	HUT	N/A	N/A	5
4/14/1983	US	Elkhart, IN	AIDS	LDVO	Incident	SW2	GSH	N/A	N/A	N/R
5/6/1983	US	Lincoln, NE	AIDS	LDVO	Incident	SW3	LNK	N/A	N/A	N/R
6/1/1983	US	Las Vegas, NV	NTSB	LDVO	Accident	C402	VGT	N/A	N/A	88
7/18/1983	US	El Paso, TX	AIDS	LDVO	Incident	LJ25	ELP	N/A	N/A	N/R
9/12/1983	US	Destin, FL	AIDS	LDVO	Incident	C500	DTS	N/A	N/A	N/R
11/8/1983	US	Franklin, PA	NTSB	LDVO	Accident	BE18	FKL	N/A	N/A	130
11/11/1983	US	Cleveland, OH	AIDS	LDVO	Incident	G159	LNN	N/A	N/A	N/R
11/23/1983	US	Chicago, IL	AIDS	LDVO	Incident	LJ55	PWK	N/A	N/A	N/R
11/28/1983	US	Johnstown, PA	AIDS	LDVO	Incident	G159	JST	N/A	N/A	N/R
2/22/1984	US	Cordova, AK	NTSB	LDVO	Incident	E110	CDV	N/A	N/A	10
7/3/1984	US	Denver, CO	NTSB	LDVO	Incident	B722	Stapleton	N/A	N/A	N/R
7/7/1984	US	Gualala, CA	NTSB	LDVO	Accident	C500	Q69	N/A	N/A	N/R
7/8/1984	US	Oakland, CA	AIDS	LDVO	Incident	SBR1	OAK	N/A	N/A	N/R
8/18/1984	US	Cedar City, UT	AIDS	LDVO	Incident		CDC	N/A	N/A	N/R
9/29/1984	US	Houston, TX	NTSB	LDVO	Incident	DHC6	IAH	N/A	N/A	30
12/5/1984	US	Minneapolis, MN	AIDS	LDVO	Incident	SW2	MSP	N/A	N/A	N/R

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
12/12/1984	US	Detroit, MI	AIDS	LDVO	Incident	LJ24	YIP	N/A	N/A	N/R
12/19/1984	US	Salt Lake City, UT	AIDS	LDVO	Incident	LJ25	SLC	N/A	N/A	N/R
12/19/1984	US	Springdale, AR	AIDS	LDVO	Incident	SBR1	XNA	N/A	N/A	N/R
1/29/1985	US	Dobbins Afb, GA	NTSB	LDVO	Accident	L188	MGE	N/A	N/A	70
1/31/1985	US	Denver, CO	AIDS	LDVO	Incident	LJ35	DEN	N/A	N/A	N/R
3/30/1985	US	Fort Lauderdale, FL	NTSB	LDVO	Incident	C402	FLL	N/A	N/A	50
9/28/1985	US	Broomfield, CO	AIDS	LDVO	Incident	WW24	BJC	N/A	N/A	N/R
10/25/1985	US	Monterey, CA	AIDS	LDVO	Incident	WW24	MRY	N/A	N/A	N/R
11/14/1985	US	Bloomington, IL	AIDS	LDVO	Incident	F27	BMI	N/A	N/A	N/R
12/5/1985	US	Lafayette, IN	AIDS	LDVO	Incident	H25A	LAF	N/A	N/A	N/R
12/20/1985	US	Cleveland, OH	AIDS	LDVO	Incident	LJ35	Unknown	N/A	N/A	N/R
2/21/1986	US	Dallas, TX	AIDS	LDVO	Incident	FA10	Unknown	N/A	N/A	N/R
5/16/1986	US	Laramie, WY	NTSB	LDVO	Accident	BE99	LAR	N/A	N/A	90
7/1/1986	US	Chicago, IL	AIDS	LDVO	Incident	LJ35	DPA	N/A	N/A	N/R
8/17/1986	US	Llano, CA	AIDS	LDVO	Incident		46CN	N/A	N/A	N/R
10/30/1986	US	Saint Louis, MO	AIDS	LDVO	Accident	AC90	Unknown	N/A	N/A	N/R
11/6/1986	US	Bedford, MA	AIDS	LDVO	Incident	AC95	BED	N/A	N/A	200
11/20/1986	US	White Plains, NY	AIDS	LDVO	Incident	C550	HPN	N/A	N/A	N/R
1/9/1987	US	Bloomington, IL	AIDS	LDVO	Incident	B190	BMI	N/A	N/A	N/R
2/25/1987	US	Durango, CO	NTSB	LDVO	Incident	B732	DRO	N/A	N/A	N/R
2/27/1987	US	Kalamazoo, MI	AIDS	LDVO	Incident	WW24	AZO	N/A	N/A	N/R
3/16/1987	US	Oklahoma City, OK	AIDS	LDVO	Incident	F900	OKC	N/A	N/A	N/R
3/18/1987	US	Atlanta, GA	AIDS	LDVO	Incident	C550	PDK	N/A	N/A	N/R
5/1/1987	US	Jacksonville, FL	AIDS	LDVO	Incident	LJ25	CRG	N/A	N/A	N/R
8/12/1987	US	Marion, IN	AIDS	LDVO	Incident	CL60	MZZ	N/A	N/A	N/R
9/18/1987	US	Reno, NV	AIDS	LDVO	Incident	AC68	RNO	N/A	N/A	N/R
10/23/1987	US	Avalon, CA	NTSB	LDVO	Accident	C402	AVX	N/A	N/A	130
11/17/1987	US	Port Angeles, WA	NTSB	LDVO	Incident	BE99	CLM	N/A	N/A	50
12/9/1987	US	Van Nuys, CA	AIDS	LDVO	Incident	C550	VNY	N/A	N/A	N/R
12/14/1987	US	Chicago, IL	AIDS	LDVO	Incident	BE20	MDW	N/A	N/A	N/R
12/24/1987	US	Aspen, CO	AIDS	LDVO	Incident	WW24	ASE	N/A	N/A	N/R
12/26/1987	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	AC11	FXE	N/A	N/A	N/R

12/27/1987	US	Denver, CO	NTSB	LDVO	Incident	MD80	DEN	N/A	N/A	70
1/4/1988	US	Belmar, NJ	AIDS	LDVO	Incident	LJ25	BLM	N/A	N/A	N/R
1/7/1988	US	Oakland, CA	AIDS	LDVO	Incident	GLF5	OAK	N/A	N/A	N/R
1/13/1988	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	LJ25	FLL	N/A	N/A	N/R
1/21/1988	US	Dallas, TX	AIDS	LDVO	Incident	FA10	DAL	N/A	N/A	N/R
1/22/1988	US	Starkville, MS	AIDS	LDVO	Incident	AC90	STF	N/A	N/A	N/R
2/2/1988	US	Denver, CO	NTSB	LDVO	Accident	CVLT	DEN	N/A	N/A	5
2/4/1988	US	Newburgh, NY	AIDS	LDVO	Incident	LJ55	SWF	N/A	N/A	N/R
2/19/1988	US	Lansing, MI	AIDS	LDVO	Incident	L29B	LAN	N/A	N/A	N/R
3/15/1988	US	Teterboro, NJ	AIDS	LDVO	Incident	BE20	TEB	N/A	N/A	N/R
4/15/1988	US	Seattle, WA	NTSB	LDVO	Accident	DH8A	SEA	N/A	N/A	1675
7/31/1988	US	Saint Louis, MO	AIDS	LDVO	Incident	BE20	SUS	N/A	N/A	N/R
8/29/1988	US	Bakersfield, CA	AIDS	LDVO	Incident	AC90	BFL	N/A	N/A	N/R
9/21/1988	US	Van Nuys, CA	AIDS	LDVO	Incident	C500	VNY	N/A	N/A	N/R
10/7/1988	US	Durango, CO	AIDS	LDVO	Incident	BE20	DRO	N/A	N/A	N/R
10/14/1988	US	Anchorage, AK	AIDS	LDVO	Incident	YS11	ANC	N/A	N/A	N/R
3/2/1989	US	Rifle, CO	AIDS	LDVO	Incident	SBR1	RIL	N/A	N/A	N/R
3/3/1989	US	Rockford, IL	AIDS	LDVO	Incident	WW24	RFD	N/A	N/A	N/R
3/17/1989	US	Waukegan, IL	AIDS	LDVO	Incident	FA10	UGN	N/A	N/A	N/R
3/31/1989	US	Windsor Locks, CT	AIDS	LDVO	Incident	CL60	BDL	N/A	N/A	N/R
10/19/1989	US	Waukegan, IL	AIDS	LDVO	Incident	C650	UGN	N/A	N/A	N/R
11/28/1989	US	Houma, LA	AIDS	LDVO	Incident	C550	HUM	N/A	N/A	N/R
12/10/1989	US	Denver, CO	AIDS	LDVO	Incident	WW24	APA	N/A	N/A	N/R
12/27/1989	US	Merced, CA	AIDS	LDVO	Incident	LJ25	MCE	N/A	N/A	N/R
1/24/1990	US	Olathe, KS	AIDS	LDVO	Incident	LJ55	IXD	N/A	N/A	N/R
2/20/1990	US	Chicago, IL	AIDS	LDVO	Incident	C650	ARR	N/A	N/A	N/R
6/6/1990	US	Alton, IL	AIDS	LDVO	Incident	LJ35	ALN	N/A	N/A	N/R
8/8/1990	US	Ames, IA	AIDS	LDVO	Incident	SBR1	AMW	N/A	N/A	N/R
10/12/1990	US	Burlington, VT	AIDS	LDVO	Incident	B190	BTV	N/A	N/A	N/R
11/18/1990	US	Atlanta, GA	AIDS	LDVO	Incident	FA10	PDK	N/A	N/A	N/R
12/10/1990	US	Indianapolis, IN	AIDS	LDVO	Incident	AC90	IND	N/A	N/A	N/R
1/9/1991	US	Philadelphia, PA	AIDS	LDVO	Incident	WW24	PNE	N/A	N/A	N/R

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
1/13/1991	US	Palmyra, PA	AIDS	LDVO	Incident	AC68	58N	N/A	N/A	N/R
1/30/1991	US	Cleveland, OH	AIDS	LDVO	Incident	SBR1	CGF	N/A	N/A	N/R
2/5/1991	US	Cochran, GA	NTSB	LDVO	Incident		48A	N/A	N/A	75
2/15/1991	US	Louisville, KY	AIDS	LDVO	Incident	SW3	SDF	N/A	N/A	N/R
3/3/1991	US	Columbus, OH	AIDS	LDVO	Incident	LJ35	OSU	N/A	N/A	N/R
4/10/1991	US	Richmond, VA	AIDS	LDVO	Incident	SBR1	RIC	N/A	N/A	N/R
5/1/1991	US	Oxford, CT	NTSB	LDVO	Accident	WW24	OXC	N/A	N/A	100
6/11/1991	US	Seattle, WA	AIDS	LDVO	Incident	DHC6	BFI	N/A	N/A	N/R
7/19/1991	US	Boone, NC	AIDS	LDVO	Incident		NC14	N/A	N/A	N/R
9/5/1991	US	Waukegan, IL	AIDS	LDVO	Incident	FA10	UGN	N/A	N/A	N/R
11/11/1991	US	Rochester, NY	AIDS	LDVO	Incident	B190	ROC	N/A	N/A	N/R
1/10/1992	US	Coeur D Alene, ID	AIDS	LDVO	Incident	LJ35	COE	N/A	N/A	N/R
1/27/1992	US	Louisville, KY	AIDS	LDVO	Incident	LJ35	LOU	N/A	N/A	N/R
3/31/1992	US	Garden City, KS	AIDS	LDVO	Incident		GCK	N/A	N/A	N/R
4/11/1992	US	South Lake Tahoe, CA	AIDS	LDVO	Incident	SW2	TVL	N/A	N/A	N/R
4/12/1992	US	Albany, NY	AIDS	LDVO	Incident	GLF4	ALB	N/A	N/A	N/R
4/20/1992	US	Waukegan, IL	AIDS	LDVO	Incident	FA10	UGN	N/A	N/A	N/R
4/24/1992	US	Cleveland, OH	AIDS	LDVO	Incident	LJ35	CGF	N/A	N/A	N/R
6/24/1992	Puerto Rico	Mayaguez	NTSB	LDVO	Incident	C212	MAZ	N/A	N/A	45
6/25/1992	US	Boston, MA	NTSB	LDVO	Accident	SW4	BOS	N/A	N/A	85
8/2/1992	US	Saint Petersburg, FL	AIDS	LDVO	Incident	AC90	PIE	N/A	N/A	N/R
12/26/1992	US	Wellington, KS	AIDS	LDVO	Incident	SW2	EGT	N/A	N/A	N/R
2/21/1993	US	Bellingham, WA	AIDS	LDVO	Incident	B461	BLI	N/A	N/A	N/R
3/24/1993	US	Soldiers Grove, WI	AIDS	LDVO	Incident	C560	WS51	N/A	N/A	N/R
4/14/1993	US	Dallas, TX	NTSB	LDVO	Accident	DC10	DFW	N/A	N/A	175
8/7/1993	US	Spruce Creek, FL	AIDS	LDVO	Incident		7FL6	N/A	N/A	N/R
8/28/1993	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	LJ23	FXE	N/A	N/A	N/R
8/30/1993	US	Hartford, CT	AIDS	LDVO	Incident	BE40	HFD	N/A	N/A	N/R
11/9/1993	US	Indianapolis, IN	AIDS	LDVO	Incident	SBR1	IND	N/A	N/A	N/R
12/22/1993	US	Morrisville, VT	AIDS	LDVO	Incident	BE20	MVL	N/A	N/A	N/R
1/3/1994	US	Cleveland, OH	MITRE	LDVO	Accident	SW3	CGF	N/A	N/A	25

1/25/1994	US	Lexington, KY	AIDS	LDVO	Incident	SW2	LEX	N/A	N/A	N/R
2/10/1994	US	Chicago, IL	AIDS	LDVO	Incident	FA50	ORD	N/A	N/A	N/R
2/24/1994	US	Teterboro, NJ	AIDS	LDVO	Incident	WW24	TEB	N/A	N/A	N/R
4/14/1994	US	Lincoln, NE	AIDS	LDVO	Incident	FA10	LNK	N/A	N/A	N/R
5/15/1994	US	Coeur D Alene, ID	AIDS	LDVO	Incident	SW4	COE	N/A	N/A	N/R
6/8/1994	US	Beckley, WV	AIDS	LDVO	Incident	MU30	BKW	N/A	N/A	N/R
6/30/1994	US	Gambell, AK	AIDS	LDVO	Incident	BE18	GAM	N/A	N/A	N/R
7/6/1994	US	Point Lookout, MO	AIDS	LDVO	Incident	BE20	PLK	N/A	N/A	N/R
7/7/1994	US	Las Vegas, NV	AIDS	LDVO	Incident	C402	LAS	N/A	N/A	N/R
7/17/1994	US	Plymouth, FL	AIDS	LDVO	Incident		X04	N/A	N/A	N/R
7/27/1994	US	Sioux Falls, SD	AIDS	LDVO	Incident	T18	FSD	N/A	N/A	N/R
8/13/1994	US	Santa Fe, NM	AIDS	LDVO	Incident		SAF	N/A	N/A	N/R
8/28/1994	US	Oakland, CA	AIDS	LDVO	Incident	LJ24	OAK	N/A	N/A	N/R
8/31/1994	US	Fort Smith, AR	AIDS	LDVO	Incident	BE20	FSM	N/A	N/A	N/R
9/2/1994	US	Chicago, IL	AIDS	LDVO	Incident	DC91	MDW	N/A	N/A	N/R
9/17/1994	US	Parkersburg, WV	AIDS	LDVO	Incident	WW24	PKB	N/A	N/A	N/R
9/26/1994	US	Fort Lauderdale, FL	MITRE	LDVO	Incident	C402	FLL	N/A	N/A	60
10/17/1994	US	Grand Canyon, AZ	MITRE	LDVO	Incident	C402	GCN	N/A	N/A	50
10/20/1994	US	Dyersburg, TN	AIDS	LDVO	Incident	SBR1	DYR	N/A	N/A	N/R
10/25/1994	US	Shreveport, LA	AIDS	LDVO	Incident	BE18	SHV	N/A	N/A	N/R
10/26/1994	Unknown	Unknown	AIDS	LDVO	Incident	BE18	Unknown	N/A	N/A	N/R
10/27/1994	US	Washington, PA	AIDS	LDVO	Incident	SW3	AFJ	N/A	N/A	N/R
11/1/1994	US	Fort Lauderdale, FL	MITRE	LDVO	Incident	C402	FLL	N/A	N/A	N/R
11/15/1994	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	B731	FLL	N/A	N/A	N/R
11/23/1994	US	Akron, OH	AIDS	LDVO	Incident	AC90	CAK	N/A	N/A	N/R
12/13/1994	US	Chicago, IL	AIDS	LDVO	Incident	SBR1	DPA	N/A	N/A	N/R
1/10/1995	US	Cahokia, IL	AIDS	LDVO	Incident	FA20	CPS	N/A	N/A	N/R
1/26/1995	US	Lexington, KY	AIDS	LDVO	Incident	SW4	LEX	N/A	N/A	35
1/31/1995	US	Chinle, AZ	AIDS	LDVO	Accident	C421	E91	N/A	N/A	N/R
3/3/1995	US	Salt Lake City, UT	AIDS	LDVO	Incident	SW4	SLC	N/A	N/A	N/R
3/7/1995	US	Tupelo, MS	AIDS	LDVO	Incident	H25A	TUP	N/A	N/A	N/R
4/10/1995	US	Dallas, TX	AIDS	LDVO	Incident	C402	DAL	N/A	N/A	N/R

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
5/2/1995	US	Shreveport, LA	AIDS	LDVO	Incident	BE18	SHV	N/A	N/A	N/R
5/5/1995	US	Rapid City, SD	AIDS	LDVO	Incident	AC90	RAP	N/A	N/A	N/R
5/17/1995	US	Shreveport, LA	AIDS	LDVO	Incident	BE18	SHV	N/A	N/A	N/R
6/3/1995	US	Susanville, CA	AIDS	LDVO	Incident	C421	SVE	N/A	N/A	N/R
6/7/1995	US	Omaha, NE	AIDS	LDVO	Incident	STAR	OMA	N/A	N/A	N/R
6/30/1995	US	Saginaw, MI	AIDS	LDVO	Incident	FA10	MBS	N/A	N/A	N/R
7/17/1995	US	Allentown, PA	AIDS	LDVO	Incident	F28	ABE	N/A	N/A	N/R
7/24/1995	US	Binghamton, NY	AIDS	LDVO	Incident	LJ55	BGM	N/A	N/A	N/R
8/1/1995	US	Van Nuys, CA	MITRE	LDVO	Incident	B752	VNY	N/A	N/A	N/R
8/3/1995	US	Portland, OR	MITRE	LDVO	Incident	D328	PDX	N/A	N/A	62
8/3/1995	US	Portland, OR	NTSB	LDVO	Accident	D328	PDX	N/A	N/A	N/R
8/14/1995	US	Denver, CO	MITRE	LDVO	Accident	B752	APA	N/A	N/A	N/R
8/18/1995	US	Columbus, OH	AIDS	LDVO	Incident	B731	CMH	N/A	N/A	N/R
9/14/1995	US	Atlanta, GA	AIDS	LDVO	Incident	LJ24	PDK	N/A	N/A	N/R
9/16/1995	US	Charleston, SC	AIDS	LDVO	Incident	MD80	CHS	N/A	N/A	N/R
10/23/1995	US	San Juan, PR	AIDS	LDVO	Incident	C402	SJU	N/A	N/A	N/R
11/8/1995	US	Saginaw, MI	AIDS	LDVO	Incident	BE18	MBS	N/A	N/A	N/R
11/17/1995	US	Brenham, TX	AIDS	LDVO	Incident	WW24	11R	N/A	N/A	N/R
11/21/1995	US	Rexburg, ID	AIDS	LDVO	Incident	BE30	RXE	N/A	N/A	N/R
12/10/1995	Netherlands	Amsterdam	NTSB	LDVO	Incident	B742	EHAM	N/A	N/A	N/R
12/19/1995	US	Saint Louis, MO	AIDS	LDVO	Incident	DC91	STL	N/A	N/A	N/R
1/24/1996	US	Detroit, MI	MITRE	LDVO	Accident	FA10	DTW	N/A	N/A	N/R
1/26/1996	US	Atlanta, GA	AIDS	LDVO	Incident	E120	ATL	N/A	N/A	0
1/31/1996	US	Morristown, NJ	AIDS	LDVO	Incident	WW24	MMU	N/A	N/A	N/R
2/2/1996	US	Memphis, TN	AIDS	LDVO	Incident	CVLP	MEM	N/A	N/A	N/R
2/28/1996	US	Grand Canyon, AZ	MITRE	LDVO	Accident	PA31	GCN	N/A	N/A	N/R
3/20/1996	US	Portland, TN	AIDS	LDVO	Incident	LJ25	PLD	N/A	N/A	75
4/2/1996	US	Beckley, WV	AIDS	LDVO	Incident	SH33	BKW	N/A	N/A	N/R
4/6/1996	US	Birmingham, AL	AIDS	LDVO	Incident	H25A	EGBB	N/A	N/A	N/R
4/20/1996	US	Albuquerque, NM	AIDS	LDVO	Incident		AEG	N/A	N/A	N/R
5/1/1996	US	Denver, CO	AIDS	LDVO	Incident	SBR1	DEN	N/A	N/A	N/R
5/10/1996	US	Dallas, TX	NTSB	LDVO	Incident	B733	DFW	N/A	N/A	75

5/16/1996	US	Houston, TX	MITRE	LDVO	Accident	MU2	HOU	N/A	N/A	N/R
7/5/1996	US	Moultonboro, NH	AIDS	LDVO	Incident	C414	5M3	N/A	N/A	175
7/27/1996	US	Saint Paul, MN	AIDS	LDVO	Incident	CONI	STP	N/A	N/A	N/R
8/3/1996	US	West Palm Beach, FL	AIDS	LDVO	Incident	B731	PBI	N/A	N/A	N/R
9/30/1996	US	Aspen, CO	MITRE	LDVO	Accident	ASTR	ASE	N/A	N/A	N/R
10/9/1996	US	Pittsburgh, PA	AIDS	LDVO	Incident	LJ25	AGC	N/A	N/A	N/R
12/11/1996	US	Grand Forks, ND	AIDS	LDVO	Incident	LJ35	GFK	N/A	N/A	N/R
12/15/1996	US	Honolulu, HI	NTSB	LDVO	Accident	DH8A	HNL	N/A	N/A	N/R
12/20/1996	US	Denver, CO	AIDS	LDVO	Incident	LJ25	DEN	N/A	N/A	N/R
1/3/1997	US	Watertown, SD	AIDS	LDVO	Incident	WW24	ATY	N/A	N/A	N/R
1/3/1997	England	Liverpool	AAIB	LDVO	Accident	SH33	EGGP	N/A	N/A	N/R
1/8/1997	US	El Paso, TX	AIDS	LDVO	Incident	FA20	ELP	N/A	N/A	N/R
1/16/1997	US	Terre Haute, IN	AIDS	LDVO	Incident	DC85	HUF	N/A	N/A	20
1/23/1997	US	Lebanon, MO	AIDS	LDVO	Incident	C402	LBO	N/A	N/A	N/R
1/24/1997	US	Washington, IN	AIDS	LDVO	Incident	C500	DCY	N/A	N/A	22
1/24/1997	US	Chicago, IL	AIDS	LDVO	Incident	C550	Unknown	N/A	N/A	N/R
2/2/1997	US	Grand Forks, ND	AIDS	LDVO	Incident	DC91	GFK	N/A	N/A	N/R
2/5/1997	US	New York, NY	AIDS	LDVO	Incident	B741	JFK	N/A	N/A	N/R
2/14/1997	US	Ames, IA	AIDS	LDVO	Incident	SW4	AMW	N/A	N/A	N/R
2/22/1997	US	Alma, MI	AIDS	LDVO	Incident	C550	AMN	N/A	N/A	N/R
3/4/1997	US	Abilene, TX	MITRE	LDVO	Incident	SW4	ABI	N/A	N/A	5
3/5/1997	US	Cleveland, OH	NTSB	LDVO	Accident		CLE	N/A	N/A	115
3/10/1997	US	Boise, ID	AIDS	LDVO	Incident	WW24	BOI	N/A	N/A	230
3/20/1997	US	Hailey, ID	MITRE	LDVO	Accident	SBR1	SUN	N/A	N/A	N/R
3/27/1997	US	San Carlos, CA	MITRE	LDVO	Accident	BE10	SQL	N/A	N/A	N/R
4/18/1997	US	Rangeley, ME	AIDS	LDVO	Incident	BE20	8B0	N/A	N/A	N/R
5/14/1997	US	Arcata, CA	AIDS	LDVO	Incident	JS431	ACV	N/A	N/A	N/R
5/19/1997	US	New Orleans, LA	AIDS	LDVO	Incident	B721	MSY	N/A	N/A	N/R
7/21/1997	US	Elko, NV	MITRE	LDVO	Accident	DHC6	EKO	N/A	N/A	N/R
7/31/1997	US	Newark, NJ	MITRE	LDVO	Accident	MD11	EWR	N/A	N/A	505
8/13/1997	US	Seattle, WA	MITRE	LDVO	Accident	B190	SEA	N/A	N/A	37
9/24/1997	US	Lake Charles, LA	AIDS	LDVO	Incident	BE20	CWF	N/A	N/A	N/R

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
9/24/1997	US	Salt Lake City, UT	NTSB	LDVO	Incident	B732	SLC	N/A	N/A	75
11/25/1997	US	Billings, MT	NTSB	LDVO	Accident	SH36	BIL	N/A	N/A	765
12/11/1997	US	Chicago, IL	AIDS	LDVO	Incident	C560	PWK	N/A	N/A	N/R
12/24/1997	Netherlands	Amsterdam	Netherland TSB	LDVO	Accident	B752	EHAM	N/A	N/A	20
12/27/1997	US	Denver, CO	AIDS	LDVO	Incident	SW3	APA	N/A	N/A	N/R
12/29/1997	US	Newburgh, NY	AIDS	LDVO	Incident	MD80	SWF	N/A	N/A	N/R
1/8/1998	US	Chicago, IL	AIDS	LDVO	Incident	LJ35	PWK	N/A	N/A	N/R
1/20/1998	US	Saranac Lake, NY	NTSB	LDVO	Accident	B190	SLK	N/A	N/A	15
2/22/1998	US	Lawton, OK	MITRE	LDVO	Incident	SF34	LAW	N/A	N/A	75
2/26/1998	US	Birmingham, AL	MITRE	LDVO	Accident	F28	BHM	N/A	N/A	235
2/26/1998	US	Birmingham, AL	NTSB	LDVO	Accident	F28	BHM	N/A	N/A	N/R
2/27/1998	England	Leeds	AAIB	LDVO	Incident	SF34	EGNM	N/A	N/A	N/R
3/10/1998	US	Cleveland, OH	AIDS	LDVO	Incident	MD80	CLE	N/A	N/A	5
3/18/1998	US	Denver, CO	AIDS	LDVO	Incident	LJ25	APA	N/A	N/A	N/R
3/31/1998	US	Des Moines, IA	AIDS	LDVO	Incident	B721	DSM	N/A	N/A	N/R
4/1/1998	US	Las Vegas, NV	AIDS	LDVO	Incident	C402	VGT	N/A	N/A	N/R
4/3/1998	US	West Palm Beach, FL	MITRE	LDVO	Accident	C402	PBI	N/A	N/A	N/R
6/19/1998	US	Fishers Island, NY	AIDS	LDVO	Incident	C500	0B8	N/A	N/A	N/R
8/5/1998	US	Bend, OR	AIDS	LDVO	Incident	C421	S21	N/A	N/A	55
8/12/1998	US	Kneeland, CA	AIDS	LDVO	Incident	PA31	O19	N/A	N/A	N/R
8/17/1998	US	Nome, AK	AIDS	LDVO	Incident	C402	OME	N/A	N/A	10
9/4/1998	US	Springdale, AR	AIDS	LDVO	Incident	C402	ASG	N/A	N/A	N/R
9/11/1998	US	Houston, TX	NTSB	LDVO	Accident	B763	EFD	N/A	N/A	N/R
9/12/1998	US	Hot Springs, AR	AIDS	LDVO	Incident	SW4	HOT	N/A	N/A	N/R
9/13/1998	US	Las Vegas, NV	AIDS	LDVO	Incident	SW3	VGT	N/A	N/A	N/R
9/16/1998	Mexico	Guadalajara	NTSB	LDVO	Accident	B735	MMGL	N/A	N/A	6
9/28/1998	US	Pueblo, CO	MITRE	LDVO	Accident	C551	PUB	N/A	N/A	N/R
10/1/1998	US	Denver, CO	AIDS	LDVO	Incident	CL60	DEN	N/A	N/A	N/R
11/1/1998	US	Atlanta, GA	MITRE	LDVO	Accident	B731	ATL	N/A	N/A	235
11/1/1998	US	Atlanta, GA	NTSB	LDVO	Accident	B732	ATL	N/A	N/A	N/R
11/8/1998	US	Amarillo, TX	AIDS	LDVO	Incident	B731	AMA	N/A	N/A	N/R
11/27/1998	US	Austin, TX	MITRE	LDVO	Accident	L29A	AUS	N/A	N/A	135

12/10/1998	US	Charlotte Amalie, VI	MITRE	LDVO	Accident	BE18	STT	N/A	N/A	N/R
12/10/1998	US	Monroe, MI	AIDS	LDVO	Incident	SW3	TTF	N/A	N/A	N/R
12/17/1998	US	Traverse City, MI	MITRE	LDVO	Accident	AT43	TVC	N/A	N/A	85
12/17/1998	US	Traverse City, MI	NTSB	LDVO	Accident	AT43	TVC	N/A	N/A	N/R
12/17/1998	US	Los Angeles, CA	MITRE	LDVO	Accident	LJ55	LAX	N/A	N/A	N/R
12/20/1998	US	Denver, CO	AIDS	LDVO	Incident	H25B	APA	N/A	N/A	N/R
12/26/1998	US	Jackson, WY	AIDS	LDVO	Incident	B731	JAC	N/A	N/A	N/R
12/27/1998	US	Weiser, ID	AIDS	LDVO	Incident	BE20	S87	N/A	N/A	N/R
1/2/1999	US	Springfield, MO	AIDS	LDVO	Incident		SGF	N/A	N/A	N/R
1/3/1999	US	Muskegon, MI	AIDS	LDVO	Incident	B190	MKG	N/A	N/A	N/R
1/6/1999	US	Plymouth, IN	NTSB	LDVO	Accident	AC50	C65	N/A	N/A	20
1/8/1999	US	Columbus, OH	AIDS	LDVO	Incident	MD80	CMH	N/A	N/A	N/R
1/14/1999	US	Youngstown, OH	NTSB	LDVO	Accident	C421	YNG	N/A	N/A	N/R
1/14/1999	US	Youngstown, OH	MITRE	LDVO	Accident	C421	YNG	N/A	N/A	5
1/22/1999	US	Hyannis, MA	MITRE	LDVO	Accident	B190	HYA	N/A	N/A	10
1/22/1999	US	Columbus, OH	MITRE	LDVO	Accident	C650	CMH	N/A	N/A	75
1/22/1999	US	Oakland, CA	AIDS	LDVO	Incident	LJ25	OAK	N/A	N/A	N/R
2/13/1999	US	State College, PA	AIDS	LDVO	Incident	JS31	UNV	N/A	N/A	N/R
2/17/1999	Bahamas	Nassau	NTSB	LDVO	Accident	DC3	MYNN	N/A	N/A	N/R
2/24/1999	Unknown	Unknown	AIDS	LDVO	Incident	SW3	Unknown	N/A	N/A	N/R
3/18/1999	US	Lincoln, NE	AIDS	LDVO	Incident	LJ25	LNK	N/A	N/A	N/R
4/23/1999	Papua New Guinea	Freida River	NTSB	LDVO	Accident	DHC6	FAQ	N/A	N/A	N/R
5/14/1999	US	Hickory, NC	MITRE	LDVO	Accident	BE10	HKY	N/A	N/A	195
5/18/1999	US	Georgetown, SC	AIDS	LDVO	Incident	BE20	GGE	N/A	N/A	N/R
5/21/1999	US	Midland, TX	AIDS	LDVO	Incident	F27	MAF	N/A	N/A	N/R
5/21/1999	US	South Bend, IN	AIDS	LDVO	Incident	F28	SBN	N/A	N/A	N/R
8/16/1999	US	Fort Lauderdale, FL	MITRE	LDVO	Accident	CL60	FXE	N/A	N/A	50
9/14/1999	Spain	Girona	Spain TSB	LDVO	Accident	B752	LEGE	N/A	N/A	408
10/11/1999	US	Miami, FL	MITRE	LDVO	Accident	SW4	OPF	N/A	N/A	N/R
11/7/1999	Spain	Barcelona	Spain TSB	LDVO	Accident	F100	LEBL	N/A	N/A	254
11/12/1999	US	Fremont, OH	AIDS	LDVO	Incident	SW3	S24	N/A	N/A	50

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
11/18/1999	US	Lawrence, KS	AIDS	LDVO	Incident	SW4	LWC	N/A	N/A	N/R
11/27/1999	US	Boise, ID	MITRE	LDVO	Accident	FA20	BOI	N/A	N/A	N/R
12/21/1999	Guatemala	Guatemala	BEA	LDVO	Accident	DC10	MGGT	N/A	N/A	58
1/28/2000	US	Newark, NJ	AIDS	LDVO	Incident	B731	EWR	N/A	N/A	150
1/28/2000	US	Fayetteville, AR	MITRE	LDVO	Accident	SW4	FYV	N/A	N/A	N/R
2/15/2000	US	Escanaba, MI	NTSB	LDVO	Accident	B190	ESC	N/A	N/A	75
2/16/2000	US	Palm Springs, CA	AIDS	LDVO	Incident	MD80	PSP	N/A	N/A	N/R
2/25/2000	US	Atlanta, GA	AIDS	LDVO	Incident	LJ25	FTY	N/A	N/A	N/R
3/6/2000	US	Adrian, MI	AIDS	LDVO	Incident	PA31	ADG	N/A	N/A	N/R
4/2/2000	US	Yap, FM	AIDS	LDVO	Incident	B721	YAP	N/A	N/A	N/R
4/4/2000	US	Miami, FL	MITRE	LDVO	Incident	FA20	OPF	N/A	N/A	N/R
4/19/2000	US	Hyannis, MA	AIDS	LDVO	Incident	LJ35	HYA	N/A	N/A	N/R
5/2/2000	US	Saint Paul, MN	AIDS	LDVO	Incident	C402	STP	N/A	N/A	N/R
5/2/2000	France	Lyon	BEA	LDVO	Accident	LJ35	LYS	N/A	N/A	500
5/5/2000	US	Cahokia, IL	AIDS	LDVO	Incident	C402	CPS	N/A	N/A	1550
5/8/2000	US	Nantucket, MA	AIDS	LDVO	Incident	C402	ACK	N/A	N/A	N/R
5/18/2000	Barbados	Bridgetown	NTSB	LDVO	Incident		BGI	N/A	N/A	N/R
6/5/2000	US	Cedar Rapids, IA	AIDS	LDVO	Incident	MD80	CID	N/A	N/A	N/R
6/7/2000	US	Birmingham, AL	AIDS	LDVO	Incident	SW4	EGBB	N/A	N/A	N/R
7/16/2000	US	Denver, CO	AIDS	LDVO	Incident	B190	DEN	N/A	N/A	N/R
8/24/2000	US	Milwaukee, WI	AIDS	LDVO	Incident	BE40	MKE	N/A	N/A	N/R
9/22/2000	US	Missoula, MT	NTSB	LDVO	Accident	BE99	MSO	N/A	N/A	N/R
9/26/2000	US	Charlotte, NC	MITRE	LDVO	Accident	DC3	CLT	N/A	N/A	N/R
9/29/2000	US	Show Low, AZ	AIDS	LDVO	Incident	C421	SOW	N/A	N/A	N/R
10/16/2000	US	Saint Louis, MO	AIDS	LDVO	Incident	MD80	STL	N/A	N/A	N/R
10/22/2000	US	Bethel, AK	MITRE	LDVO	Accident	B190	BET	N/A	N/A	N/R
10/29/2000	Ireland	Cork	AAIU	LDVO	Incident	F50	EICK	N/A	N/A	143
11/5/2000	France	Paris	BEA	LDVO	Accident	B741	CDG	N/A	N/A	446
11/10/2000	US	Dickinson, ND	AIDS	LDVO	Incident	B190	DIK	N/A	N/A	N/R
11/19/2000	US	Grand Rapids, MI	AIDS	LDVO	Incident	DC91	GRR	N/A	N/A	N/R
12/13/2000	US	Pensacola, FL	MITRE	LDVO	Accident	C421	PNS	N/A	N/A	N/R
12/14/2000	US	Atlanta, GA	AIDS	LDVO	Incident	SW4	PDK	N/A	N/A	N/R

12/17/2000	US	Farmingdale, NY	AIDS	LDVO	Accident	BE10	FRG	N/A	N/A	N/R
12/22/2000	US	Holland, MI	AIDS	LDVO	Incident	FA10	HLM	N/A	N/A	N/R
1/15/2001	US	Two Harbors, MN	AIDS	LDVO	Incident	BE20	TWM	N/A	N/A	N/R
1/21/2001	US	New York, NY	NTSB	LDVO	Incident	A320	JFK	N/A	N/A	15
2/7/2001	Spain	Balboa	Spain TSB	LDVO	Accident	A320	LEBB	N/A	N/A	20
2/13/2001	US	Salina, KS	AIDS	LDVO	Incident	C650	SLN	N/A	N/A	N/R
2/20/2001	US	Manassas, VA	AIDS	LDVO	Incident	SF34	HEF	N/A	N/A	N/R
3/3/2001	US	Fort Lauderdale, FL	MITRE	LDVO	Accident	C402	FLL	N/A	N/A	30
3/9/2001	US	Denver, CO	AIDS	LDVO	Incident	D328	DEN	N/A	N/A	N/R
3/16/2001	US	Cedar Rapids, IA	AIDS	LDVO	Incident	B721	CID	N/A	N/A	N/R
3/18/2001	US	Monument Valley, UT	AIDS	LDVO	Incident	DHC6	UT25	N/A	N/A	88
3/24/2001	US	Pittsburgh, PA	AIDS	LDVO	Incident	E145	PIT	N/A	N/A	N/R
4/19/2001	US	Denver, CO	AIDS	LDVO	Incident	H25B	APA	N/A	N/A	N/R
4/26/2001	US	Saint George, UT	AIDS	LDVO	Incident	LJ25	SGU	N/A	N/A	N/R
6/4/2001	US	Las Vegas, NV	MITRE	LDVO	Accident	PA31	VGT	N/A	N/A	N/R
6/10/2001	US	Miami, FL	AIDS	LDVO	Incident	BE18	OPF	N/A	N/A	N/R
6/12/2001	US	Kotzebue, AK	AIDS	LDVO	Incident	B731	OTZ	N/A	N/A	N/R
7/10/2001	England	Exeter	AAIB	LDVO	Incident	AN12	EGTE	N/A	N/A	N/R
8/25/2001	US	Kansas City, MO	MITRE	LDVO	Accident	B731	MCI	N/A	N/A	30
10/24/2001	Canada	Peace River, AB	Canada TSB	LDVO	Incident	DH8A	CYPE	N/A	N/A	176
11/29/2001	US	Flagstaff, AZ	NTSB	LDVO	Accident	BE99	FLG	N/A	N/A	N/R
1/5/2002	US	Sacramento, CA	AIDS	LDVO	Incident	B731	SMF	N/A	N/A	N/R
1/10/2002	US	Fort Collins/Loveland, CO	AIDS	LDVO	Incident	LJ35	FNL	N/A	N/A	N/R
2/3/2002	Ireland	Dublin	AAIU	LDVO	Incident	MD11	EIDW	N/A	N/A	12
3/4/2002	US	Chicago, IL	AIDS	LDVO	Incident	BE20	DPA	N/A	N/A	N/R
3/12/2002	US	Albuquerque, NM	MITRE	LDVO	Accident	C402	ABQ	N/A	N/A	N/R
3/13/2002	US	Salt Lake City, UT	AIDS	LDVO	Incident	LJ25	SLC	N/A	N/A	15
3/17/2002	US	Laramie, WY	AIDS	LDVO	Incident	BE20	LAR	N/A	N/A	N/R
3/27/2002	Canada	Toronto, ON	Canada TSB	LDVO	Incident	F28	CYYZ	N/A	N/A	15
3/28/2002	US	Jackson, WY	AIDS	LDVO	Incident	GLF4	JAC	N/A	N/A	N/R
4/16/2002	Canada	Winnipeg, MB	Canada TSB	LDVO	Accident	SW3	CYWG	N/A	N/A	0
5/10/2002	US	Meridian, MS	AIDS	LDVO	Incident	SW2	MEI	N/A	N/A	100

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
6/15/2002	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SW3	FXE	N/A	N/A	N/R
6/19/2002	US	Prineville, OR	AIDS	LDVO	Incident	BE30	S39	N/A	N/A	N/R
7/25/2002	US	Columbia, SC	AIDS	LDVO	Incident	D328	CAE	N/A	N/A	N/R
8/28/2002	US	Phoenix, AZ	NTSB	LDVO	Accident	A320	PHX	N/A	N/A	N/R
9/7/2002	Spain	Madrid	Spain TSB	LDVO	Incident	A346	LEMD	N/A	N/A	33
9/15/2002	US	Rock Springs, WY	NTSB	LDVO	Accident	B190	RKS	N/A	N/A	N/R
9/21/2002	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	GA7	FLL	N/A	N/A	N/R
11/22/2002	US	Fort Lauderdale, FL	AIDS	LDVO	Accident	SW4	FLL	N/A	N/A	N/R
1/6/2003	US	Chicago, IL	AIDS	LDVO	Incident	C525	MDW	N/A	N/A	N/R
2/2/2003	Canada	Enfield, NS	Canada TSB	LDVO	Incident	B731	CYHZ	N/A	N/A	0
2/7/2003	US	Mountain Village, AK	AIDS	LDVO	Incident	C402	MOU	N/A	N/A	N/R
2/15/2003	US	Marietta, GA	AIDS	LDVO	Incident	SBR1	RYY	N/A	N/A	N/R
2/16/2003	US	Cahokia, IL	MITRE	LDVO	Accident	SW3	CPS	N/A	N/A	N/R
2/20/2003	US	Pierre, SD	AIDS	LDVO	Incident	H25B	PIR	N/A	N/A	N/R
2/28/2003	US	Oakland, CA	AIDS	LDVO	Incident	BE99	OAK	N/A	N/A	N/R
3/2/2003	US	Reno, NV	AIDS	LDVO	Incident	SBR1	RNO	N/A	N/A	N/R
3/8/2003	US	Kinston, NC	MITRE	LDVO	Accident	F27	ISO	N/A	N/A	75
3/25/2003	US	Columbus, OH	AIDS	LDVO	Incident	BE20	OSU	N/A	N/A	N/R
4/16/2003	US	Yuma, AZ	AIDS	LDVO	Incident	C421	NYL	N/A	N/A	N/R
4/17/2003	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SBR1	FXE	N/A	N/A	N/R
5/24/2003	US	Amarillo, TX	MITRE	LDVO	Accident	B731	AMA	N/A	N/A	N/R
5/28/2003	US	Detroit, MI	AIDS	LDVO	Incident	MU2	DET	N/A	N/A	N/R
7/3/2003	US	Carlsbad, CA	AIDS	LDVO	Incident	F900	CRQ	N/A	N/A	N/R
8/9/2003	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SBR1	FXE	N/A	N/A	N/R
9/3/2003	US	Richmond, VA	AIDS	LDVO	Incident	SW4	RIC	N/A	N/A	N/R
9/13/2003	US	Butte, MT	AIDS	LDVO	Incident	DH8A	BTM	N/A	N/A	N/R
9/22/2003	US	Gulfport, MS	AIDS	LDVO	Incident	B731	GPT	N/A	N/A	N/R
9/26/2003	Canada	Toronto, ON	Canada TSB	LDVO	Incident	ASTR	CYYZ	N/A	N/A	350
10/20/2003	US	Key West, FL	AIDS	LDVO	Incident	PA31	EYW	N/A	N/A	N/R
12/4/2003	US	Little Rock, AR	AIDS	LDVO	Incident	C560	LIT	N/A	N/A	N/R
12/15/2003	US	Bangor, ME	AIDS	LDVO	Incident	D228	BGR	N/A	N/A	N/R
12/18/2003	US	Memphis, TN	MITRE	LDVO	Accident	MD11	MEM	N/A	N/A	N/R

1/14/2004	US	Saint Louis, MO	AIDS	LDVO	Incident	FA10	SUS	N/A	N/A	N/R
1/15/2004	Canada	Dryden, ON	Canada TSB	LDVO	Incident	SW4	CYHD	N/A	N/A	30
1/17/2004	US	Rapid City, SD	NTSB	LDVO	Incident	CL60	RAP	N/A	N/A	N/R
1/21/2004	US	Pueblo, CO	MITRE	LDVO	Accident	FA20	PUB	N/A	N/A	150
1/24/2004	Singapore	Singapore	Singapore AAI	LDVO	Incident	B772	WSSS	N/A	N/A	20
1/29/2004	US	Huntsville, AL	AIDS	LDVO	Incident	CVLP	HSV	N/A	N/A	N/R
2/6/2004	US	Richmond, VA	AIDS	LDVO	Incident	C560	FCI	N/A	N/A	20
2/6/2004	US	Kansas City, MO	AIDS	LDVO	Incident	C550	MKC	N/A	N/A	N/R
2/15/2004	US	Chicago, IL	AIDS	LDVO	Incident	LJ35	DPA	N/A	N/A	N/R
2/25/2004	Canada	Edmonton, AB	Canada TSB	LDVO	Incident	B731	CYEG	N/A	N/A	185
3/3/2004	US	Saint Paul Island, AK	AIDS	LDVO	Incident	SW4	SNP	N/A	N/A	N/R
3/4/2004	US	Springdale, AR	MITRE	LDVO	Accident	BE20	ASG	N/A	N/A	N/R
3/4/2004	US	Broomfield, CO	AIDS	LDVO	Incident	F900	BJC	N/A	N/A	N/R
3/15/2004	US	Manhattan, KS	NTSB	LDVO	Accident	B190	MHK	N/A	N/A	5
3/19/2004	US	Utica, NY	MITRE	LDVO	Accident	LJ35	UCA	N/A	N/A	20
3/31/2004	US	Fort Lauderdale, FL	NTSB	LDVO	Accident	C402	FXE	N/A	N/A	N/R
5/9/2004	US	San Juan, PR	NTSB	LDVO	Accident	AT72	SJU	N/A	N/A	112
5/11/2004	US	Roseau, MN	AIDS	LDVO	Incident	BE9L	ROX	N/A	N/A	N/R
5/15/2004	US	Oakland, CA	AIDS	LDVO	Incident	AC52	OAK	N/A	N/A	N/R
6/11/2004	US	Dallas, TX	NTSB	LDVO	Incident	E135	DFW	N/A	N/A	N/R
6/14/2004	US	Pittsburgh, PA	AIDS	LDVO	Incident	B731	PIT	N/A	N/A	N/R
6/16/2004	US	Indianapolis, IN	AIDS	LDVO	Incident	C550	TYQ	N/A	N/A	N/R
8/10/2004	US	Grand Canyon, AZ	AIDS	LDVO	Incident	DHC6	GCN	N/A	N/A	N/R
8/31/2004	Canada	Moncton, NB	Canada TSB	LDVO	Incident	B721	CCG4	N/A	N/A	200
9/3/2004	US	Houston, TX	AIDS	LDVO	Incident	GLF2	HOU	N/A	N/A	N/R
9/21/2004	Canada	La Ronge, SK	Canada TSB	LDVO	Accident	SW4	CYVC	N/A	N/A	275
9/21/2004	US	Garden City, KS	AIDS	LDVO	Incident	B190	GCK	N/A	N/A	N/R
10/29/2004	US	Dubuque, IA	AIDS	LDVO	Incident	E145	DBQ	N/A	N/A	N/R
11/5/2004	US	Houston, TX	AIDS	LDVO	Incident	WW24	HOU	N/A	N/A	N/R
11/21/2004	US	Denver, CO	AIDS	LDVO	Incident	MD80	DEN	N/A	N/A	N/R
11/29/2004	US	Eagle, CO	MITRE	LDVO	Accident	GLF4	EGE	N/A	N/A	N/R
12/1/2004	Canada	Saint-Georges, QC	Canada TSB	LDVO	Accident	BE30	CYSG	N/A	N/A	95

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
12/4/2004	US	Mc Allen, TX	MITRE	LDVO	Accident	CVLT	MFE	N/A	N/A	475
12/8/2004	US	Twin Falls, ID	AIDS	LDVO	Incident	SW3	TWF	N/A	N/A	N/R
12/9/2004	US	Atlanta, GA	AIDS	LDVO	Incident	B721	ATL	N/A	N/A	N/R
12/13/2004	US	Cleveland, OH	AIDS	LDVO	Incident	LJ35	BKL	N/A	N/A	N/R
12/14/2004	US	Cleveland, OH	AIDS	LDVO	Incident	MU30	CGF	N/A	N/A	N/R
12/19/2004	Canada	Gaspé, QC	Canada TSB	LDVO	Accident	PA31	CYGP	N/A	N/A	60
12/20/2004	US	Cedar Rapids, IA	MITRE	LDVO	Accident	LJ25	CID	N/A	N/A	754
12/24/2004	Canada	Kuujjuaq, QC	Canada TSB	LDVO	Accident	BE10	CYVP	N/A	N/A	40
1/4/2005	US	Cleveland, OH	MITRE	LDVO	Accident	AC90	CGF	N/A	N/A	N/R
1/6/2005	US	Stillwater, OK	AIDS	LDVO	Incident	LJ35	SWO	N/A	N/A	N/R
1/20/2005	Canada	Calgary, AB	Canada TSB	LDVO	Incident	DC91	CYYC	N/A	N/A	40
1/25/2005	US	Montrose, CO	AIDS	LDVO	Incident	SW4	MTJ	N/A	N/A	N/R
1/28/2005	US	Kansas City, MO	AIDS	LDVO	Incident	MD80	MCI	N/A	N/A	N/R
1/31/2005	US	Everett, WA	AIDS	LDVO	Incident	BE18	PAE	N/A	N/A	N/R
2/7/2005	US	Columbus, OH	AIDS	LDVO	Incident	MD80	CMH	N/A	N/A	5
2/21/2005	Canada	Bromont, QC	Canada TSB	LDVO	Accident	H25A	CZBM	N/A	N/A	250
3/11/2005	US	Milwaukee, WI	MITRE	LDVO	Accident	CL60	MKE	N/A	N/A	571
3/23/2005	US	Brigham City, UT	AIDS	LDVO	Incident	LJ24	BMC	N/A	N/A	N/R
3/26/2005	US	El Paso, TX	AIDS	LDVO	Incident	C680	ELP	N/A	N/A	N/R
4/26/2005	US	Lawrenceville, GA	MITRE	LDVO	Accident	SW3	LZU	N/A	N/A	N/R
5/28/2005	US	Denver, CO	AIDS	LDVO	Incident	MD80	DEN	N/A	N/A	N/R
5/31/2005	US	Teterboro, NJ	MITRE	LDVO	Accident	SW3	TEB	N/A	N/A	30
6/8/2005	US	Washington, DC	MITRE	LDVO	Incident	SF34	IAD	N/A	N/A	785
6/15/2005	US	Charlotte Amalie, VI	AIDS	LDVO	Incident	C402	STT	N/A	N/A	N/R
7/1/2005	US	Amarillo, TX	MITRE	LDVO	Accident	LJ25	AMA	N/A	N/A	150
7/8/2005	US	Islesboro, ME	AIDS	LDVO	Incident	C404	57B	N/A	N/A	N/R
7/15/2005	US	Eagle, CO	MITRE	LDVO	Accident	LJ35	EGE	N/A	N/A	331
8/9/2005	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	C402	FLL	N/A	N/A	N/R
8/10/2005	US	Spearfish, SD	AIDS	LDVO	Incident	BE20	SPF	N/A	N/A	N/R
9/11/2005	US	Las Vegas, NV	AIDS	LDVO	Incident	DHC6	VGT	N/A	N/A	N/R
9/12/2005	Netherlands	Rotterdam	Netherland TSB	LDVO	Incident	SW4	EHRD	N/A	N/A	38
9/23/2005	US	Dallas, TX	AIDS	LDVO	Incident	C402	ADS	N/A	N/A	N/R

10/6/2005	US	Hayden, CO	AIDS	LDVO	Incident	C500	HDN	N/A	N/A	5
11/17/2005	US	Jamestown, NY	AIDS	LDVO	Incident	H25A	JHW	N/A	N/A	N/R
12/1/2005	US	Sioux Falls, SD	AIDS	LDVO	Incident	SW4	FSD	N/A	N/A	N/R
12/3/2005	US	Ann Arbor, MI	AIDS	LDVO	Incident	D328	ARB	N/A	N/A	50
12/13/2005	US	Kotzebue, AK	AIDS	LDVO	Incident	DC6	OTZ	N/A	N/A	N/R
12/26/2005	Canada	Winnipeg, MB	Canada TSB	LDVO	Incident	A319	CYWG	N/A	N/A	15
12/27/2005	US	Marquette, MI	AIDS	LDVO	Incident	B190	SAW	N/A	N/A	N/R
2/1/2006	US	Yakutat, AK	AIDS	LDVO	Incident	B731	YAK	N/A	N/A	N/R
2/12/2006	US	New York, NY	AIDS	LDVO	Incident	A345	JFK	N/A	N/A	100
2/25/2006	England	London	AAIB	LDVO	Incident	A344	EGLL	N/A	N/A	0
2/25/2006	US	Trenton, NJ	AIDS	LDVO	Incident	F900	TTN	N/A	N/A	N/R
3/10/2006	US	Dallas, TX	AIDS	LDVO	Incident	L29B	DAL	N/A	N/A	N/R
3/13/2006	US	Houston, TX	AIDS	LDVO	Incident	B731	IAH	N/A	N/A	N/R
3/20/2006	US	Minneapolis, MN	AIDS	LDVO	Incident	A30B	MSP	N/A	N/A	N/R
4/27/2006	Australia	Mabuiag Island	ATSB	LDVO	Incident	C206	YMAA	N/A	N/A	170
5/2/2006	US	Chicago, IL	AIDS	LDVO	Incident	E145	ORD	N/A	N/A	N/R
5/18/2006	US	Fairbanks, AK	AIDS	LDVO	Incident	MD80	AFA	N/A	N/A	N/R
6/12/2006	US	Kaunakakai, HI	AIDS	LDVO	Incident	BE99	MKK	N/A	N/A	N/R
7/28/2006	US	Memphis, TN	NTSB	LDVO	Accident	MD11	MEM	N/A	N/A	N/R
8/6/2006	US	Salina, KS	AIDS	LDVO	Incident	H25A	SLN	N/A	N/A	150
8/13/2006	England	Middlesex	AAIB	LDVO	Accident	BE58	EGLD	N/A	N/A	164
9/16/2006	US	Modesto, CA	AIDS	LDVO	Incident	LJ35	MOD	N/A	N/A	N/R
9/20/2006	England	Bedfordshire	AAIB	LDVO	Incident	C750	EGGW	N/A	N/A	12
10/27/2006	US	Louisville, KY	AIDS	LDVO	Incident	E135	SDF	N/A	N/A	N/R
10/30/2006	France	Rouen	BEA	LDVO	Incident	AT43	LFOP	N/A	N/A	144
11/11/2006	US	Indianapolis, IN	AIDS	LDVO	Incident	B721	IND	N/A	N/A	N/R
12/14/2006	US	Sarasota, FL	AIDS	LDVO	Incident	WW24	SRQ	N/A	N/A	N/R
1/8/2007	US	Denver, CO	AIDS	LDVO	Accident	BE30	APA	N/A	N/A	N/R
1/12/2007	US	Denver, CO	AIDS	LDVO	Incident	SW4	DEN	N/A	N/A	N/R
1/13/2007	US	Laramie, WY	AIDS	LDVO	Incident	SW3	LAR	N/A	N/A	N/R
1/17/2007	England	Southampton	AAIB	LDVO	Incident	CRJ1	EGHI	N/A	N/A	52
2/4/2007	US	Miami, FL	NTSB	LDVO	Incident	DC87	MIA	N/A	N/A	N/R

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
2/14/2007	US	Teterboro, NJ	AIDS	LDVO	Incident	WW24	TEB	N/A	N/A	20
2/17/2007	US	Indianapolis, IN	AIDS	LDVO	Accident	BE20	EYE	N/A	N/A	22
2/20/2007	US	Cordova, AK	NTSB	LDVO	Accident	C402	CKU	N/A	N/A	N/R
2/24/2007	US	Dallas, TX	NTSB	LDVO	Incident	E145	DAL	N/A	N/A	115
3/4/2007	US	Fayetteville, AR	AIDS	LDVO	Incident	BE20	FYV	N/A	N/A	N/R
4/4/2007	US	Knoxville, TN	AIDS	LDVO	Incident	C560	RKW	N/A	N/A	N/R
4/13/2007	US	Teterboro, NJ	AIDS	LDVO	Incident	D328	TEB	N/A	N/A	75
4/16/2007	US	New Castle, DE	AIDS	LDVO	Incident	C680	ILG	N/A	N/A	N/R
4/23/2007	US	Baton Rouge, LA	AIDS	LDVO	Incident	AC68	BTR	N/A	N/A	N/R
7/30/2007	US	Madison, WI	AIDS	LDVO	Incident	E145	MSN	N/A	N/A	N/R
8/7/2007	US	Ankeny, IA	AIDS	LDVO	Incident	C650	IKV	N/A	N/A	N/R
8/23/2007	US	Westhampton, NY	NTSB	LDVO	Accident	LJ60	FOK	N/A	N/A	N/R
9/30/2007	US	Houston, TX	AIDS	LDVO	Incident	WW24	SGR	N/A	N/A	20
10/9/2007	US	Chicago, IL	NTSB	LDVO	Incident	A320	ORD	N/A	N/A	N/R
11/17/2007	US	Vineyard Haven, MA	AIDS	LDVO	Incident	GALX	MVY	N/A	N/A	N/R
11/25/2007	US	Minneapolis, MN	AIDS	LDVO	Incident	GA7	FCM	N/A	N/A	N/R
1/15/2008	France	Paris	BEA	LDVO	Incident	A30B	CDG	N/A	N/A	39
1/15/2008	US	Kenosha, WI	AIDS	LDVO	Incident	SH33	ENW	N/A	N/A	N/R
1/17/2008	US	Bigfork, MN	AIDS	LDVO	Incident	BE30	FOZ	N/A	N/A	N/R
1/19/2008	US	Dillingham, AK	AIDS	LDVO	Incident	B731	DLG	N/A	N/A	N/R
1/30/2008	US	West Palm Beach, FL	AIDS	LDVO	Incident	GLF5	PBI	N/A	N/A	N/R
2/1/2008	US	Morristown, NJ	AIDS	LDVO	Incident	C560	MMU	N/A	N/A	N/R
2/3/2008	US	Jackson, WY	AIDS	LDVO	Incident	CL60	JAC	N/A	N/A	N/R
2/13/2008	US	Cedar City, UT	AIDS	LDVO	Incident	E120	CDC	N/A	N/A	N/R
3/1/2008	US	Saint Louis, MO	AIDS	LDVO	Incident	C560	SUS	N/A	N/A	6
3/8/2008	US	Milwaukee, WI	AIDS	LDVO	Incident	DC91	MKE	N/A	N/A	10
4/9/2008	US	Oklahoma City, OK	AIDS	LDVO	Incident	STAR	HSD	N/A	N/A	10
4/12/2008	US	Potsdam, NY	NTSB	LDVO	Accident	E110	PTD	N/A	N/A	N/R
4/24/2008	US	Sterling, CO	NTSB	LDVO	Accident	C421	STK	N/A	N/A	N/R
5/23/2008	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	SBR1	FXE	N/A	N/A	N/R
5/24/2008	US	Fort Lauderdale, FL	AIDS	LDVO	Incident	C402	FLL	N/A	N/A	N/R
6/13/2008	US	Atlanta, GA	AIDS	LDVO	Incident	C560	PDK	N/A	N/A	N/R

7/3/2008	US	Destin, FL	AIDS	LDVO	Incident	C525	DTS	N/A	N/A	N/R
7/15/2008	US	Portland, OR	AIDS	LDVO	Incident	C402	TTD	N/A	N/A	N/R
9/7/2008	US	San Antonio, TX	AIDS	LDVO	Incident	CL60	SAT	N/A	N/A	N/R
9/19/2008	US	Van Nuys, CA	AIDS	LDVO	Incident	EGRT	VNY	N/A	N/A	N/R
9/22/2008	US	Chicago, IL	NTSB	LDVO	Incident	B752	ORD	N/A	N/A	35
10/3/2008	US	Lewiston, ID	AIDS	LDVO	Incident	SW4	LWS	N/A	N/A	N/R
11/27/2008	US	Ironwood, MI	AIDS	LDVO	Incident	B190	IWD	N/A	N/A	N/R
1/12/2009	US	Chicago, IL	AIDS	LDVO	Incident	LJ55	ARR	N/A	N/A	20
1/13/2009	US	Kodiak, AK	AIDS	LDVO	Incident	B731	ADQ	N/A	N/A	N/R
4/27/2009	US	Nantucket, MA	AIDS	LDVO	Incident	C402	ACK	N/A	N/A	N/R
1/27/1978	US	Nashville, TN	AIDS	TOOR	Incident	B721	BNA	150	0	N/A
2/13/1980	US	Chicago, IL	AIDS	TOOR	Incident	C500	Unknown	N/R	N/R	N/A
2/19/1981	US	Pittsburg, PA	AIDS	TOOR	Incident	DC91	PTS	N/R	N/R	N/A
3/4/1981	US	Hagerstown, MD	AIDS	TOOR	Incident	C500	HGR	N/R	N/R	N/A
2/3/1982	US	Philadelphia, PA	NTSB	TOOR	Accident	DC10	PHL	600	0	N/A
4/16/1982	US	Tucson, AZ	AIDS	TOOR	Incident	DC85	TUS	N/R	N/R	N/A
6/4/1982	US	Wichita, KS	NTSB	TOOR	Accident	BE65	AAO	300	50	N/A
7/5/1982	US	Boise, ID	MITRE	TOOR	Incident	DC91	BOI	50	0	N/A
7/9/1982	US	New Orleans, LA	NTSB	TOOR	Accident	B721	MSY	2376	564	N/A
9/13/1982	US	Denver, CO	NTSB	TOOR	Incident	SW3	DEN	10	0	N/A
10/3/1982	US	New Orleans, LA	MITRE	TOOR	Incident	B721	MSY	443	0	N/A
1/11/1983	US	Detroit, MI	NTSB	TOOR	Accident	DC85	DTW	299	1200	N/A
7/2/1983	US	King Salmon, AK	AIDS	TOOR	Incident	DC7	AKN	N/R	N/R	N/A
11/23/1983	US	Perris, CA	AIDS	TOOR	Incident	DHC6	L65	N/R	N/R	N/A
12/3/1983	US	Olney, TX	AIDS	TOOR	Incident	FA10	SPS	N/R	N/R	N/A
12/23/1983	US	Anchorage, AK	NTSB	TOOR	Accident	DC10	ANC	1434	40	N/A
5/31/1984	US	Denver, CO	NTSB	TOOR	Accident	B721	DEN	1074	0	N/A
7/28/1984	US	Waterville, ME	NTSB	TOOR	Accident	LJ25	WVL	100	10	N/A
1/17/1985	US	Flushing, NY	MITRE	TOOR	Incident	B721	LGA	N/R	N/R	N/A
1/21/1985	US	Johnstown, PA	NTSB	TOOR	Accident	LJ25	JST	N/R	N/R	N/A
4/3/1985	US	Grand Rapids, MI	NTSB	TOOR	Accident	DHC6	GRR	N/R	N/R	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
6/27/1985	Puerto Rico	San Juan	NTSB	TOOR	Accident	DC10	SJU	63	161	N/A
6/27/1985	US	San Juan, PR	NTSB	TOOR	Accident	DC10	SJU	140	0	N/A
8/13/1985	US	Madison, WI	NTSB	TOOR	Accident	LJ23	MSN	900	0	N/A
7/20/1986	Canada	Wabush, NL	Canada TSB	TOOR	Accident	B731	YWK	200	0	N/A
8/6/1986	US	Rutland, VT	NTSB	TOOR	Accident	LJ55	RUT	N/R	N/R	N/A
5/12/1987	US	Pittsburgh, PA	NTSB	TOOR	Accident	LJ35	AGC	1320	300	N/A
5/26/1987	US	New Orleans, LA	NTSB	TOOR	Accident	JS31	MSY	1180	20	N/A
7/16/1987	US	Jackson, MS	NTSB	TOOR	Accident	JCOM	JAN	N/R	N/R	N/A
8/3/1987	US	Denver, CO	NTSB	TOOR	Incident	A30B	DEN	N/R	N/R	N/A
9/21/1987	US	Tyndall AFB, FL	NTSB	TOOR	Incident	LJ35	PAM	230	-50	N/A
9/24/1987	US	Twin Falls, ID	NTSB	TOOR	Accident	SW4	TWF	245	1144	N/A
10/5/1987	US	Oakland, CA	AIDS	TOOR	Incident	LJ25	OAK	50	0	N/A
11/15/1987	US	Denver, CO	NTSB	TOOR	Accident	DC91	Stapleton	1300	325	N/A
12/19/1987	US	Bethel, AK	MITRE	TOOR	Accident	C208	BET	N/R	N/R	N/A
5/21/1988	US	Dallas, TX	NTSB	TOOR	Accident	DC10	DFW	1112	0	N/A
6/27/1988	UK	Newcastle	UK AAIB	TOOR	Incident	BA11	NCL	161	0	N/A
8/16/1988	US	Cleveland, OH	NTSB	TOOR	Accident	SW3	CLE	837	387	N/A
8/19/1988	US	Cleveland, OH	ASRS	TOOR	Incident		CLE	500	300	N/A
8/31/1988	US	Dallas, TX	NTSB	TOOR	Accident	B721	DFW	2833	0	N/A
9/11/1988	US	New Orleans, LA	AIDS	TOOR	Incident	L29A	MSY	400	0	N/A
11/15/1988	US	Minneapolis, MN	NTSB	TOOR	Incident	DC91	MSP	330	0	N/A
8/19/1989	US	New Orleans, LA	ASRS	TOOR	Incident		MSY	800	0	N/A
8/25/1989	US	New Orleans, LA	MITRE	TOOR	Incident	B721	MSY	600	0	N/A
9/13/1989	US	Warsaw, IN	AIDS	TOOR	Incident	WW24	ASW	1000	0	N/A
9/20/1989	US	Flushing, NY	NTSB	TOOR	Accident	B731	LGA	194	0	N/A
1/6/1990	US	Miami, FL	NTSB	TOOR	Accident	L29A	MIA	1180	100	N/A
1/30/1990	US	Rochester, NY	MITRE	TOOR	Incident	DC91	ROC	250	0	N/A
3/13/1990	US	Teterboro, NJ	MITRE	TOOR	Incident	LJ35	TEB	250	0	N/A
3/12/1991	US	New York, NY	NTSB	TOOR	Accident	DC85	JFK	835	550	N/A
7/22/1991	US	Detroit, MI	NTSB	TOOR	Accident	LJ23	DET	828	0	N/A
7/31/1991	US	Denver, CO	AIDS	TOOR	Incident	B721	DEN	150	0	N/A

10/11/1991	US	Dallas, TX	MITRE	TOOR	Incident	JS31	DFW	N/R	N/R	N/A
1/31/1992	US	Bellingham, WA	MITRE	TOOR	Incident	B461	BLI	N/R	N/R	N/A
4/15/1992	US	Charlotte, NC	NTSB	TOOR	Incident	F28	CLT	100	0	N/A
4/19/1992	US	Charlotte, NC	ASRS	TOOR	Incident		CLT	200	-130	N/A
7/30/1992	US	New York, NY	NTSB	TOOR	Accident	L101	JFK	N/R	N/R	N/A
8/19/1992	US	Washington, DC	MITRE	TOOR	Incident	SW4	DCA	170	0	N/A
12/18/1992	US	Mccall, ID	NTSB	TOOR	Accident	FA10	MYL	500	50	N/A
4/19/1993	US	Merced, CA	NTSB	TOOR	Accident	JS31	MCE	200	250	N/A
9/19/1993	France	Troyes	France BEA	TOOR	Incident	SW4	QYR	885	98	N/A
9/29/1993	France	Besançon	France BEA	TOOR	Accident	FA10	QBQ	99	49	N/A
11/2/1993	US	Houston, TX	AIDS	TOOR	Incident	CL60	HOU	200	0	N/A
3/2/1994	US	Flushing, NY	NTSB	TOOR	Accident		LGA	500	0	N/A
4/6/1994	US	Jackson, WY	AIDS	TOOR	Incident	C421	JAC	N/R	N/R	N/A
5/19/1994	US	Texarkana, TX	ASRS	TOOR	Incident	SF34	TXK	80	0	N/A
7/13/1994	US	Atlantic City, NJ	NTSB	TOOR	Accident	LJ35	ACY	446	0	N/A
8/26/1994	US	New Orleans, LA	NTSB	TOOR	Accident	FA20	NEW	500	0	N/A
5/23/1995	US	Rogers, AR	NTSB	TOOR	Accident	LJ35	ROG	1200	0	N/A
6/25/1995	US	Atlanta, GA	MITRE	TOOR	Incident	LJ35	ATL	N/R	N/R	N/A
9/18/1995	US	Ames, IA	AIDS	TOOR	Incident	C402	AMW	N/R	N/R	N/A
9/21/1995	US	Houston, TX	AIDS	TOOR	Incident	LJ25	HOU	225	0	N/A
10/19/1995	Canada	Vancouver, BC	TSB	TOOR	Incident	DC10	YVR	400	141	N/A
5/1/1996	US	Albuquerque, NM	NTSB	TOOR	Accident	SBR1	ABQ	212	212	N/A
7/8/1996	US	Nashville, TN	NTSB	TOOR	Accident	B731	BNA	750	-100	N/A
8/1/1996	UK	Cambridge	UK AAIB	TOOR	Incident		EGSC	N/R	N/R	N/A
8/14/1996	US	Pottstown, PA	NTSB	TOOR	Accident	PA31	N47	1429	457	N/A
8/16/1996	England	Liverpool	AAIB	TOOR	Incident	A748	LPL	718	200	N/A
1/10/1997	US	Bangor, ME	NTSB	TOOR	Accident	B190	BGR	N/R	N/R	N/A
1/19/1997	Italy	Rome	ASRS	TOOR	Incident	DC10	FCO	N/R	N/R	N/A
6/13/1997	US	San Antonio, TX	AIDS	TOOR	Incident	C421	SAT	N/R	N/R	N/A
8/7/1997	US	Miami, FL	NTSB	TOOR	Accident	DC85	MIA	575	0	N/A
11/29/1997	Canada	Island Lake, MB	Canada TSB	TOOR	Accident	B190	YIV	200	0	N/A

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
2/20/1998	England	Norwich	UK AAIB	TOOR	Incident	JPRO	NWI	N/R	N/R	N/A
3/19/1998	US	Portland, OR	NTSB	TOOR	Accident	S601	PDX	N/R	N/R	N/A
3/30/1998	UK	Stansted	UK AAIB	TOOR	Incident	A748	STN	386	0	N/A
5/12/1998	US	Monroe, MI	NTSB	TOOR	Accident	FA20	TTF	N/R	N/R	N/A
6/23/1998	US	Washington, DC	AIDS	TOOR	Incident	LJ60	IAD	250	0	N/A
6/23/1998	US	Washington, DC	AIDS	TOOR	Incident	LJ60	IAD	N/R	N/R	N/A
7/19/1998	US	Raleigh, NC	ASRS	TOOR	Incident	B721	RDU	200	0	N/A
8/28/1998	US	El Paso, TX	MITRE	TOOR	Accident	FA20	ELP	2010	0	N/A
12/3/1998	Canada	Iqaluit, NU	Canada TSB	TOOR	Accident	A748	YFB	800	-100	N/A
11/11/1999	US	Chicago, IL	NTSB	TOOR	Accident	BE20	CGX	300	100	N/A
5/11/2000	Canada	Edmonton, AB	Canada TSB	TOOR	Incident	DC91	YEG	500	0	N/A
8/17/2000	US	Ottawa, IL	AIDS	TOOR	Incident	SC7	8N2	N/R	N/R	N/A
10/15/2000	US	Anchorage, AK	NTSB	TOOR	Incident	B741	ANC	690	0	N/A
10/19/2000	US	Concord, CA	NTSB	TOOR	Accident	BE30	CCR	496	0	N/A
1/4/2001	US	Schenectady, NY	NTSB	TOOR	Accident	LJ35	SCH	470	0	N/A
2/1/2001	US	San Luis Obispo, CA	MITRE	TOOR	Incident	WW24	SBP	35	0	N/A
3/17/2001	US	Detroit, MI	NTSB	TOOR	Accident	A320	DTW	530	73	N/A
3/22/2001	France	Orleans	France BEA	TOOR	Accident	PA31	LFOZ	590	-66	N/A
8/16/2001	US	Traverse City, MI	MITRE	TOOR	Incident	LJ25	TVC	630	0	N/A
8/24/2001	US	Ithaca, NY	NTSB	TOOR	Accident	LJ25	ITH	1000	10	N/A
11/18/2001	US	Delavan, WI	AIDS	TOOR	Incident	DHC6	C59	N/R	N/R	N/A
4/1/2002	US	Cambridge, MD	ASRS	TOOR	Incident	BE40	CGE	75	0	N/A
5/20/2002	US	Oklahoma City, OK	NTSB	TOOR	Accident	C550	PWA	700	0	N/A
10/3/2002	US	Everett, WA	AIDS	TOOR	Incident	C500	PAE	N/R	N/R	N/A
6/12/2003	US	Fort Lauderdale, FL	AIDS	TOOR	Incident	LJ24	FXE	1000	0	N/A
7/17/2003	Netherlands	Eelde	Netherland TSB	TOOR	Accident	MD88	EHGG	100	0	N/A
7/22/2003	US	Pittston, PA	MITRE	TOOR	Accident	HUNT	AVP	740	0	N/A
8/7/2003	US	Duluth, MN	MITRE	TOOR	Incident	WW24	DLH	6	0	N/A
8/17/2003	US	Groton, CT	AIDS	TOOR	Incident	LJ25	GON	125	0	N/A
11/11/2003	US	Chicago, IL	NTSB	TOOR	Accident	C560	PWK	500	0	N/A
12/16/2003	US	Teterboro, NJ	NTSB	TOOR	Incident	CL60	TEB	188	0	N/A
10/14/2004	Canada	Halifax, NS	Canada TSB	TOOR	Accident	B741	YHZ	1750	40	N/A

12/20/2004	US	El Paso, TX	ASRS	TOOR	Incident	LJ25	ELP	200	0	N/A
2/2/2005	US	Teterboro, NJ	MITRE	TOOR	Accident	CL60	TEB	545	0	N/A
3/9/2005	US	Tupelo, MS	NTSB	TOOR	Accident	CL60	TUP	120	30	N/A
5/9/2005	US	Brownwood, TX	NTSB	TOOR	Accident	SBR1	BWD	1300	0	N/A
7/25/2005	Australia	Nhill	ATSB	TOOR	Incident	PA31	YNHL	162	0	N/A
8/1/2006	US	Angola, IN	AIDS	TOOR	Incident	C560	ANQ	75	0	N/A
8/27/2006	US	Lexington, KY	NTSB	TOOR	Accident	CRJ1	LEX	975	0	N/A
1/25/2007	France	Pau	ASN	TOOR	Accident	F100	PUF	1598	100	N/A
4/30/1970	Italy	Rome	ATSB	TOVO	Incident	B701	LIRF	N/A	N/A	370
3/1/1978	US	Lawrence, KS	AIDS	TOVO	Incident	AC80	LWC	N/A	N/A	N/R
2/21/1979	US	Detroit, MI	AIDS	TOVO	Incident	DC85	DET	N/A	N/A	N/R
11/18/1980	US	Rochester, NY	AIDS	TOVO	Incident	FA10	ROC	N/A	N/A	N/R
6/23/1981	US	Philadelphia, PA	AIDS	TOVO	Incident	H25A	PHL	N/A	N/A	500
12/9/1981	US	San Diego, CA	AIDS	TOVO	Incident	C500	Unknown	N/A	N/A	N/R
12/16/1981	US	Des Moines, IA	AIDS	TOVO	Incident	WW24	DSM	N/A	N/A	N/R
2/3/1982	US	Detroit, MI	AIDS	TOVO	Incident	SW3	Unknown	N/A	N/A	N/R
3/30/1982	US	Chicago, IL	NTSB	TOVO	Incident	SW4	ORD	N/A	N/A	70
7/14/1982	US	Santa Fe, NM	AIDS	TOVO	Incident	SW4	SAF	N/A	N/A	N/R
7/11/1983	US	Morristown, NJ	AIDS	TOVO	Incident	SBR1	MMU	N/A	N/A	N/R
1/11/1984	US	Old Town, ME	AIDS	TOVO	Incident	BE20	OLD	N/A	N/A	N/R
1/12/1984	US	Plymouth, MA	AIDS	TOVO	Incident	SW3	PYM	N/A	N/A	N/R
1/23/1984	US	Chicago, IL	NTSB	TOVO	Incident	DC86	ORD	N/A	N/A	N/R
10/25/1984	US	Houston, TX	AIDS	TOVO	Incident	LJ35	SGR	N/A	N/A	N/R
12/19/1984	US	Detroit, MI	NTSB	TOVO	Accident	BE18	YIP	N/A	N/A	N/R
2/5/1986	US	Philadelphia, PA	AIDS	TOVO	Incident	CL60	PHL	N/A	N/A	N/R
2/7/1986	US	Brigham City, UT	AIDS	TOVO	Incident	WW24	BMC	N/A	N/A	N/R
3/22/1986	US	Melbourne, FL	AIDS	TOVO	Incident	GLF2	MLB	N/A	N/A	N/R
11/29/1986	Puerto Rico	San Juan	NTSB	TOVO	Incident	DHC6	Unknown	N/A	N/A	N/R
1/22/1987	US	Washington, DC	AIDS	TOVO	Incident	C650	IAD	N/A	N/A	N/R
2/26/1987	US	Denver, CO	NTSB	TOVO	Accident	LJ35	APA	N/A	N/A	80
3/24/1987	US	Dallas, TX	NTSB	TOVO	Accident	CVLT	DFW	N/A	N/A	95

(continued on next page)

Date	Country	City/State	Source	Event Type	Event Class	Aircraft ICAO Code	Airport Code	Location X (ft)	Location Y (ft)	Maximum Veer-off (ft)
2/8/1988	US	Springfield, IL	AIDS	TOVO	Incident	SW3	SPI	N/A	N/A	N/R
2/24/1988	US	Morganton, NC	NTSB	TOVO	Accident	BE18	MRN	N/A	N/A	62
9/3/1988	US	South Saint Paul, MN	AIDS	TOVO	Incident	AC90	SGS	N/A	N/A	N/R
10/22/1988	US	Houston, TX	AIDS	TOVO	Incident	LJ24	HOU	N/A	N/A	N/R
10/29/1988	US	Aspen, CO	NTSB	TOVO	Accident	CL60	ASE	N/A	N/A	300
1/6/1989	US	Washington, DC	AIDS	TOVO	Incident	FA10	IAD	N/A	N/A	N/R
6/20/1989	US	Frankfort, KY	AIDS	TOVO	Incident	SW3	FFT	N/A	N/A	N/R
7/11/1989	US	Rochester, NY	AIDS	TOVO	Incident	F27	ROC	N/A	N/A	N/R
8/16/1989	US	Dallas, TX	AIDS	TOVO	Incident	AC90	DAL	N/A	N/A	N/R
4/6/1990	US	Orlando, FL	AIDS	TOVO	Incident	WW24	MCO	N/A	N/A	N/R
8/17/1990	US	Nantucket, MA	AIDS	TOVO	Incident	SW4	ACK	N/A	N/A	N/R
1/7/1991	US	Kansas City, MO	NTSB	TOVO	Incident	B733	MCI	N/A	N/A	40
4/15/1991	US	Houston, TX	AIDS	TOVO	Incident	H25A	HOU	N/A	N/A	N/R
4/26/1991	US	Teterboro, NJ	AIDS	TOVO	Incident	SW4	TEB	N/A	N/A	N/R
7/19/1991	US	Albuquerque, NM	NTSB	TOVO	Accident	DC3	ABQ	N/A	N/A	50
10/31/1991	US	Wichita, KS	AIDS	TOVO	Incident	LJ31	ICT	N/A	N/A	N/R
1/10/1992	US	Baton Rouge, LA	AIDS	TOVO	Incident	AC90	BTR	N/A	N/A	N/R
1/28/1994	US	Washington, DC	MITRE	TOVO	Incident	DC91	IAD	N/A	N/A	700
1/31/1994	US	Anderson, IN	NTSB	TOVO	Accident	DC3	AID	N/A	N/A	50
3/31/1994	US	Orlando, FL	AIDS	TOVO	Incident	SW4	ORL	N/A	N/A	N/R
9/14/1994	US	Rochester, NY	AIDS	TOVO	Incident	SW2	ROC	N/A	N/A	N/R
9/20/1994	US	Portsmouth, NH	AIDS	TOVO	Incident	GLF2	PSM	N/A	N/A	N/R
11/29/1994	US	Spokane, WA	AIDS	TOVO	Incident	B731	GEG	N/A	N/A	N/R
9/1/1995	US	Denver, CO	AIDS	TOVO	Incident	SW3	APA	N/A	N/A	N/R
12/17/1995	US	Philadelphia, PA	AIDS	TOVO	Incident	LJ55	PHL	N/A	N/A	55
12/20/1995	US	New York, NY	NTSB	TOVO	Accident	B741	JFK	N/A	N/A	N/R
1/10/1996	US	Hyannis, MA	AIDS	TOVO	Incident	C560	HYA	N/A	N/A	N/R
1/25/1996	US	Louisville, KY	AIDS	TOVO	Incident	LJ35	SDF	N/A	N/A	N/R
1/27/1996	US	Pendleton, OR	AIDS	TOVO	Incident	SW4	PDT	N/A	N/A	N/R
4/7/1996	US	Saint Corix, VI	NTSB	TOVO	Accident	DHC6	STX	N/A	N/A	145
5/30/1996	US	Newark, NJ	AIDS	TOVO	Incident	CL60	EWR	N/A	N/A	N/R
6/6/1996	US	San Luis Obispo, CA	MITRE	TOVO	Accident	JS31	SBP	N/A	N/A	5

9/17/1996	US	Miami, FL	AIDS	TOVO	Incident	BE18	MIA	N/A	N/A	N/R
10/30/1996	US	Chicago, IL	MITRE	TOVO	Accident	GLF4	PWK	N/A	N/A	25
12/10/1996	US	Chicago, IL	AIDS	TOVO	Incident	AC56	PWK	N/A	N/A	N/R
12/30/1996	US	Orlando, FL	MITRE	TOVO	Incident	DC85	MCO	N/A	N/A	75
1/10/1997	US	Bangor, ME	NTSB	TOVO	Accident	B190	BGR	N/A	N/A	10
1/19/1997	US	Aspen, CO	AIDS	TOVO	Incident	LJ35	ASE	N/A	N/A	N/R
1/25/1997	US	Hayden, CO	AIDS	TOVO	Incident	B731	HDN	N/A	N/A	N/R
2/22/1997	US	Austin, TX	AIDS	TOVO	Incident	BE30	AUS	N/A	N/A	N/R
3/6/1997	US	Providence, RI	AIDS	TOVO	Incident	C650	PVD	N/A	N/A	50
3/14/1997	US	Concord, NH	AIDS	TOVO	Incident	SW3	POH	N/A	N/A	N/R
5/1/1997	US	Ontario, CA	AIDS	TOVO	Incident	SW4	KONT	N/A	N/A	N/R
10/24/1997	US	Portland, ME	AIDS	TOVO	Incident	LJ24	PWM	N/A	N/A	N/R
10/28/1997	England	East Midlands	AAIB	TOVO	Incident	SF34	EGNX	N/A	N/A	90
1/10/1998	US	San Francisco, CA	AIDS	TOVO	Incident	A320	SFO	N/A	N/A	N/R
1/30/1998	US	Missoula, MT	AIDS	TOVO	Incident	SW4	MSO	N/A	N/A	N/R
3/2/1998	US	Johnstown, PA	AIDS	TOVO	Incident	JS31	JST	N/A	N/A	N/R
3/10/1998	US	Detroit, MI	AIDS	TOVO	Incident	C212	YIP	N/A	N/A	N/R
5/1/1998	US	Fort Lauderdale, FL	AIDS	TOVO	Incident	SW4	FLL	N/A	N/A	N/R
6/30/1998	England	Stansted Mountfitchet	AAIB	TOVO	Incident	JS31	EGSS	N/A	N/A	417
11/23/1998	US	Long Beach, CA	AIDS	TOVO	Incident	BE18	LGB	N/A	N/A	N/R
12/19/1998	US	Colorado Springs, CO	AIDS	TOVO	Incident	B731	COS	N/A	N/A	20
1/8/1999	US	Lewistown, MT	AIDS	TOVO	Incident	SW4	LWT	N/A	N/A	N/R
8/8/1999	US	Chicago, IL	AIDS	TOVO	Incident	B731	MDW	N/A	N/A	N/R
9/24/1999	US	Chicago, IL	AIDS	TOVO	Incident	C402	MDW	N/A	N/A	N/R
10/1/1999	US	Louisville, KY	AIDS	TOVO	Incident	FA10	SDF	N/A	N/A	N/R
11/19/1999	France	Paris	BEA	TOVO	Accident	B731	CDG	N/A	N/A	35
2/3/2000	US	Peru, IN	AIDS	TOVO	Accident	BE20	I76	N/A	N/A	N/R
3/16/2000	US	Fort Lauderdale, FL	NTSB	TOVO	Accident	C402	FLL	N/A	N/A	330
5/21/2000	US	Nantucket, MA	AIDS	TOVO	Incident	C402	ACK	N/A	N/A	N/R
7/31/2000	US	Las Vegas, NV	AIDS	TOVO	Incident	B731	LAS	N/A	N/A	N/R
12/28/2000	US	Erie, PA	AIDS	TOVO	Incident	LJ25	ERI	N/A	N/A	15
3/10/2001	US	Bar Harbor, ME	AIDS	TOVO	Incident	B190	BHB	N/A	N/A	N/R

(continued on next page)

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4/7/2001	US	Anchorage, AK	AIDS	TOVO	Incident	B190	ANC	N/A	N/A	N/R
8/28/2001	US	Chicago, IL	MITRE	TOVO	Accident	SW3	DPA	N/A	N/A	340
3/9/2002	US	Chicago, IL	AIDS	TOVO	Incident	F2TH	MDW	N/A	N/A	175
7/20/2002	US	Ardmore, OK	AIDS	TOVO	Incident	GLF2	ADM	N/A	N/A	55
9/21/2002	US	Chicago, IL	AIDS	TOVO	Incident	C560	MDW	N/A	N/A	N/R
9/29/2002	US	Hawthorne, CA	NTSB	TOVO	Accident	SW4	HHR	N/A	N/A	N/R
12/8/2002	US	New Orleans, LA	AIDS	TOVO	Incident	WW24	NEW	N/A	N/A	25
12/13/2002	US	Manassas, VA	MITRE	TOVO	Accident		HEF	N/A	N/A	250
2/17/2003	US	Richmond, VA	AIDS	TOVO	Incident	SW4	RIC	N/A	N/A	N/R
3/16/2003	US	Cedar City, UT	NTSB	TOVO	Incident	E120	CDC	N/A	N/A	35
4/2/2003	Netherlands	Amsterdam	Netherland TSB	TOVO	Incident	B741	EHAM	N/A	N/A	60
5/28/2003	US	Bismarck, ND	AIDS	TOVO	Incident	SW4	BIS	N/A	N/A	N/R
8/18/2003	US	St Augustine, FL	MITRE	TOVO	Accident	BE40	SGJ	N/A	N/A	45
6/4/2004	US	Fairbanks, AK	AIDS	TOVO	Incident	LJ35	AFA	N/A	N/A	N/R
6/17/2004	US	Lancaster, PA	AIDS	TOVO	Incident	LJ35	LNS	N/A	N/A	N/R
7/29/2005	US	Mount Pleasant, SC	AIDS	TOVO	Incident	BE20	LRO	N/A	N/A	N/R
11/8/2005	US	Eureka, CA	AIDS	TOVO	Incident	PA31	EKA	N/A	N/A	N/R
1/20/2006	England	Glasgow	AAIB	TOVO	Incident	AT43	EGPK	N/A	N/A	17
1/21/2006	US	Caldwell, ID	AIDS	TOVO	Incident	AC68	EUL	N/A	N/A	N/R
1/29/2006	US	Las Vegas, NV	AIDS	TOVO	Incident	A319	LAS	N/A	N/A	N/R
1/30/2006	US	Las Vegas, NV	Canada TSB	TOVO	Incident	A319	LAS	N/A	N/A	40
2/20/2006	US	Casper, WY	NTSB	TOVO	Incident	SW4	CPR	N/A	N/A	25
6/6/2006	US	Fort Lauderdale, FL	AIDS	TOVO	Incident	SW3	FXE	N/A	N/A	N/R
7/27/2006	US	Louisville, KY	AIDS	TOVO	Incident	B721	SDF	N/A	N/A	N/R
8/12/2006	US	Amarillo, TX	AIDS	TOVO	Incident	LJ31	AMA	N/A	N/A	50
5/22/2007	England	Exeter	AAIB	TOVO	Accident	HUNT	EGTE	N/A	N/A	N/R
7/14/2007	Australia	Sydney	ATSB	TOVO	Incident	B731	YSSY	N/A	N/A	165
11/11/2007	US	Kansas City, MO	AIDS	TOVO	Incident	LJ60	MKC	N/A	N/A	N/R
1/19/2008	US	New York, NY	AIDS	TOVO	Incident	B741	JFK	N/A	N/A	N/R
2/14/2008	US	Greensboro, NC	AIDS	TOVO	Incident	DC85	GSO	N/A	N/A	25
5/26/2008	US	Everett, WA	AIDS	TOVO	Incident	SW3	PAE	N/A	N/A	N/R
8/20/2008	US	Chicago, IL	AIDS	TOVO	Accident	C525	PWK	N/A	N/A	N/R
12/20/2008	US	Denver, CO	NTSB	TOVO	Accident	B731	DEN	N/A	N/A	525

APPENDIX C

Sample of Normal Operations Data

Table C1. Example of normal operations data.

LOCID	YYYYMMDD	HOUR	FLT_TYPE	TERRAIN	HUB	USER_CLASS	ETMSARR	NEQPT_CLASS	NEQPT_TYPE	Wx Stratum	CEILING Ft	VIS Sm	TEMP	Fog	Icing	Elec. Storm	Frozen Precip	Snow	PRECIP FINAL	Light	XWIND Knts	Light2	PRECIP FINAL2	CEILING100FT	TEMP10C	DawnDusk
ADS	20040501	23	0	0	2	4	1	4	2	NHASWF	3000	10.00	11	0	0	0	0	0	0	2	0.57	1	0	30	1.1	0
ADS	20040501	23	1	0	2	4	1	4	2	NHASWF	3000	10.00	11	0	0	0	0	0	0	2	0.57	1	0	30	1.1	0
ADS	20020201	17	0	0	2	4	1	4	2	NHASWF	3000	10.00	9	0	0	0	0	0	0	2	0.48	1	0	30	0.9	0
ADS	20020201	17	0	0	2	1	1	4	2	NHASWF	3000	10.00	9	0	0	0	0	0	0	2	0.48	1	0	30	0.9	0
ADS	20020201	17	0	0	2	1	1	4	2	NHASWF	3000	10.00	9	0	0	0	0	0	0	2	0.48	1	0	30	0.9	0
ADS	20040501	22	0	0	2	1	1	4	2	NHASWF	3000	10.00	12	0	0	0	0	0	0	2	0.24	1	0	30	1.2	0
ADS	20020201	11	0	0	2	1	1	5	1	NHASWF	3000	10.00	7	0	0	0	0	0	0	1	0.53	0	0	30	0.7	0
ADS	20020201	11	0	0	2	4	1	4	2	NHASWF	3000	10.00	7	0	0	0	0	0	0	1	0.53	0	0	30	0.7	0
ADS	20020201	11	0	0	2	1	1	4	2	NHASWF	3000	10.00	7	0	0	0	0	0	0	1	0.53	0	0	30	0.7	0
ADS	20021101	9	0	0	2	4	1	4	1	NHASWF	1083	4.000	9	0	0	0	0	0	0	1	0.24	0	0	10.8	0.9	0
ADS	20021101	9	0	0	2	4	1	4	2	NHASWF	1083	4.000	9	0	0	0	0	0	0	1	0.24	0	0	10.8	0.9	0
ADS	20021101	8	0	0	2	4	1	4	2	NHASWF	1083	4.000	9	0	0	0	0	0	2	1	0.38	0	1	10.8	0.9	0
ADS	20021101	7	0	0	2	3	1	5	1	NHASWF	1280	5.000	9	0	0	0	0	0	0	1	0.38	0	0	12.8	0.9	0
ADS	20021101	7	0	0	2	4	1	4	2	NHASWF	1280	5.000	9	0	0	0	0	0	0	1	0.38	0	0	12.8	0.9	0
ADS	20030501	23	0	0	2	4	1	4	2	NHASWF	3000	10.00	23	0	0	0	0	0	0	2	0	1	0	30	2.3	0
ADS	20030501	23	0	0	2	4	1	4	2	NHASWF	3000	10.00	23	0	0	0	0	0	0	2	0	1	0	30	2.3	0
ADS	20040501	19	0	0	2	4	1	4	1	NHASWF	3000	10.00	15	0	0	0	0	0	0	4	0	1	0	30	1.5	1
ADS	20040501	19	0	0	2	1	1	4	2	NHASWF	3000	10.00	15	0	0	0	0	0	0	4	0	1	0	30	1.5	1
ADS	20040501	18	1	0	2	4	1	4	2	NHASWF	3000	10.00	16	0	0	0	0	0	0	1	0	0	0	30	1.6	0
ADS	20040501	18	0	0	2	4	1	4	2	NHASWF	3000	10.00	16	0	0	0	0	0	0	1	0	0	0	30	1.6	0
ADS	20040501	15	0	0	2	4	1	5	1	NHASWF	1575	10.00	14	0	0	0	0	0	0	1	0	0	0	15.7	1.4	0
ADS	20040501	15	0	0	2	1	1	4	2	NHASWF	1575	10.00	14	0	0	0	0	0	0	1	0	0	0	15.7	1.4	0

Table C2. Codes used for NOD.

Field	Notes
LOCID	Airport IATA/FAA code
YYYYMMDD	Date
HOUR	Local Time
FLT_TYPE	Foreign Origin/destination = 1; Domestic = 0
TERRAIN	Significant terrain (code 1) if the terrain within the plan view exceeds 4,000 feet above the airport elevation, or if the terrain within a 6.0 nautical mile radius of the Airport Reference Point rises to at least 2,000 feet above the airport elevation.
HUB	1 Hub; 2 Non-hub
USER_CLASS	1 Commercial; 2 Air Taxi; 3 Freight; 4 GA
ETMSARR	Arrival counts
ETMSDEP	Departure counts
NEQPT_CLASS	1 A/B (255000lbs+/B757 Heavy); 2 C(41000-255000lbs Large Jet); 3 D(41000-255000lbs Large commuter); 4 E (12500-41000lbs Medium); 5 F (<12500lbs Small)
NEQPT_TYPE	1 Turboprop; 2 Jet
Wx Stratum	For stratified sampling purposes
CEILING Ft	Ceiling in feet
VIS Sm	Visibility capped Max 10SM
TEMP	Degree C
Fog	Yes = 1; No = 0
Icing	Yes = 1; No = 0
Elec. Storm	Yes = 1; No = 0
Frozen Precip	Yes = 1; No = 0
Snow	Yes = 1; No = 0
PRECIP FINAL	0 None; 1 Trace/Light; 2 Moderate; 3 Heavy
Light	1 Day; 2 Night; 3 Dawn; 4 Dusk
APP XIND Knts	In knots
DEP XWIND Knts	In knots
Light2	0 Day; 1 Night/Dawn/Dusk
PRECIP FINAL2	0 None; 1 Trace/Light/Moderate/Heavy
CEILING100FT	Ceiling capped Max 3000ft
DawnDusk	0 Day/Night; 1 Dawn/Dusk

APPENDIX D

Aircraft Database Summary

Aircraft Name	Manufacturer	ICAO Code	Wingspan (ft)	Length (ft)	Height (ft)	Engine Type	Engines (#)	MTOW (lb)	Takeoff Distance (ft)	Landing Distance (ft)	V2 (kts)	Approach Speed (kts)
Mohawk 298	Aerospatiale	N262	71.9	63.3	20.3	Turboprop	2	23,369	2,296.6	1,312.3	100	110
Aerostar 600	Aerostar	AEST	36.7	34.8	12.8	Piston	2	6,305	1,804.5	1,148.3	95	94
A-300	Airbus	A30B	147.1	177.5	54.3	Jet	2	378,534	7,349.1	5,026.2	160	135
A-300-600	Airbus	A306	147.1	177.5	54.3	Jet	2	378,534	7,349.1	5,026.2	160	135
A-310-200/300	Airbus	A310	144.0	153.1	51.8	Jet	2	330,693	7,513.1	4,888.5	160	135
A-318	Airbus	A318	111.9	103.2	41.2	Jet	2	130,073	4,593.2	4,265.1	135	138
A-319	Airbus	A319	111.9	111.2	38.6	Jet	2	141,096	5,741.5	4,429.1	135	138
A-320	Airbus	A320	111.9	123.3	38.6	Jet	2	162,040	7,185.0	4,724.4	145	138
A-321	Airbus	A321	111.9	146.0	38.6	Jet	2	182,984	7,250.7	5,249.3	145	138
A-330-200	Airbus	A332	197.8	192.9	57.1	Jet	2	507,063	7,545.9	5,905.5	145	140
A-330-300	Airbus	A333	197.8	208.7	55.3	Jet	2	507,063	7,545.9	5,905.5	145	130
A-340-200	Airbus	A342	197.8	194.8	54.8	Jet	4	606,271	9,071.5	5,790.7	145	150
A-340-300	Airbus	A343	197.8	208.7	55.3	Jet	4	606,271	9,071.5	6,003.9	145	150
A-340-500	Airbus	A345	208.2	222.8	56.1	Jet	4	811,301	10,498.7	6,299.2	145	150
A-340-600	Airbus	A346	208.2	247.0	56.8	Jet	4	811,301	10,301.8	6,561.7	145	150
A-380-800	Airbus	A388	261.8	239.5	79.1	Jet	4	1,234,589	9,744.1	6,594.5	150	145
Alenia ATR-42-200/300	ATR	AT43	80.7	74.5	24.9	Turboprop	2	36,817	3,608.9	3,280.8	110	104
Alenia ATR-72-200/210	ATR	AT72	88.9	89.2	25.3	Turboprop	2	47,399	4,921.3	3,608.9	110	105
Avro 748	Avro	A748	98.2	66.9	24.9	Turboprop	2	46,495	3,280.8	2,034.1	110	100
Jetsream 31	Bae Systems	JS31	52.0	47.1	17.5	Turboprop	2	15,562	5,905.5	4,265.1	110	125
Jetsream 32	Bae Systems	JS32	52.0	47.1	17.7	Turboprop	2	16,226	5,150.9	4,002.6	110	125
Jetsream 41	Bae Systems	JS41	60.4	63.4	18.4	Turboprop	2	24,000	4,921.3	4,265.1	110	120
100 King Air	Beech	BE10	45.9	40.0	15.4	Turboprop	2	11,795	1,476.4	2,132.5	105	111
33 Debonair	Beech	BE33	33.5	25.6	8.2	Piston	1	3,064	1,148.3	984.3	75	70
Beech 55 Baron	Beech	BE55	37.7	27.9	9.5	Piston	2	5,071	1,476.4	1,476.4	95	90
Beech 60 Duke	Beech	BE60	39.4	33.8	12.5	Piston	2	6,768	1,968.5	1,312.3	95	98
Beech 76 Duchess	Beech	BE76	38.1	29.2	9.5	Piston	2	3,902	2,132.5	1,968.5	85	76
Beech 99 Airliner	Beech	BE99	45.9	44.6	14.4	Turboprop	2	16,755	3,280.8	2,952.8	115	107

Bonanza V35B	Beech	BE35	33.4	26.3	7.6	Piston	1	3,400	1150	1480		70
King Air F90	Beech	BE9T	45.9	39.8		Turboprop	2	10,950				108
Super King Air 300	Beech	BE30	54.5	44.0	14.8	Turboprop	2	13,889	1,870.1	1,771.7	115	103
Premier 1A	Beechcraft	PRM1	44.5	46.0	15.3	Jet	2	12,500	3,792.0	3,170.0		121
B707-100	Boeing	B701	130.9	144.7	42.3	Jet	4	190,003	8,694.2	6,496.1		139
B717-200	Boeing	B712	93.2	124.0	29.5	Jet	2	120,999	6,889.8	5,249.3	130	139
B727 Stage 3 Noise Acft	Boeing	B727Q	107.9	153.2	34.1	Jet	3	210,101	9,842.5	4,921.3	145	150
B727-100	Boeing	B721	108.0	133.2	34.3	Jet	3	169,095	8,202.1	4,921.3		125
B727-200	Boeing	B722	107.9	153.2	34.1	Jet	3	210,101	9,842.5	4,921.3	145	150
B737 Stage 3 Noise Acft	Boeing	B737Q	93.0	94.0	37.2	Jet	2	110,121	5,905.5	4,593.2	145	137
B737-100	Boeing	B731	93.0	94.0	37.2	Jet	2	110,121	5,905.5	4,593.2	145	137
B737-200	Boeing	B732	93.0	100.2	37.2	Jet	2	115,500	6,003.9	4,593.2	145	137
B737-300	Boeing	B733	94.8	109.6	36.6	Jet	2	124,495	5,249.3	4,593.2	140	135
B737-400	Boeing	B734	94.8	119.4	36.6	Jet	2	138,494	6,561.7	4,921.3	150	139
B737-500	Boeing	B735	94.8	101.7	36.6	Jet	2	115,500	4,921.3	4,593.2	139	140
B737-600	Boeing	B736	112.6	102.5	40.8	Jet	2	123,988	6,233.6	4,265.1	135	125
B737-700	Boeing	B737	112.6	110.3	40.8	Jet	2	146,211	5,905.5	4,593.2	140	130
B737-800	Boeing	B738	112.6	129.5	40.6	Jet	2	155,492	7,545.9	5,249.3	145	141
B737-900	Boeing	B739	112.6	138.2	40.6	Jet	2	174,198	7,545.9	5,577.4	149	144
B747-100	Boeing	B741	195.3	229.0	64.2	Jet	4	735,021	10,465.9	6,233.6	170	152
B747-200	Boeing	B742	195.7	229.0	64.2	Jet	4	826,403	10,498.7	6,233.6	173	152
B747-300	Boeing	B743	195.7	229.0	64.2	Jet	4	826,403	10,826.8	7,217.8	178	160
B747-400	Boeing	B744	195.6	229.2	64.2	Jet	4	874,993	10,826.8	6,988.2	185	154
B747-400ER	Boeing	B744ER	213.0	231.9	64.3	Jet	4	910,002	10,498.7	7,841.2		157
B747-8	Boeing	B748	224.4	246.9	64.3	Jet	4	975,001	10,000.0	8,595.8		159
B757-200	Boeing	B752	124.8	155.2	45.1	Jet	2	255,031	6,233.6	4,593.2	145	135
B757-300	Boeing	B753	124.8	177.4	44.8	Jet	2	272,491	8,530.2	5,905.5	145	142
B767-200	Boeing	B762	156.1	159.2	52.9	Jet	2	395,002	8,858.3	4,921.3	160	130
B767-300	Boeing	B763	156.1	180.2	52.6	Jet	2	412,000	9,514.4	5,905.5	160	130
B767-400	Boeing	B764	170.3	201.3	55.8	Jet	2	449,999	9,514.4	5,905.5	160	150
B767-400ER	Boeing	B764ER	170.3	201.3	55.8	Jet	2	449,999	9,514.4	5,905.5	160	150
B777-200	Boeing	B772	199.9	209.1	61.5	Jet	2	545,005	9,514.4	5,577.4	170	145

(continued on next page)

Aircraft Name	Manufacturer	ICAO Code	Wingspan (ft)	Length (ft)	Height (ft)	Engine Type	Engines (#)	MTOW (lb)	Takeoff Distance (ft)	Landing Distance (ft)	V2 (kts)	Approach Speed (kts)
B777-200LR	Boeing	B772LR	212.6	209.1	61.5	Jet	2	766,001	9,514.4	5,577.4	170	139
B777-300	Boeing	B773	199.9	242.3	61.5	Jet	2	659,998	9,842.5	5,905.5	168	145
B777-300ER	Boeing	B773ER	212.6	242.3	61.8	Jet	2	775,002	9,514.4	5,905.5	160	145
B787-8 Dreamliner	Boeing	B788	197.2	186.1	55.5	Jet	2	484,001				140
BMD-90	Boeing	MD90	107.8	152.6	31.2	Jet	2	164,244	7,217.8	3,937.0	140	140
BD-700 Global Express	Bombardier	GLEX	93.8	99.4	24.9	Jet	2	98,106	6,135.2	1,358.3	120	126
BAC 1-11	British Aerospace	BA11	93.5	107.0	25.4	Jet	2	99,651	7,470.5	4,757.2	140	129
BAE-146-200	British Aerospace	B462	86.4	93.7	28.2	Jet	4	93,035	3,379.3	4,051.8	125	125
CL-600 Challenger	Canadair	CL60	61.8	68.4		Jet	2	47,600				125
RJ-100 Regional Jet	Canadair	CRJ1	69.6	87.9	20.7	Jet	2	47,399	5,249.3	4,593.2	135	135
RJ-200 Regional Jet	Canadair	CRJ2	69.6	87.9	20.7	Jet	2	47,399	5,249.3	4,593.2	135	135
RJ-700 Regional Jet	Canadair	CRJ7	76.2	106.7	24.8	Jet	2	72,753	5,249.3	4,849.1	135	135
RJ-900 Regional Jet	Canadair	CRJ9	76.4	118.8	24.6	Jet	2	80,491	6,168.0	5,118.1	170	150
Aviocar	Casa	C212	66.6	53.1	21.7	Turboprop	2	16,976	2,952.8	1,640.4	100	81
500 Citation	Cessna	C500	47.2	43.6	14.4	Jet	2	10,847	3,274.3	1,870.1	120	125
Cessna 120	Cessna	C120	32.8	21.0		Piston	1	1,450	650.0	460.0		
Cessna 150 Commuter	Cessna	C150	33.5	21.7	6.9	Piston	1	1,499	820.2	656.2	55	55
Cessna 172 Skyhawk	Cessna	C172	35.8	26.9	8.9	Piston	1	2,315	984.3	524.9	60	65
Cessna 182 Skylane	Cessna	C182	36.1	28.2	9.2	Piston	1	2,800	656.2	1,348.4	65	92
Cessna 185 Skywagon	Cessna	C185	36.2	25.8	7.8	Piston	1	3,351	650.0	610.0		
Cessna 206 Caravan 1	Cessna	C208	52.2	37.7	14.1	Turboprop	1	8,001	1,640.4	1,476.4	85	104
Cessna 210 Centurion	Cessna	C210	36.7	28.2	9.8	Piston	1	4,012	1,312.3	1,476.4	70	75
Cessna 340 Rocket	Cessna	C340	38.1	34.4	12.5	Piston	2	5,975	2,132.5	1,640.4	95	110
Cessna 402 Utililiner	Cessna	C402	44.2	36.4	11.8	Piston	2	6,305	2,221.1	1,765.1	95	95
Cessna 404 Titan	Cessna	C404	49.5	39.0	13.1	Piston	2	8,444	2,296.6	1,968.5	100	100
Cessna 414 Chancellor	Cessna	C414	41.0	33.8	11.8	Piston	2	6,746	1,706.0	2,296.6	100	94
Cessna 421 Golden Eagle	Cessna	C421	40.0	33.8	11.8	Piston	2	6,834	1,968.5	2,460.6	100	96
Cessna 425 Corsair	Cessna	C425	44.3	35.8	12.8	Turboprop	2	8,598	2,460.6	2,132.5	105	110
Cessna 441 Conquest	Cessna	C441	49.3	39.0	13.1	Turboprop	2	9,855	1,804.5	1,148.3	105	100
Cessna 500 Citation 1	Cessna	C500	47.2	43.6	14.4	Jet	2	10,847	3,274.3	1,870.1	120	108
Cessna 501 Citation 1SP	Cessna	C501	47.2	43.6	14.4	Jet	2	10,847	3,274.3	1,870.1	120	125

Cessna 525 Citation CJ1	Cessna	C525	46.9	42.7	13.8	Jet	2	10,399	3,080.7	2,749.3	115	107
Cessna 550 Citation 2	Cessna	C550	52.2	47.2	15.1	Jet	2	15,102	3,280.8	3,002.0	115	108
Cessna 560 Citation 5 Ultra	Cessna	C560	45.3	48.9	13.8	Jet	2	15,895	3,159.4	2,919.9	105	108
Cessna 650 Citation 3	Cessna	C650	53.5	55.4	16.8	Jet	2	30,997	5,249.3	2,952.8	125	114
Cessna 750 Citation 10	Cessna	C750	64.0	72.2	19.0	Jet	2	35,699	5,708.7	3,818.9	125	130
Cessna Stationair 6	Cessna	C206	35.8	28.2	9.8	Piston	1	3,638	820.2	1,476.4	75	92
Cessna T303 Crusader	Cessna	C303	39.0	30.5	13.5	Piston	2	5,159	1,748.7	1,460.0	85	110
Cessna T310	Cessna	C310	37.1	31.8	10.8	Piston	2	5,498	1,663.4	1,791.3	95	110
Citation CJ2	Cessna	C25A	49.5	46.9	13.8	Jet	2	12,375	3,418.6	2,985.6	115	118
Citation CJ3	Cessna	C25B	49.5	46.9	13.8	Jet	2	12,375	3,418.6	2,985.6	115	118
Citation Excel	Cessna	C56X	55.8	51.8	17.1	Jet	2	19,200	3,461.3	2,919.9	115	125
Falcon 10	Dassault	FA10	42.9	45.5		Jet	2	18,739				104
Falcon 200	Dassault	FA20	53.5	56.4	17.4	Jet	2	29,013	5,249.3	3,608.9	120	107
Falcon 2000	Dassault	F2TH	63.3	66.3	23.3	Jet	2	35,803	5,249.3	5,249.3	120	114
Falcon 50	Dassault	FA50	61.9	60.8	29.4	Jet	3	38,801	4,593.2	3,608.9	120	113
Falcon 900	Dassault	F900	63.3	66.3	24.9	Jet	3	46,738	4,921.3	2,296.6	125	100
DHC-5 Buffalo	De Havilland Canada	DHC5	65.0	49.5	19.4	Turboprop	2	12,500	1,640.4	984.3	80	77
DHC-7 Dash 7	De Havilland Canada	DHC7	93.2	80.7	26.2	Turboprop	4	47,003	2,952.8	3,280.8	90	83
DHC-8-100 Dash 8	De Havilland Canada	DH8A	85.0	73.2	24.6	Turboprop	2	34,502	2,952.8	2,952.8	100	100
DHC-8-300 Dash 8	De Havilland Canada	DH8C	89.9	84.3	24.6	Turboprop	2	41,099	3,608.9	3,280.8	110	90
DHC-8-400 Dash 8	De Havilland Canada	DH8D	93.2	107.6	27.2	Turboprop	2	63,930	4,265.1	3,608.9	115	115
DC-8 Stage 3 Noise Aircraft	Douglas	DC8Q	142.4	150.6	42.3	Jet	4	324,961	9,842.5	6,561.7	130	137
DC-8-50	Douglas	DC85	142.4	150.6	42.3	Jet	4	324,961	9,842.5	6,561.7	130	137
DC-8-60	Douglas	DC86	142.4	187.3	42.3	Jet	4	349,874	9,842.5	6,561.7	130	137
DC-8-70	Douglas	DC87	148.3	187.3	43.0	Jet	4	357,204	10,006.6	6,561.7	160	150
DC-9-10	Douglas	DC91	89.6	119.4	27.5	Jet	2	110,099	6,889.8	4,921.3	140	127
DC-9-30	Douglas	DC93	89.6	119.4	27.6	Jet	2	110,099	6,889.8	4,921.3	140	127
DC-9-40	Douglas	DC94	93.5	133.5	28.0	Jet	2	121,109	6,889.8	4,921.3	140	130

(continued on next page)

Aircraft Name	Manufacturer	ICAO Code	Wingspan (ft)	Length (ft)	Height (ft)	Engine Type	Engines (#)	MTOW (lb)	Takeoff Distance (ft)	Landing Distance (ft)	V2 (kts)	Approach Speed (kts)
DC-9-50	Douglas	DC95	93.5	133.5	27.9	Jet	2	121,109	6,889.8	4,921.3	140	132
DC-9-50	Douglas	DC95	93.5	133.5	27.9	Jet	2	121,109	6,889.8	4,921.3	140	132
EMB-110 Bandeirante	Embraer	E110	50.2	46.6	16.1	Turboprop	2	13,007	3,937.0	4,265.1	90	92
EMB-120 Brasilia	Embraer	E120	65.0	65.6	21.0	Turboprop	2	26,455	4,593.2	4,593.2	120	120
EMB-145	Embraer	E145	65.7	98.0	22.2	Jet	2	46,734	6,561.7	4,429.1	130	135
EMB-145XR	Embraer	E45X	68.9	98.0	22.2	Jet	2	46,734	6,561.7	4,429.1	130	135
Embraer 140	Embraer	E140	65.7	93.3	22.1	Jet	2	46,518	6,069.6	4,527.6	130	135
Embraer 175	Embraer	E175	85.3	103.9	31.9	Jet	2	82,673	7,362.2	4,137.1	140	145
Embraer 195	Embraer	E195	94.2	126.8	34.6	Jet	2	107,564	7,149.0	4,206.0	140	145
ERJ-135	Embraer	E135	65.7	86.4	22.2	Jet	2	44,070	5,774.3	4,461.9	125	130
ERJ-170	Embraer	E170	85.3	98.1	32.3	Jet	2	79,344	5,393.7	4,176.5	140	145
ERJ-190	Embraer	E190	94.2	118.9	34.7	Jet	2	105,359	6,745.4	4,340.6	140	145
328 Jet Envoy 3	Fairchild-Dornier	J328	68.8	69.9	23.6	Jet	2	33,510	4,265.1	3,937.0	135	120
Fairchild-Dornier 328	Fairchild-Dornier	D328	68.8	69.3	23.9	Turboprop	2	30,843	3,280.8	3,937.0	110	110
F-27 Friendship	Fokker	F27	95.1	75.8	27.9	Turboprop	2	44,996	2,296.6	1,968.5	100	120
F-28 Fellowship	Fokker	F28	88.8	89.9	27.9	Jet	2	72,995	5,577.4	3,280.8	135	125
Fokker 100	Fokker	F100	92.2	116.5	27.9	Jet	2	95,659	5,577.4	4,593.2	135	130
Fokker 50	Fokker	F50	95.1	82.7	27.2	Turboprop	2	43,982	3,608.9	3,608.9	120	120
Fokker 70	Fokker	F70	95.5	101.4	27.9	Turboprop	2	71,981	4,265.1	3,937.0	125	120
Greyhound C2	Grumman	C2	80.7	57.7	18.4	Turboprop	2	54,426	2,608.3	1,476.4	105	105
695 JetProp Commander 980/1000	Gulfstream Aerospace	AC95	52.2	43.0	15.1	Turboprop	2	11,199	1,640.4	1,640.4	100	500
G-1159 Gulfstream 2	Gulfstream Aerospace	GLF2	68.1	79.1		Jet	2	65,301				141
G-1159A Gulfstream 3	Gulfstream Aerospace	GLF3	77.8	83.0	24.6	Jet	2	69,710	5,905.5	3,280.8	145	136
G-1159C Gulfstream 4	Gulfstream Aerospace	GLF4	77.8	88.3	24.3	Jet	2	73,193	5,249.3	3,280.8	145	128
G-1159D Gulfstream 5	Gulfstream Aerospace	GLF5	93.5	96.5	25.9	Jet	2	90,689	5,150.9	2,900.3	145	145
Ilyushin IL-62	Ilyushin	IL62	141.7	174.2	40.7	Jet	4	363,763	10,826.8	7,545.9	150	152
Ilyushin IL-96	Ilyushin	IL96	197.2	181.4	57.4	Jet	4	595,248	9,186.4	6,561.7	150	150

1124 Westwind	Israel Aerospace Industries	WW24	44.9	52.2	15.7	Jet	2	22,928	4,839.2	2,460.6	125	129
1125 Astra	Israel Aerospace Industries	ASTR	52.8	55.4	18.0	Jet	2	24,648	5,249.3	2,952.8	130	126
1126 Galaxy	Israel Aerospace Industries	GALX	58.1	62.3	21.3	Jet	2	34,851	5,905.5	3,444.9	125	130
Learjet 24	Learjet	LJ24	35.1	43.0		Jet	2	13,001				128
Learjet 25	Learjet	LJ25	35.4	47.6	12.1	Jet	2	14,991	3,937.0	2,952.8	130	137
Learjet 31	Learjet	LJ31	43.6	48.6	12.5	Jet	2	15,498	3,608.9	2,952.8	130	120
Learjet 35	Learjet	LJ35	39.4	48.6	12.1	Jet	2	18,298	4,265.1	2,952.8	140	125
Learjet 35	Learjet	LJ35	39.4	48.6	12.1	Jet	2	18,298	4,265.1	2,952.8	140	125
Learjet 45	Learjet	LJ45	47.9	58.1	14.1	Jet	2	19,511	4,265.1	2,952.8	140	140
Learjet 55	Learjet	LJ55	43.6	55.1	14.8	Jet	2	21,010	4,593.2	3,280.8	140	140
Learjet 60	Learjet	LJ60	44.0	58.7	14.8	Jet	2	23,104	5,249.3	3,608.9	140	140
AC-130 Spectre	Lockheed	C130	132.5	97.8	38.7	Turboprop	4	155,007	3,608.9	2,624.7	120	130
Electra	Lockheed	L188	99.1	104.3	32.8	Turboprop	4	112,987	4,265.1	2,952.8	120	130
L-1011 TriStar	Lockheed	L101	155.5	178.1	55.4	Jet	3	429,990	7,874.0	5,905.5	150	138
P-3 Orion	Lockheed	P3	99.7	116.8	0.0	Turboprop	4	135,000				134
DC-10	McDonnell Douglas	DC10	165.4	180.4	58.1	Jet	3	572,009	9,842.5	5,905.5	150	136
MD-11	McDonnell Douglas	MD11	169.9	200.8	57.7	Jet	3	630,500	10,170.6	6,889.8	160	155
MD-80	McDonnell Douglas	MD80	107.8	147.7	30.2	Jet	3	149,500	6,732.3	5,200.1	140	150
MD-81	McDonnell Douglas	MD81	107.8	147.7	30.2	Jet	3	149,500	6,732.3	5,200.1	140	150
MD-82	McDonnell Douglas	MD82	107.8	147.7	30.2	Jet	3	149,500	6,732.3	5,200.1	140	150
MD-83	McDonnell Douglas	MD83	107.8	147.7	30.2	Jet	3	160,001	6,732.3	5,200.1	140	150
MD-88	McDonnell Douglas	MD88	107.8	147.7	30.2	Jet	3	149,500	6,732.3	5,200.1	140	150
LR-1 Marquise	Mitsubishi	MU2	39.0	33.1	12.8	Turboprop	2	10,053	2,132.5	1,968.5	120	88
Aerostar 200	Mooney	M20P	35.1	23.3	8.2	Piston	1	2,579	1,476.4	820.2	70	70

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Aircraft Name	Manufacturer	ICAO Code	Wingspan (ft)	Length (ft)	Height (ft)	Engine Type	Engines (#)	MTOW (lb)	Takeoff Distance (ft)	Landing Distance (ft)	V2 (kts)	Approach Speed (kts)
Observer	Partenavia	P68	39.4	30.8	11.2	Piston	2	4,586	1,312.3	1,968.5	75	73
P-180 Avanti	Piaggio	P180	45.9	47.2	12.8	Turboprop	2	11,552	2,952.8	2,952.8	120	120
Astra	Pilatus	PC7	34.1	32.2	10.5	Turboprop	1	6,393	984.3	1,312.3	90	90
Eagle	Pilatus	PC12	53.1	47.2	14.1	Turboprop	1	9,921	1,968.5	1,804.5	110	85
Apache	Piper	PA23	37.0	27.1	10.3	Piston	2	4,799				
Arrow 4	Piper	P28T	35.4	27.2	8.2	Piston	1	2,910	1,148.3	656.2	70	70
Aztec	Piper	PA27	37.4	31.2	10.2	Piston	2	5,203	984.3	1,640.4	75	70
Cherokee Lance	Piper	P32R	36.1	28.2	8.5	Piston	1	3,616	1,640.4	1,804.5	75	75
Cherokee Six	Piper	PA32	36.1	26.9	8.2	Piston	1	3,616	1,640.4	1,804.5	75	75
Cheyenne 2	Piper	PAY2	42.7	36.4	12.8	Turboprop	2	8,995	2,132.5	2,460.6	100	100
Cheyenne 3	Piper	PAY3	47.6	43.3	14.8	Turboprop	2	11,244	2,296.6	2,132.5	105	105
Cheyenne 400	Piper	PAY4	47.6	43.3	17.1	Turboprop	2	12,059	2,296.6	2,132.5	125	110
Comanche	Piper	PA24	36.0	24.1	7.5	Piston	1	2,551				
Malibu Meridian	Piper	P46T	43.0	29.5	11.5	Turboprop	1	4,740	1,476.4	1,476.4	80	75
Malibu Mirage	Piper	PA46	43.0	28.5	11.5	Piston	1	4,299	1,476.4	1,476.4	80	75
Navajo Chieftain	Piper	PA31	40.7	32.5	13.1	Piston	2	6,504	1,312.3	1,968.5	90	100
PA-28-140 Cherokee	Piper	P28A	35.1	24.0	7.2	Piston	1	2,425	984.3	984.3	65	65
PA-28R Cherokee Arrow	Piper	P28R	29.9	24.3	7.9	Piston	1	2,491	984.3	984.3	70	70
Seminole	Piper	PA44	38.7	27.6	8.5	Piston	2	3,792	984.3	1,312.3	75	80
Seneca	Piper	PA34	39.0	28.5	9.8	Piston	2	4,762	984.3	1,312.3	80	80
Tomahawk	Piper	PA38	35.1	23.0	9.2	Piston	1	1,676	820.2	656.2	60	65
Twin Comanche	Piper	PA30	36.0	25.0	8.3	Piston	2	3,600				
400 Beechjet	Raytheon	BE40	43.6	48.6	13.8	Jet	2	16,094	3,937.0	3,608.9	130	111
90 King Air	Raytheon	BE9L	50.2	35.4	14.1	Turboprop	2	10,099	2,296.6	1,246.7	100	100
Bae 125-1000	Raytheon	H25C	51.5	53.8	17.1	Jet	2	30,997	6,233.6	2,916.7	125	132
Bae 125-700/800	Raytheon	H25B	54.5	51.2	18.0	Jet	2	27,403	5,577.4	2,952.8	125	125
Beech 1900	Raytheon	B190	58.1	57.7	15.4	Turboprop	2	16,954	3,773.0	2,706.7	110	113
Beech 36 Bonanza	Raytheon	BE36	27.6	26.6	8.5	Piston	1	3,638	1,148.3	1,476.4	75	75
Beech 58 Baron	Raytheon	BE58	37.7	29.9	9.7	Piston	2	5,512	2,296.6	1,968.5	100	96
Super King Air 200	Raytheon	BE20	54.5	44.0	14.8	Turboprop	2	12,500	1,870.1	1,771.7	115	103
Super King Air 350	Raytheon	B350	58.1	46.6	14.4	Turboprop	2	14,991	3,280.8	2,690.3	120	110

Aero Commander 500	Rockwell International	AC50	48.9	36.7	15.1	Piston	2	6,746	1,312.3	1,312.3	80	97
Sabreliner 60	Rockwell International	SBR1	44.5	48.3		Jet	2	20,000				120
Turbo Commander 680	Rockwell International	AC80	46.8	44.5		Turboprop	2	11,199				97
Turbo Commander 690	Rockwell International	AC90	46.7	44.4	15.0	Turboprop	2	10,251				97
SAAB 2000	SAAB	SB20	81.4	89.6	25.3	Turboprop	2	46,297	4,265.1	4,265.1	110	110
SAAB 340	SAAB	SF34	70.2	64.6	23.0	Turboprop	2	28,440	4,265.1	3,608.9	110	115
C-23 Sherpa	Short	SH33	74.8	58.1	16.4	Turboprop	2	22,597	3,608.9	3,608.9	100	96
SD3-60	Short	SH36	74.8	70.9	24.0	Turboprop	2	27,117	4,265.1	3,608.9	110	100
Short SC-7 Skyvan	Short	SC7	65.0	40.0	15.1	Turboprop	2	13,669	1,968.5	2,296.6	90	90
Fairchiled 300	Swearingen	SW3	46.3	42.3	16.7	Turboprop	2	12,566	4,265.1	4,265.1	115	120
Socata TBM-700	TBM	TBM7	40.0	34.1	13.8	Turboprop	1	6,614	2,132.5	1,640.4	85	80

APPENDIX E

EMAS

The Federal Aviation Administration (FAA) requires that standard-size runway safety areas (RSA) be provided to minimize the risks associated with aircraft overruns and undershoots. In some instances, however, natural or manmade obstacles, local developments, surface conditions, or environmental constraints make it difficult or impossible to comply with the FAA standards.

As part of the study described in *ACRP Report 3,* historical records of accidents and incidents were compiled and used to develop risk models for overrun and undershoot events. However, the study did not address the evaluation of RSAs when EMAS is used. The models used in the approach developed in this study are based on data provided by ESCO.

To evaluate the risk mitigation provided by EMAS, it is necessary to normalize the EMAS distance to an equivalent conventional RSA distance so that the value can be used directly in the location probability models for landing and takeoff overruns. No adjustments are necessary to the distances entered into the location models for landing undershoots.

To accomplish this, the length of the conventional RSA is modified by a runway length factor (RLF), which is calculated by taking into account the effectiveness of the EMAS in decelerating a specific type of aircraft. In other words, the length of the conventional RSA is increased to provide an equivalent distance where the aircraft can stop when entering the EMAS bed at a certain speed. Figure E1 shows the schematics of an RSA with EMAS and its equivalent conventional RSA.

The relationship between the aircraft deceleration, a, the aircraft speed when entering the RSA, v, and the RSA length, S, is as follows:

$$a = \frac{v^2}{2S} \qquad \text{[Eq. 1]}$$

In addition, since the speed of the aircraft entering the RSA is assumed to be the same for the same aircraft entering the equivalent conventional RSA, it is established that:

$$a_{EMAS} S_{EMAS} = a_{RSA} S_{RSA} \qquad \text{[Eq. 2]}$$

To estimate a_{EMAS}, data provided by ESCO were used as shown next. For a_{RSA} a maximum runway exit speed of $v = 70$ knots and a standard RSA dimension of $S = 1{,}000$ feet was employed in Eq. 1, resulting in $a_{RSA} = 2.156$ m/s^2.

The data included the necessary lengths and estimated aircraft performance in terms of the maximum runway exit speed. The study includes values for a spectrum of aircraft models and maximum takeoff weights (MTOW). Table E1 lists the aircraft manufacturers, models, and MTOW that are included in the ESCO data. Table E2 shows the data provided by ESCO.

The maximum runway exit speed for all aircrafts models was combined in a single dataset and employed in a regression analysis to generate the model for the maximum runway exit speed (v) in terms of the EMAS length and aircraft MTOW. A total of 84 data points were included in the regression. A logarithmic transformation was performed on the EMAS length and the aircraft weight before performing the analysis. The resulting regression equation is listed next, where W is the MTOW of the aircraft in kg and S the EMAS bed length in meters.

$$v = 3.0057 - 6.8329\log(W) + 31.1482\log(S) \qquad \text{[Eq. 3]}$$

The R-squared of the linear regression was 0.89, and the standard error was equal to 2.91m/s. Figure E2 shows the relationship between the reported ESCO maximum runway exit speeds and the predicted speed values obtained using Eq. 3. The 45-degree angle dashed line represents the equality line between the values.

The maximum runway exit speed estimated using the regression equation (Eq. 3), along with the EMAS bed length (S_{EMAS}), was input in Eq. 1 to estimate the deceleration of the RSA with EMAS bed (a_{EMAS}). The runway length factor was then estimated as follows:

$$RLF = \frac{a_{EMAS}}{a_{RSA}} \qquad \text{[Eq. 4]}$$

where a_{RSA} is 2.156 m/s^2 as explained before.

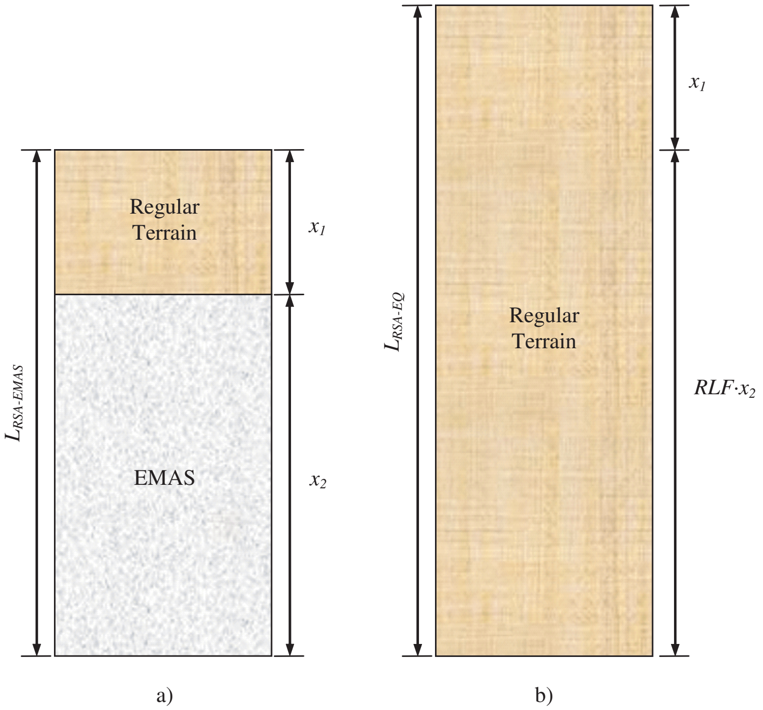


Figure E1. Schematic of a) RSA with EMAS and b) equivalent conventional RSA.

Table E1. Aircraft models included in ESCO data.

Aircraft Manufacturer	Aircraft Model	MTOW ($\times 10^3$ lb)
Airbus	A-319 (B737)	141.0
	A-320 (B737)	162.0
	A-340	567.0
Boeing	B-737-400	150.0
	B-747	870.0
	B-757	255.0
	B-767	407.0
	B-777	580.0
Cessna	CITATION 560	16.3
Canadair	CRJ-200	53.0
	CRJ-700	75.0
Embraer	EMB-120	28.0
	ERJ-190 (ERJ170)	51.0
McDonnell Douglas	MD-83 (MD 82)	160.0

Table E2. Data provided by ESCO.

Aircraft	Weight (lb)	Speed (knots)	EMAS (feet)	Speed (m/s)
A319(B737)	141,000	80	550	41.2
A319(B737)	141,000	79	350	40.6
A319(B737)	141,000	40	120	20.6
A320(B737)	162,000	80	550	41.2
A320(B737)	162,000	75	350	38.6
A320(B737)	162,000	37	120	19.0
A340	567,000	70	550	36.0
A340	567,000	50	350	25.7
A340	567,000	28	120	14.4
B747	870,000	66	550	34.0
B747	870,000	47	350	24.2
B747	870,000	29	120	14.9
B757	255,000	80	550	41.2
B757	255,000	58	350	29.8
B757	255,000	31	120	15.9
B767	407,000	75	550	38.6
B767	407,000	54	350	27.8
B767	407,000	30	120	15.4
B777	580,000	70	550	36.0
B777	580,000	50	350	25.7
B777	580,000	29	120	14.9
CITATION 560	16,300	80	550	41.2
CITATION 560	16,300	77	350	39.6
CITATION 560	16,300	48	120	24.7
CRJ 200	53,000	80	550	41.2
CRJ 200	53,000	80	350	41.2
CRJ 200	53,000	45	120	23.1
CRJ 700	75,000	80	550	41.2
CRJ 700	75,000	77	350	39.6
CRJ 700	75,000	41	120	21.1
EMB 120(SAAB340)	28,000	75	550	38.6
EMB 120(SAAB340)	28,000	70	350	36.0
EMB 120(SAAB340)	28,000	41	120	21.1
ERJ 190(ERJ170)	51,800	80	550	41.2
ERJ 190(ERJ170)	51,800	65	350	33.4
ERJ 190(ERJ170)	51,800	37	120	19.0
MD 83(MD 82)	160,000	80	550	41.2
MD 83(MD 82)	160,000	70	350	36.0
MD 83(MD 82)	160,000	35	120	18.0

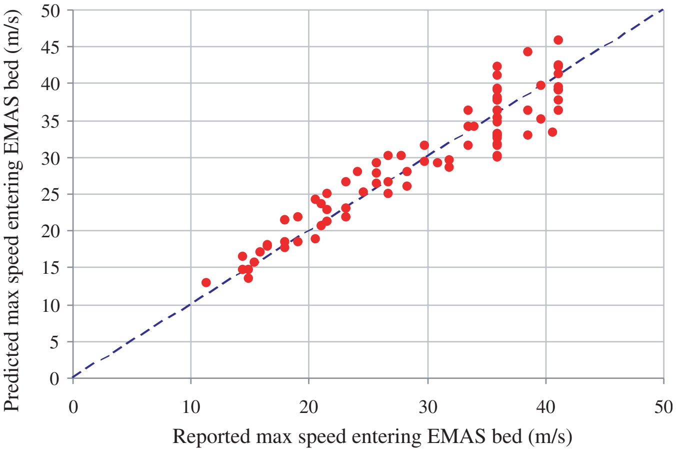


Figure E2. Relationship between reported and predicted maximum aircraft speeds entering the EMAS bed.

Subsequently, based on the relationship established in Eq. 2, RLF was multiplied by the length of the EMAS bed to estimate the equivalent length of the conventional RSA:

$$S_{RSA} = \frac{a_{EMAS}}{a_{RSA}} S_{EMAS} = RLF \quad S_{EMAS} \qquad \text{[Eq. 5]}$$

Note that, depending on the RSA configuration and the type of aircraft, different operations will generate different RLFs.

APPENDIX F

Risk Criteria Used by the FAA

Although the main objective of this research was to develop a tool to help airport planners evaluate RSA alternatives, the basis for the analysis was a quantitative assessment of risk associated with runway excursions and undershoots.

Risk is the composite of the likelihood of the occurrence and severity of the outcome or effect (harm) of the hazard. Severity is the measure of how bad the results of an event are predicted to be. Likelihood should be considered only after determining severity. Table F1 provides the FAA specific definitions of severity.

Likelihood is an expression of how often an event can be expected to occur at the worst credible severity. Table F2 shows FAA likelihood definitions. A risk classification (high, medium, or low) is provided based on the FAA risk matrix shown in Figure F1 and the likelihood and severity scenario for each hazard.

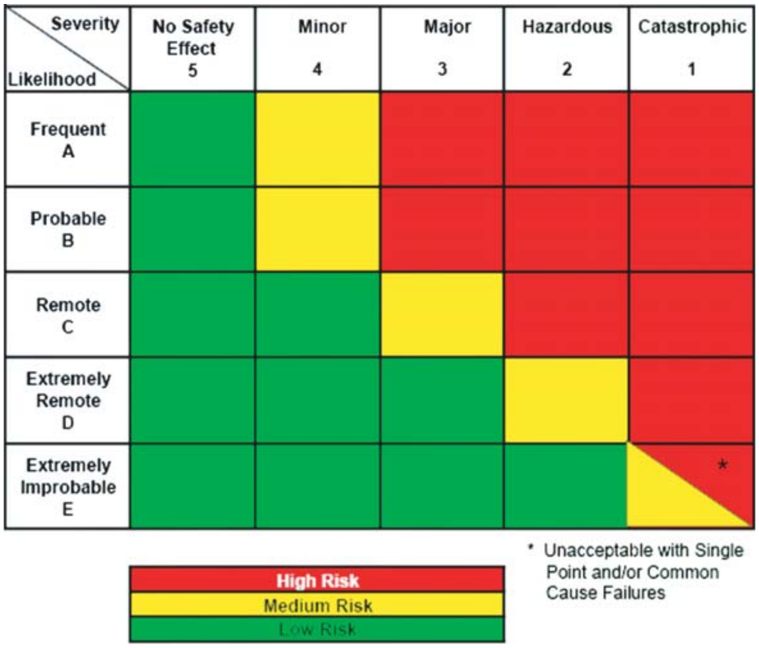
Table F1. FAA severity definitions (FAA 2010).

Hazard Severity Classification				
Minimal 5	**Minor 4**	**Major 3**	**Hazardous 2**	**Catastrophic 1**
No damage to aircraft but minimal injury or discomfort of little consequence to passenger(s) or workers	- Minimal damage to aircraft; - Minor injury to passengers; - Minimal unplanned airport operations limitations (i.e. taxiway closure); - Minor incident involving the use of airport emergency procedures	- Major damager to aircraft and/or minor injury to passenger(s)/ worker(s); - Major unplanned disruption to airport operations; - Serious incident; - Deduction on the airport's ability to deal with adverse conditions	- Severe damage to aircraft and/or serious injury to passenger(s)/ worker(s); - Complete unplanned airport closure; - Major unplanned operations limitations (i.e. runway closure); - Major airport damage to equipment and facilities-	- Complete loss of aircraft and/or facilities or fatal injury in passenger(s)/worker(s); - Complete unplanned airport closure and destruction of critical facilities; - Airport facilities and equipment destroyed

Table F2. FAA likelihood levels (FAA 2010).

	General	Airport Specific	ATC Operational	
			Per Facility[3]	NAS-wide[4]
Frequent A	Probability of occurrence per operation is equal to or greater than 1x10^{-3}	Expected to occur more than once per week or every 2500 departures (4x10^{-4}), whichever occurs sooner	Expected to occur more than once per week	Expected to occur every 1-2 days
Probable B	Probability of occurrence per operation is less than 1x10^{-3}, but equal to or greater than 1x10^{-5}	Expected to occur about once every month or 250,000 departures (4x10^{-6}), whichever occurs sooner	Expected to occur about once every month	Expected to occur several times per month
Remote C	Probability of occurrence per operation is less than 1x10^{-5} but equal to or greater than 1x10^{-7}	Expected to occur about once every year or 2.5 million departures (4x10^{-7}), whichever occurs sooner	Expected to occur about once every 1 -10 years	Expected to occur about once every few months
Extremely Remote D	Probability of occurrence per operation is less than 1x10^{-7} but equal to or greater than 1x10^{-9}	Expected to occur once every 10-100 years or 25 million departures (4x10^{-8}), whichever occurs sooner	Expected to occur about once every 10-100 years	Expected to occur about once every 3 years
Extremely Improbable E	Probability of occurrence per operation is less than 1x10^{-9}	Expected to occur less than every 100 years	Expected to occur less than once every 100 years	Expected to occur less than once every 30 years

Note: Occurrence is defined per movement.



Severity / Likelihood	No Safety Effect 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A	🟩	🟨	🟥	🟥	🟥
Probable B	🟩	🟨	🟥	🟥	🟥
Remote C	🟩	🟩	🟨	🟥	🟥
Extremely Remote D	🟩	🟩	🟩	🟨	🟥
Extremely Improbable E	🟩	🟩	🟩	🟩	🟨🟥 *

🟥 High Risk
🟨 Medium Risk
🟩 Low Risk

* Unacceptable with Single Point and/or Common Cause Failures

Figure F1. FAA risk matrix (FAA 1988, 2010).

APPENDIX G

Plan to Field Test Software Tool

Objective

The objective of this task was to test the software developed for risk analysis of runway safety areas (RSA) developed under ACRP 4-08. The feedback obtained helped improve the final software and mitigate any problems associated with its installation, operation, and analysis of results.

This plan describes the procedures used for testing the software developed in this project. It includes the identification of volunteer stakeholders that utilized a beta version to carry out analysis with sample data provided.

Phase I

During this phase, the software was evaluated during development before a final beta version was released to volunteers for testing.

Software Development and Algorithm Tests

During this phase the software algorithms and database management procedures were tested before a beta version was created.

Input Data Quality Assurance (QA)

Users may input incorrect information, use units that are not compatible, or enter the correct information in incorrect fields. Several help features were incorporated, including the checking of values to ensure the input was within allowable ranges.

The analysis software includes features to check missing data and advise the user to make the necessary corrections. The software will not run if there are missing data or if the values are outside normal ranges.

Portability

Before the release of a beta version, the software was evaluated for portability using different computers with various operational systems (e.g., Windows 7, Windows XP). The objective was to search for possible conflicts with computer operational systems and supporting software versions.

Installation

The installation was tested on different computers to check for problems with installation of the files required to run the program and the supporting software that is required. The analysis software makes use of common Microsoft Office products, including Excel and Access. The user must have such software to run the risk assessment analysis. Access is necessary to handle the various databases, and Excel is used to characterize the RSA's, the type of terrain, and the existing obstacles with their classification.

Preliminary Testing

The research team installed the software and ran some analysis using the guidance material prepared. Any problems detected were solved before the final beta release was provided to volunteers for testing.

Phase II

During this phase, a beta version of the software was tested by volunteers. Despite the attempts to make the software tool as user-friendly and practical as possible, the research team asked the volunteers that are familiar with airport planning

Table G1. List of volunteers to test analysis software.

Name	Stakeholder	Organization	Comments
Doug Mansel	Airport Operator	Oakland International Airport	Chair of ACI-NA Operations and Technical Affairs Committee
Mike Hines	Airport Operator	Metropolitan Washington Airport Authority	MWAA Planner
Don Andrews	Consultant	Reynolds, Smith and Hill	Airport planning
Tom Cornell	Consultant	Landrum and Brown	Consultant
Amiy Varma	Professor	University of North Dakota	Chair of TRB Committee of Aircraft/ Airport Compatibility
Ernie Heymsfield	Professor	University of Arkansas	Member of TRB Committee of Aircraft/ Airport Compatibility
Michael A. Meyers	Government	FAA - AAS-100	Engineer in the Airport Engineering Division
Ken Jacobs	Government	FAA – APP-400	FAA Liaison for ACRP 4-01

and the analysis methodology rationale to provide additional suggestions to improve software and to identify any software bugs they encountered.

To facilitate the assessment, data for a couple of airports was prepared and provided to the volunteers to run the analysis.

Table G1 presents the list of eight software beta testers. The research team proposed a small number of volunteers to facilitate obtaining meaningful feedback and to ensure the research team could provide the necessary support to these volunteers during the beta testing period.

Perform Tests

Beta testers installed the software and ran analyses. A user manual was provided to the testers as well. Feedback was requested through a basic questionnaire that solicited comments on the use of the software, practicality, documentation, etc.

Assist Volunteers

A helpdesk was established to assist volunteers, answering questions and resolving software issues, particularly with installation. Volunteers could ask for help by phone or by e-mail. The phone number and e-mail address was included in the beta version user manual.

Track Problems/Bugs and Fixes

The beta testers' feedback was recorded. Bugs were fixed as soon as possible, and the updated software was distributed to the beta testers. Suggested improvements were considered and modifications made, as warranted, both during the beta testing phase and after.

Retest

After all bugs were fixed and improvements made, another round of internal tests to fix any new bugs was carried out.

ACRP 4-08—Improved Models for Risk Assessment of Runway Safety Areas (RSA)

Analysis Software Evaluation Questionnaire

The purpose of this software beta testing effort is to test and help improve the software for analysis of runway safety areas. Although measuring software effectiveness is no easy task, the feedback provided will help identify the need for critical improvements to the software.

Name:____
Organization: ____
Position: ____

1. How easy was it to install the software?
   a. Difficult to install
   b. I had problems
   c. About right
   d. Easy to install

Comments:

____
____
____
____

2. How easy was it to follow the user guide and documentation?
   a. Very difficult to follow
   b. It is necessary to understand risk assessment to use it
   c. Simple guidance but satisfactory for the purpose
   d. Easy to follow

Comments:

____
____
____
____

3. Are the screens user-friendly and easy to understand?
   a. No
   b. I had a few problems (see my comments)
   c. Easy to follow

Comments:

____
____
____
____

4. Was it easy to input operational data?
   a. No
   b. I had a few problems (see my comments)
   c. Yes

Comments:

5. Was it easy to input weather data?
   a. No
   b. I had a few problems (see my comments)
   c. Yes

Comments:

6. Was it easy to understand output results?
   a. No
   b. I had a few problems (see my comments)
   c. Yes

Comments:

7. Please list the good and the bad points of the software.

8. Would you use this software again?
   a. Yes
   b. Possibly (see my comments)
   c. No (see my comments)

9. How long did it take to run the "Example 1" analysis?________ minutes

10. Any other comments that you care to offer.

APPENDIX H

Summary of Results for Software/Model Tests

The research team gathered data for the analysis of eight airports and conducted the analyses using the analysis software developed in this study. Results obtained for each airport are presented in this appendix and are compared to historical accident rates. This effort is intended to validate the models developed in Task 4 and the software developed in Task 8. Results are shown for each airport.

Additional information on individual analyses can be provided upon request. Such information includes operations data, weather data, runway characteristics including declared distances, files defining each of the runway safety areas for aircraft overruns, undershoots, and veer-offs, as well as output files from analyses.

Ted Stevens Anchorage International Airport

ACRP **Risk of Accident - Summary of Results**

Overall Results *Risk Analysis*

Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	8.5E-09	>100	0.0	7
TOOR	6.8E-08	100	0.2	7
LDUS	3.2E-08	>100	0.3	7
LDVO	1.6E-07	42	2.3	7
TOVO	1.5E-07	47	2.2	7
Total	**2.1E-07**	**16**	**1.3**	**3**

Airport Annual Volume:	293,000
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Anchorage International
Date of Analysis: 12/13/2010
Analyst: Hamid

Note: fields in yellow may be changed by user

Notes

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2 - Results for overrun and undershoot consider all movements challenging each RSA adjacent to the ends of each runway
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4 - Each takeoff will challenge the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-offs
5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA					
	14	32	07R	25L	07L	25R
LDOR	1.68E-09	1.62E-08	1.52E-09	6.76E-09	4.26E-09	1.07E-08
TOOR	7.40E-08	7.85E-08	2.54E-08	3.44E-08	2.62E-08	5.87E-08
LDUS	2.46E-08	3.61E-08	2.92E-08	2.64E-08	4.90E-08	1.63E-08
LDVO	1.07E-07	2.41E-07	1.76E-07	1.10E-07	1.52E-07	4.75E-08
TOVO	8.71E-08	1.57E-07	6.93E-08	9.05E-08	8.15E-08	2.08E-08

Average # of Years Between Accidents

Type of Accident	RSA					
	14	32	07R	25L	07L	25R
LDOR	>100	>100	>100	>100	>100	>100
TOOR	>100	>100	>100	>100	>100	>100
LDUS	>100	>100	>100	>100	>100	>100
LDVO	>100	>100	57	>100	>100	>100
TOVO	>100	51	>100	>100	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA					
	14	32	07R	25L	07L	25R
LDOR	0.00	0.11	0.00	0.03	0.00	0.08
TOOR	0.27	0.27	0.04	0.00	0.00	0.00
LDUS	0.06	0.00	0.29	0.00	0.31	0.00
LDVO	0.68	5.76	2.86	1.42	1.37	0.00
TOVO	0.93	2.53	0.00	0.69	0.25	0.00

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA					
	14	32	07R	25L	07L	25R
LDOR	347	9327	1269	52525	122	12722
TOOR	65647	1834	8566	34	8	1967
LDUS	9327	347	52525	1269	12722	122
LDVO	9327	347	52525	1269	12722	122
TOVO	1834	65647	34	8566	1967	8
Total	86482	77502	114919	63663	27541	14941

Yeager Airport

Risk of Accident - Summary of Results

Overall Results

Risk Analysis

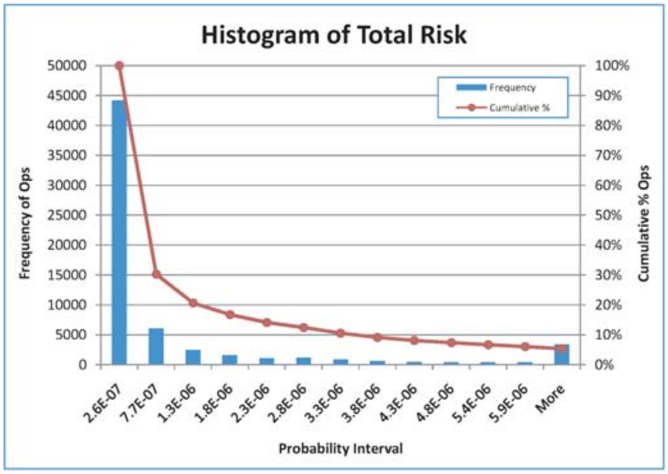
Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	9.9E-06	4	76.6	40
TOOR	1.0E-07	>100	0.5	40
LDUS	4.7E-07	86	9.0	40
LDVO	3.6E-07	>100	5.0	40
TOVO	1.5E-07	>100	1.9	40
Total	**5.5E-06**	**4**	**23.8**	**20**

Airport Annual Volume:	49,516
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Yeager Airport
Date of Analysis: 12/13/2010
Analyst: Regis Carvalho

Note: fields in yellow may be changed by user



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5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA			
	05	23	15	33
LDOR	1.11E-05	7.84E-06	4.36E-05	
TOOR	1.13E-07	9.42E-08	8.63E-08	
LDUS	4.94E-07	3.35E-07		1.80E-06
LDVO	2.82E-07	3.84E-07		1.89E-06
TOVO	1.19E-07	1.10E-07		1.46E-06

Average # of Years Between Accidents

Type of Accident	RSA			
	05	23	15	33
LDOR	10	8	40	
TOOR	>100	>100	>100	
LDUS	>100	>100		>100
LDVO	>100	>100		>100
TOVO	>100	>100		>100

Percent Events Above 1.0E-06

Type of Accident	RSA			
	05	23	15	33
LDOR	76.52	76.13	91.86	
TOOR	0.83	0.32	0.00	
LDUS	8.94	7.77		29.83
LDVO	3.14	5.71		42.37
TOVO	1.35	1.50		22.15

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA			
	05	23	15	33
LDOR	4570	7809	295	0
TOOR	5520	6812	316	0
LDUS	7809	4570	0	295
LDVO	7809	4570	0	295
TOVO	6812	5520	0	316
Total	32520	29281	611	906

Sioux Falls Regional Airport

AIRPORT COOPERATIVE RESEARCH PROGRAM
ACRP

Risk of Accident - Summary of Results

Overall Results

Risk Analysis

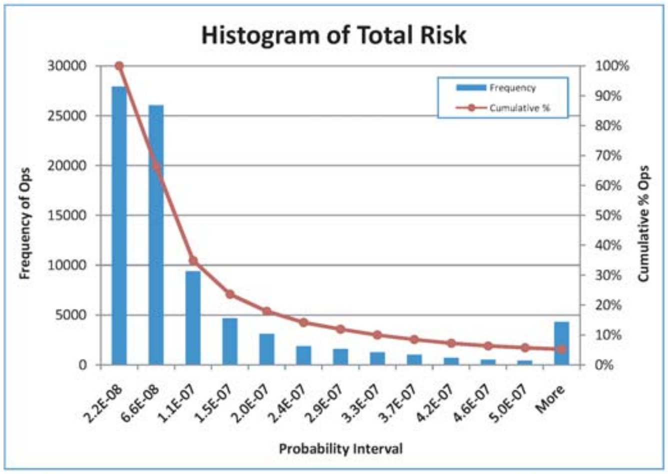
Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	3.1E-07	93	4.4	29
TOOR	1.1E-07	>100	0.8	29
LDUS	7.4E-08	>100	0.6	29
LDVO	2.9E-07	>100	3.6	29
TOVO	1.5E-07	>100	2.0	29
Total	**4.7E-07**	**31**	**2.7**	**14**

Airport Annual Volume:	69,000
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Joe Foss Field Airport
Date of Analysis: 12/13/2010
Analyst: Hamid

Note: fields in yellow may be changed by user


Histogram of Total Risk

Notes

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3 - The total risk for the airport is per movement (landing and taking-off)
4 - Each takeoff will challenge the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-offs
5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA			
	03	21	15	33
LDOR	2.17E-07	1.10E-07	6.21E-07	2.32E-07
TOOR	8.87E-08	4.58E-08	1.33E-07	2.63E-07
LDUS	6.00E-08	7.18E-08	1.10E-07	7.36E-08
LDVO	6.65E-08	3.92E-07	3.83E-07	3.02E-07
TOVO	1.12E-07	1.65E-07	1.02E-07	1.86E-07

Average # of Years Between Accidents

Type of Accident	RSA			
	03	21	15	33
LDOR	>100	>100	>100	>100
TOOR	>100	>100	>100	>100
LDUS	>100	>100	>100	>100
LDVO	>100	>100	>100	>100
TOVO	>100	>100	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA			
	03	21	15	33
LDOR	3.08	0.69	9.48	2.97
TOOR	0.55	0.00	1.42	1.90
LDUS	0.26	0.70	0.80	0.63
LDVO	0.87	5.43	4.56	3.02
TOVO	1.43	2.86	0.98	1.86

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA			
	03	21	15	33
LDOR	5983	3886	4907	1884
TOOR	6052	3706	5011	1736
LDUS	3886	5983	1884	4907
LDVO	3886	5983	1884	4907
TOVO	3706	6052	1736	5011
Total	23513	25610	15422	18445

Fort Lauderdale Executive Airport

Risk of Accident - Summary of Results

Overall Results

Risk Analysis

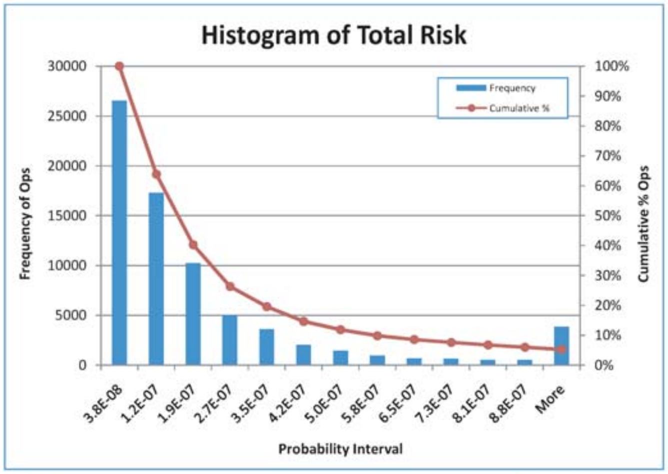
Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.0E-06	12	15.2	12
TOOR	4.1E-08	>100	0.0	12
LDUS	2.5E-07	46	1.8	12
LDVO	3.3E-07	36	7.4	12
TOVO	1.1E-07	>100	0.1	12
Total	**8.3E-07**	**7**	**2.0**	**6**

Airport Annual Volume:	169,000
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Fort Lauderdale Executive Airport
Date of Analysis: 12/13/2010
Analyst: Hamid

Note: fields in yellow may be changed by user



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5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA			
	08	26	13	31
LDOR	4.41E-07	7.90E-07	1.27E-06	8.21E-06
TOOR	2.87E-08	4.09E-08	2.36E-08	6.93E-08
LDUS	2.51E-07	2.72E-07	2.51E-07	7.93E-07
LDVO	3.10E-07	2.45E-07	1.13E-06	5.00E-07
TOVO	1.05E-07	9.47E-08	1.55E-07	1.75E-07

Average # of Years Between Accidents

Type of Accident	RSA			
	08	26	13	31
LDOR	>100	18	>100	45
TOOR	>100	>100	>100	>100
LDUS	57	>100	>100	>100
LDVO	46	>100	>100	>100
TOVO	>100	>100	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA			
	08	26	13	31
LDOR	9.80	13.68	26.87	66.53
TOOR	0.00	0.01	0.00	0.39
LDUS	1.68	2.67	0.85	11.94
LDVO	7.23	5.88	15.25	17.91
TOVO	0.09	0.00	0.78	0.00

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA			
	08	26	13	31
LDOR	1122	12290	67	472
TOOR	1316	13830	104	516
LDUS	12290	1122	472	67
LDVO	12290	1122	472	67
TOVO	13830	1316	516	104
Total	40848	29680	1631	1226

Spokane International Airport

Risk of Accident - Summary of Results

Overall Results

Risk Analysis

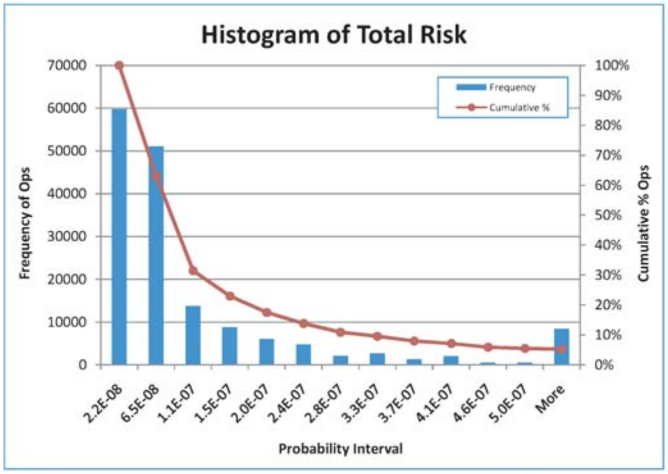
Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.4E-07	>100	2.3	25
TOOR	1.7E-07	>100	2.2	25
LDUS	1.0E-07	>100	1.2	25
LDVO	2.7E-07	90	4.4	25
TOVO	1.3E-07	>100	3.8	25
Total	**4.1E-07**	**30**	**5.5**	**12**

Airport Annual Volume:	81,580
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Spokane International Airport
Date of Analysis: 12/13/2010
Analyst: Regis Carvalho

Note: fields in yellow may be changed by user



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5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA			
	03	21	07	25
LDOR	9.91E-08	1.85E-07	2.30E-08	3.15E-08
TOOR	1.04E-07	2.50E-07	4.86E-08	1.28E-07
LDUS	1.46E-07	5.83E-08	4.84E-09	2.07E-08
LDVO	3.38E-07	2.15E-07	1.76E-07	7.01E-08
TOVO	1.69E-07	9.77E-08	4.49E-08	2.52E-08

Average # of Years Between Accidents

Type of Accident	RSA			
	03	21	07	25
LDOR	>100	>100	>100	>100
TOOR	>100	>100	>100	>100
LDUS	>100	>100	>100	>100
LDVO	>100	>100	>100	>100
TOVO	>100	>100	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA			
	03	21	07	25
LDOR	1.35	3.42	0.00	0.00
TOOR	0.57	3.99	0.00	0.00
LDUS	2.07	0.36	0.00	0.00
LDVO	6.77	2.24	0.00	0.00
TOVO	5.36	2.39	0.00	0.00

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA			
	03	21	07	25
LDOR	16682	15535	129	56
TOOR	16770	15282	142	52
LDUS	15535	16682	56	129
LDVO	15535	16682	56	129
TOVO	15282	16770	52	142
Total	79804	80951	435	508

Lambert-St. Louis International Airport

ACRP **Risk of Accident - Summary of Results**

Overall Results

Risk Analysis

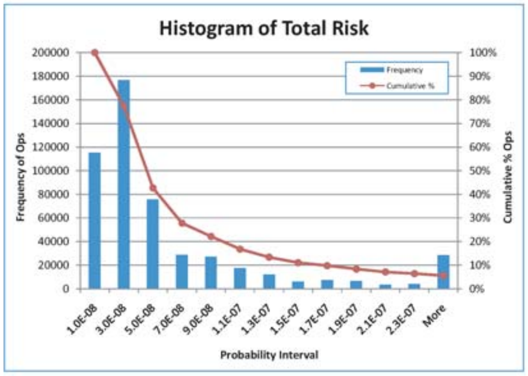
Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.9E-08	>100	0.2	10
TOOR	8.0E-08	>100	0.1	10
LDUS	3.6E-08	>100	0.3	10
LDVO	1.7E-07	56	2.4	10
TOVO	5.1E-08	>100	0.3	10
Total	**1.8E-07**	**27**	**1.6**	**5**

Airport Annual Volume:	209,094
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Lambert-St. Louis International Airport
Date of Analysis: 12/13/2010
Analyst: Regis Carvalho

Note: fields in yellow may be changed by user



Notes

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3 - The total risk for the airport is per movement (landing and taking-off)
4 - Each takeoff will challenge the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-offs
5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA							
	12R	30L	12L	30R	11	29	06	24
LDOR	1.33E-08	9.66E-09	1.94E-08	3.29E-08	1.24E-08	1.95E-08	1.34E-08	3.30E-09
TOOR	8.66E-08	7.28E-08	5.12E-08	9.28E-08	6.71E-08			2.99E-08
LDUS	2.58E-08	3.38E-08	3.44E-08	4.33E-08	2.88E-08	8.60E-08	1.05E-08	8.89E-08
LDVO	1.36E-07	1.89E-07	1.43E-07	2.09E-07	1.70E-07	9.30E-08	6.05E-08	4.10E-07
TOVO	3.75E-08	6.39E-08	3.66E-08	3.29E-08		6.98E-08	2.68E-08	

Average # of Years Between Accidents

Type of Accident	RSA							
	12R	30L	12L	30R	11	29	06	24
LDOR	>100	>100	>100	>100	>100	>100	>100	
TOOR	>100	>100	>100	>100	>100			
LDUS	>100	>100	>100	>100	>100	>100		>100
LDVO	>100	>100	>100	>100	>100	>100		>100
TOVO	>100	>100	>100	>100		>100		

Percent Events Above 1.0E-06

Type of Accident	RSA							
	12R	30L	12L	30R	11	29	06	24
LDOR	0.12	0.06	0.18	0.30	0.06	0.06	0.00	0.00
TOOR	0.14	0.02	0.00	0.17	0.09			0.00
LDUS	0.09	0.36	0.13	0.39	0.12	0.90	0.00	0.00
LDVO	1.94	2.95	1.84	3.06	2.30	1.25	0.00	1.47
TOVO	0.02	0.56	0.02	0.09		0.56	0.00	

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA							
	12R	30L	12L	30R	11	29	06	24
LDOR	18861	18073	29960	22733	3112	9083	68	0
TOOR	37896	35459	1145	14822	12567	0	0	0
LDUS	18073	18861	22733	29960	9083	3112	0	68
LDVO	18073	18861	22733	29960	9083	3112	0	68
TOVO	35459	37896	14822	1145	0	12567	0	0
Total	128362	129150	91393	98620	33845	27874	68	136

Phoenix Deer Valley Airport

Risk of Accident - Summary of Results

Overall Results

Risk Analysis

Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.2E-07	>100	2.4	13
TOOR	4.8E-08	>100	0.0	13
LDUS	5.4E-08	>100	0.0	13
LDVO	1.8E-07	72	5.3	13
TOVO	3.5E-07	38	1.2	13
Total	**3.7E-07**	**17**	**0.1**	**7**

Airport Annual Volume:	153,000
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Phoenix Deer Valley Airport
Date of Analysis: 12/13/2010
Analyst: Hamid

Note: fields in yellow may be changed by user

Notes

1 - Fields in orange may be directly changed in spreadsheet by user
2 - Results for overrun and undershoot consider all movements challenging each RSA adjacent to the ends of each runway
3 - The total risk for the airport is per movement (landing and taking-off)
4 - Each takeoff will challenge the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-offs
5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA			
	07R	25L	07L	25R
LDOR	6.28E-08	1.29E-07	1.38E-07	1.61E-07
TOOR	4.00E-08	4.92E-08	5.94E-08	4.44E-08
LDUS	4.79E-08	7.01E-08	1.15E-07	9.21E-08
LDVO	1.77E-07	2.77E-07	2.83E-08	4.39E-08
TOVO	3.38E-07	3.16E-07	5.76E-07	4.40E-07

Average # of Years Between Accidents

Type of Accident	RSA			
	07R	25L	07L	25R
LDOR	>100	>100	>100	>100
TOOR	>100	>100	>100	>100
LDUS	>100	>100	>100	>100
LDVO	83	>100	>100	>100
TOVO	52	>100	>100	>100

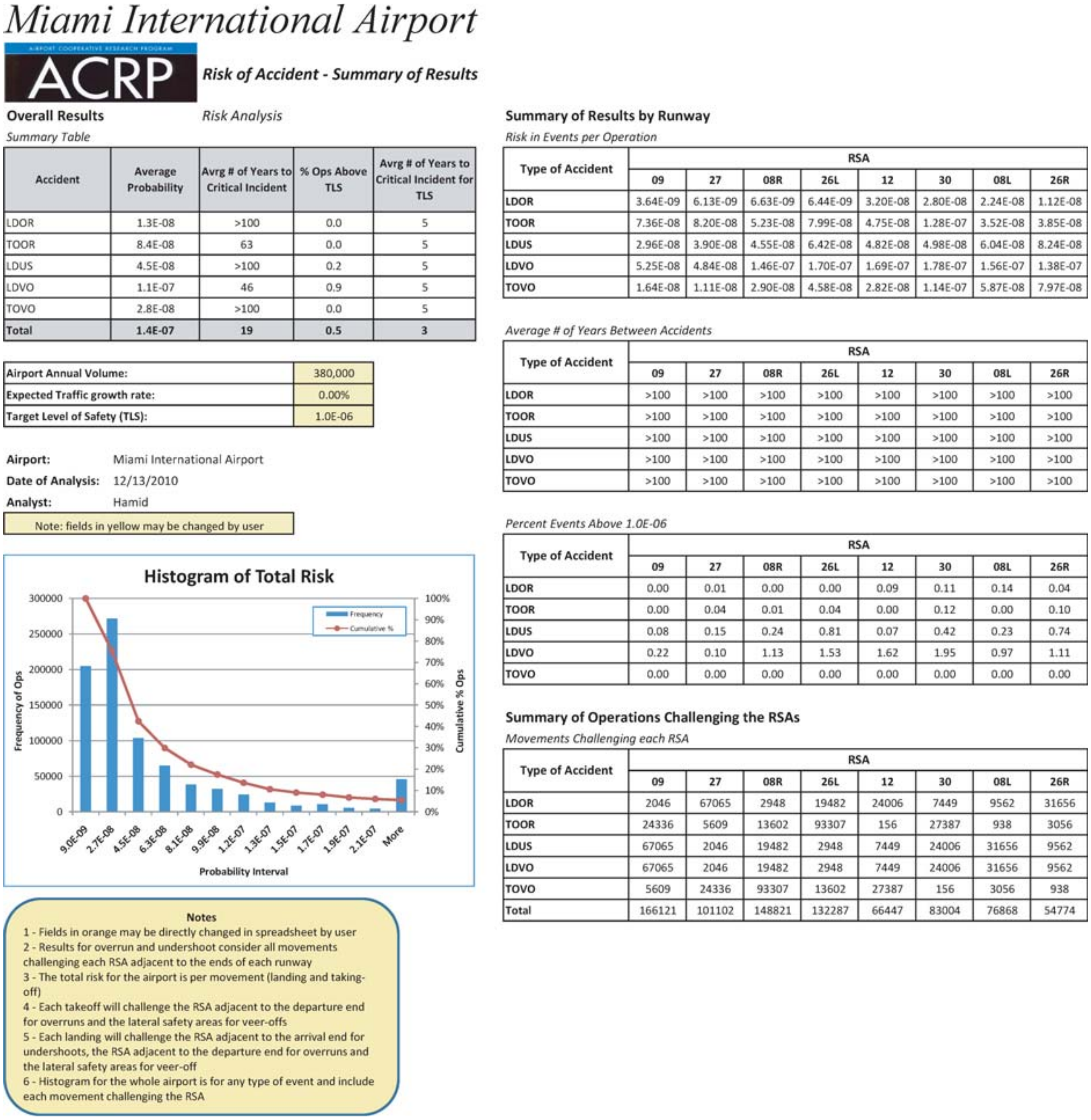
Percent Events Above 1.0E-06

Type of Accident	RSA			
	07R	25L	07L	25R
LDOR	0.41	2.84	0.00	0.00
TOOR	0.00	0.00	0.00	0.00
LDUS	0.05	0.00	0.00	0.00
LDVO	4.98	10.20	0.00	0.00
TOVO	1.10	1.60	1.16	0.00

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA			
	07R	25L	07L	25R
LDOR	245	1828	15	93
TOOR	312	1542	20	86
LDUS	1828	245	93	15
LDVO	1828	245	93	15
TOVO	1542	312	86	20
Total	5755	4172	307	229



Miami International Airport

Risk of Accident - Summary of Results

Overall Results *Risk Analysis*

Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.3E-08	>100	0.0	5
TOOR	8.4E-08	63	0.0	5
LDUS	4.5E-08	>100	0.2	5
LDVO	1.1E-07	46	0.9	5
TOVO	2.8E-08	>100	0.0	5
Total	**1.4E-07**	**19**	**0.5**	**3**

Airport Annual Volume:	380,000
Expected Traffic growth rate:	0.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Miami International Airport
Date of Analysis: 12/13/2010
Analyst: Hamid

Note: fields in yellow may be changed by user

Notes

1 - Fields in orange may be directly changed in spreadsheet by user
2 - Results for overrun and undershoot consider all movements challenging each RSA adjacent to the ends of each runway
3 - The total risk for the airport is per movement (landing and taking-off)
4 - Each takeoff will challenge the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-offs
5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA							
	09	27	08R	26L	12	30	08L	26R
LDOR	3.64E-09	6.13E-09	6.63E-09	6.44E-09	3.20E-08	2.80E-08	2.24E-08	1.12E-08
TOOR	7.36E-08	8.20E-08	5.23E-08	7.99E-08	4.75E-08	1.28E-07	3.52E-08	3.85E-08
LDUS	2.96E-08	3.90E-08	4.55E-08	6.42E-08	4.82E-08	4.98E-08	6.04E-08	8.24E-08
LDVO	5.25E-08	4.84E-08	1.46E-07	1.70E-07	1.69E-07	1.78E-07	1.56E-07	1.38E-07
TOVO	1.64E-08	1.11E-08	2.90E-08	4.58E-08	2.82E-08	1.14E-07	5.87E-08	7.97E-08

Average # of Years Between Accidents

Type of Accident	RSA							
	09	27	08R	26L	12	30	08L	26R
LDOR	>100	>100	>100	>100	>100	>100	>100	>100
TOOR	>100	>100	>100	>100	>100	>100	>100	>100
LDUS	>100	>100	>100	>100	>100	>100	>100	>100
LDVO	>100	>100	>100	>100	>100	>100	>100	>100
TOVO	>100	>100	>100	>100	>100	>100	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA							
	09	27	08R	26L	12	30	08L	26R
LDOR	0.00	0.01	0.00	0.00	0.09	0.11	0.14	0.04
TOOR	0.00	0.04	0.01	0.04	0.00	0.12	0.00	0.10
LDUS	0.08	0.15	0.24	0.81	0.07	0.42	0.23	0.74
LDVO	0.22	0.10	1.13	1.53	1.62	1.95	0.97	1.11
TOVO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA							
	09	27	08R	26L	12	30	08L	26R
LDOR	2046	67065	2948	19482	24006	7449	9562	31656
TOOR	24336	5609	13602	93307	156	27387	938	3056
LDUS	67065	2046	19482	2948	7449	24006	31656	9562
LDVO	67065	2046	19482	2948	7449	24006	31656	9562
TOVO	5609	24336	93307	13602	27387	156	3056	938
Total	166121	101102	148821	132287	66447	83004	76868	54774

APPENDIX I

Software User's Guide

ACRP 4-08

Improved Models for Risk Assessment of Runway Safety Areas

Runway Safety Area Risk Analysis (RSARA)

Software User's Guide (Version 1.0.1)

Software developed by Applied Research Associates, Inc.

Disclaimer

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Runway Safety Area Risk Analysis - RSARA

Contents

Runway Safety Area Risk Analysis (RSARA)

User's Guide – Version 1.0

1. Introduction

This software is being developed as part of the Airport Cooperative Research Program (ACRP), Project ACRP 4-08 - Improved Models for Risk Assessment of Runway Safety Areas (RSA) and is intended to serve as a tool to help airport operators evaluate risk associated with their RSA conditions.

The risk associated with the following five types of aircraft accidents may be evaluated with this software:

- Landing overruns (LDOR)
- Takeoff overruns (TOOR)
- Landing undershoots (LDUS)
- Landing veer-offs (LDVO)
- Takeoff veer-offs (TOVO)

The user may perform two types of analysis with this software. In the first type of analysis, the user can evaluate the probability that the aircraft will exit the runway and stop beyond the limits of the RSA or, in case of undershoots, that the aircraft will touch down prior to the RSA. In the second type of analysis, the user may consider the obstacles inside or in the vicinity of the RSA to evaluate the risk of an accident with catastrophic consequences (substantial aircraft damage and/or multiple injuries/fatalities).

2. System Requirements

Component	Requirement
Computer and processor	500 megahertz (MHz) processor or higher
Memory	256 megabyte (MB) RAM or higher
Hard disk	1.5 gigabyte (GB); a portion of this disk space will be freed after installation if the original download package is removed from the hard drive
Display	1024x768 or higher resolution monitor
Operating system	Microsoft Windows XP with Service Pack (SP) 2, Windows Server 2003 with SP1, or later operating system, except Windows Vista
Other	RSARA utilizes modules from Microsoft Office Suite 2007, particularly Microsoft Access to handle the databases and Microsoft Excel to handle data input and output results. Therefore, the user must have Microsoft Office 2007 with Excel and Access to run RSARA

3. Using the Guide

To facilitate reading and comprehension of this user's guide, please note the following styles and conventions used throughout:

Menu Selection

Analysis/Run Analysis means click on *Analysis* on the main menu and then click on *Run Analysis* in the *Analysis* sub-menu.

Main Window

The main window contains the top title bar with the main menu name and the Minimize, Maximize, and Close buttons.

Runway Safety Area

When defining the RSA geometry in this model, the area is associated with **the arrival end of the runway**. For example, RSA 14R is the RSA adjacent to the arrival end of runway 14R.

Movements Challenging the RSA

In a given airport one movement (landing or takeoff) will challenge specific RSAs. Each landing will challenge the RSA located at the arrival end for landing undershoots, and the same landing movement will also challenge the RSA adjacent to the departure end for landing overrun. During the takeoffs, only the RSA at the departure end is challenged for overrun. During landings and takeoffs, both sides of the RSAs will be challenged for landing veer-offs and takeoff veer-offs, respectively.

Level of Risk Format

The program provides results in scientific format (e.g., 2.3E-07 or 0.00000023). These results can also be read as number of movements to occur one event. To read in this format, you have to take the inverse of the value in scientific format (e.g. 1/2.3E-07 = 4,347,826). In the example provided, a risk of 2.3E-07 is equivalent to one accident in 4,347,826 movements.

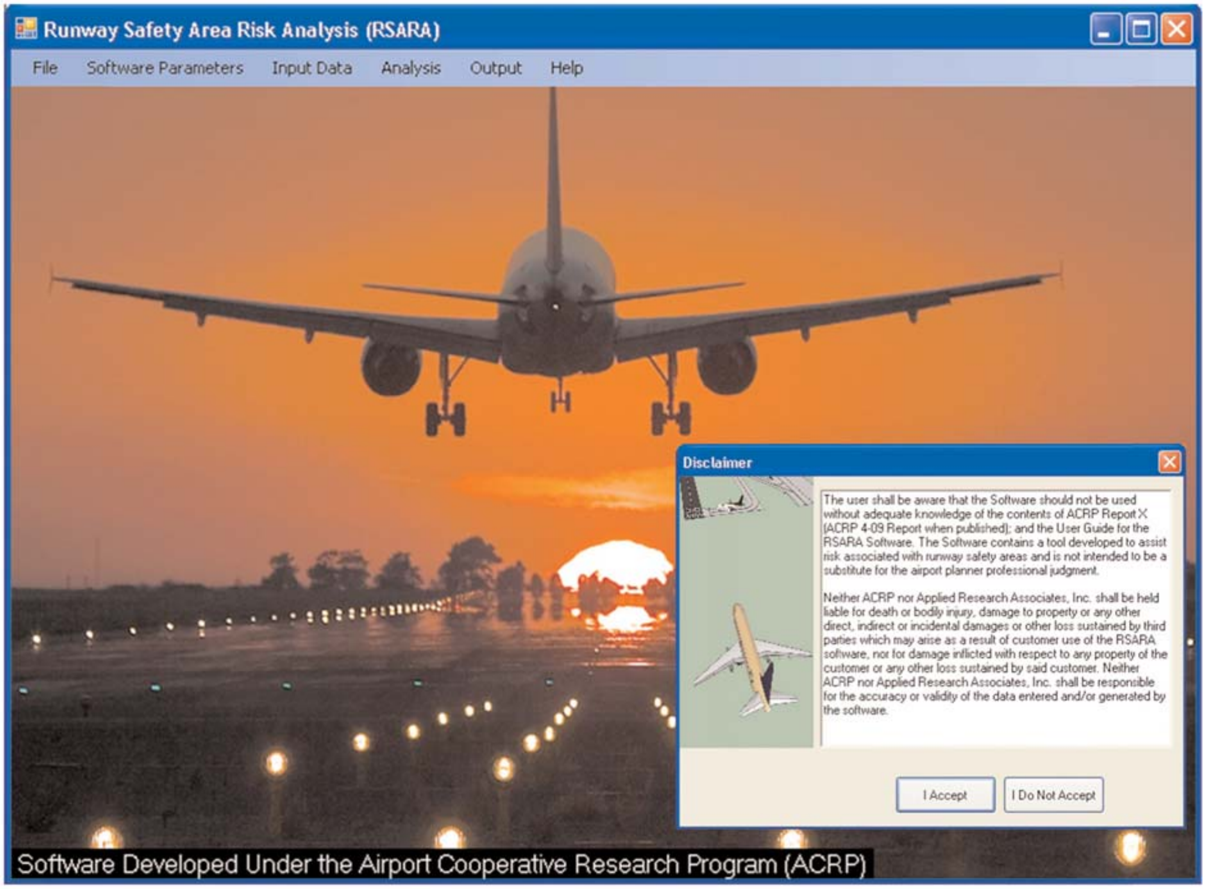
4. Software Installation

The installation of RSARA is the same process applied to other Windows programs. Go to the folder where you downloaded RSARA and double click on *setup.exe*. Then follow the on-screen instructions to install the program. It will add the program to your program group and place a shortcut on your desktop.

If you want to install a new version to replace the existing one, you first need to remove RSARA. To remove RSARA, select *Start/Control Panel* in your desktop window. Select *Add or Remove Programs*. When the program list is populated, select *RSARA* and click *Remove*.

5. Opening the Program

To open RSARA, double click on the shortcut to open the program and the *Disclaimer* screen. Please read the disclaimer and if you accept the conditions, click *I Accept*, otherwise the program will be closed. The main screen will open.

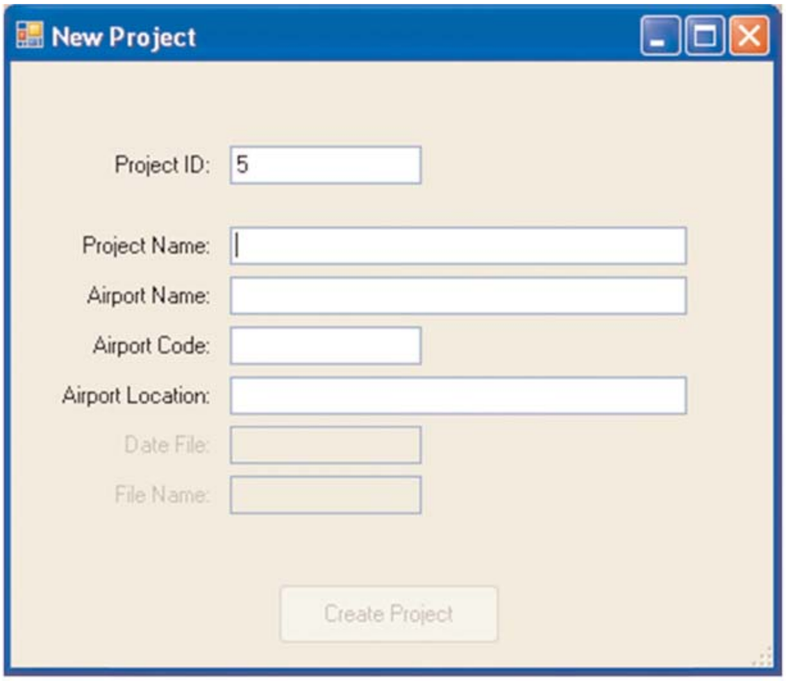


The user shall be aware that the Software should not be used without adequate knowledge of the contents of ACRP Report X (ACRP 4-09 Report when published); and the User Guide for the RSARA Software. The Software contains a tool developed to assist risk associated with runway safety areas and is not intended to be a substitute for the airport planner professional judgment.

Neither ACRP nor Applied Research Associates, Inc. shall be held liable for death or bodily injury, damage to property or any other direct, indirect or incidental damages or other loss sustained by third parties which may arise as a result of customer use of the RSARA software, nor for damage inflicted with respect to any property of the customer or any other loss sustained by said customer. Neither ACRP nor Applied Research Associates, Inc. shall be responsible for the accuracy or validity of the data entered and/or generated by the software.

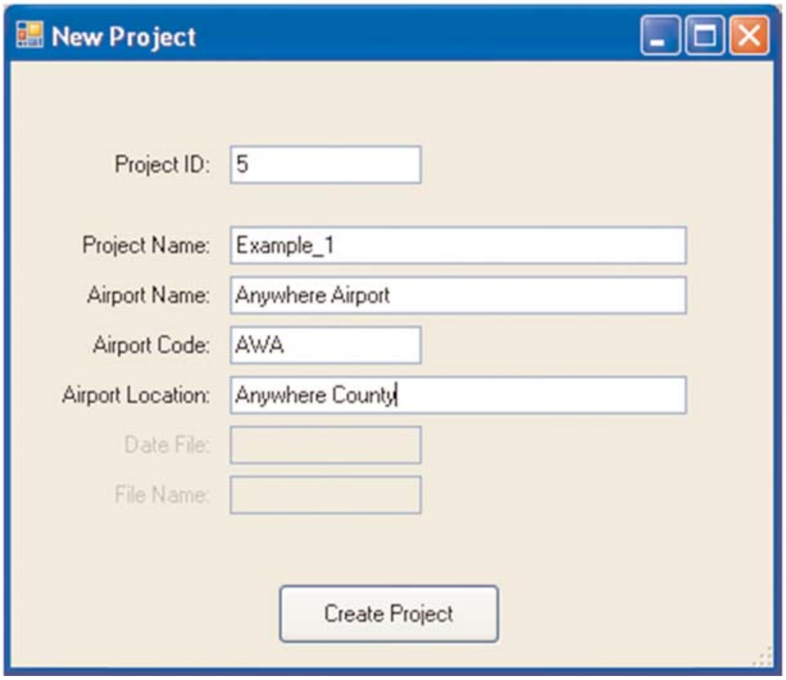
6. Creating a New Project

Click on *File/New Project* and the following screen will appear.



Project ID: 5
Project Name:
Airport Name:
Airport Code:
Airport Location:
Date File:
File Name:

Fill up the fields as shown in the example below and click *Create Project*. The project name cannot have spaces.

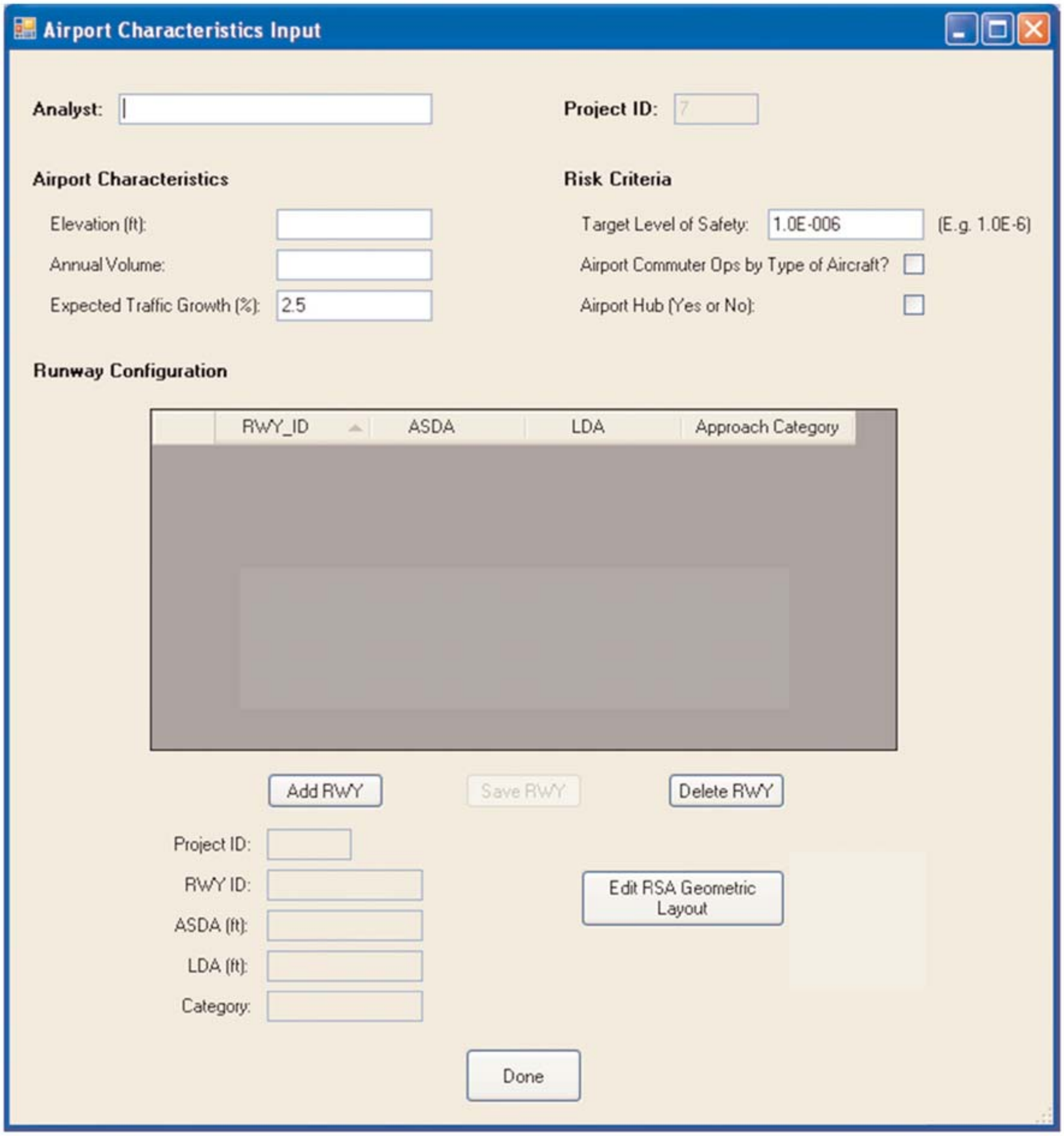


Project ID: 5
Project Name: Example_1
Airport Name: Anywhere Airport
Airport Code: AWA
Airport Location: Anywhere County
Date File:
File Name:

7. Entering Data

Defining Airport Conditions

The following screen will appear when you click on the *Create Project* button or when select *Input Data/ Airport Characteristics* in the main menu.



Project ID: 7

Expected Traffic Growth (%): 2.5

Target Level of Safety: 1.0E-006 (E.g. 1.0E-6)

Enter the specific characteristics of the airport, including the runways characteristics and available distances. Each of the fields and commands are described in the following table.

Field	Description	Example	Meaning
Elevation (ft)	The airport elevation, in feet	1200	The highest point on any of the airport's runways is 1,200 ft relative to sea level
Expected Traffic Growth (%)	The average expected annual growth for aircraft movements	2.5	The average annual growth for future years is expected to be 2.5%
Airport Hub (Yes or No)	If the airport is a hub (large, medium or small), enable the check box	☑	If the box is checked, the airport is a hub
Target Level of Safety (TLS)	The acceptable level of is expressed in the form of a Target Levels of Safety (TLS) or Criteria.	1.0E-07	In this case, the acceptable level of risk is 1 accident in 10,000,000 movements, or 0.0000001 (or 1.0E-07) accident per aircraft movement
Assume Commuter Ops by Type of Aircraft?	The frequency models use the type of flight (commercial, cargo, taxi/commuter or GA). Sometimes the information on commuter flights is not available and if the check box is marked, the type of aircraft will dictate if the flight is commuter or not	☑	The program will assume commuter flights for every aircraft typically used for commuter operations. For example, ERJ-45 (Embraer jet airliner)

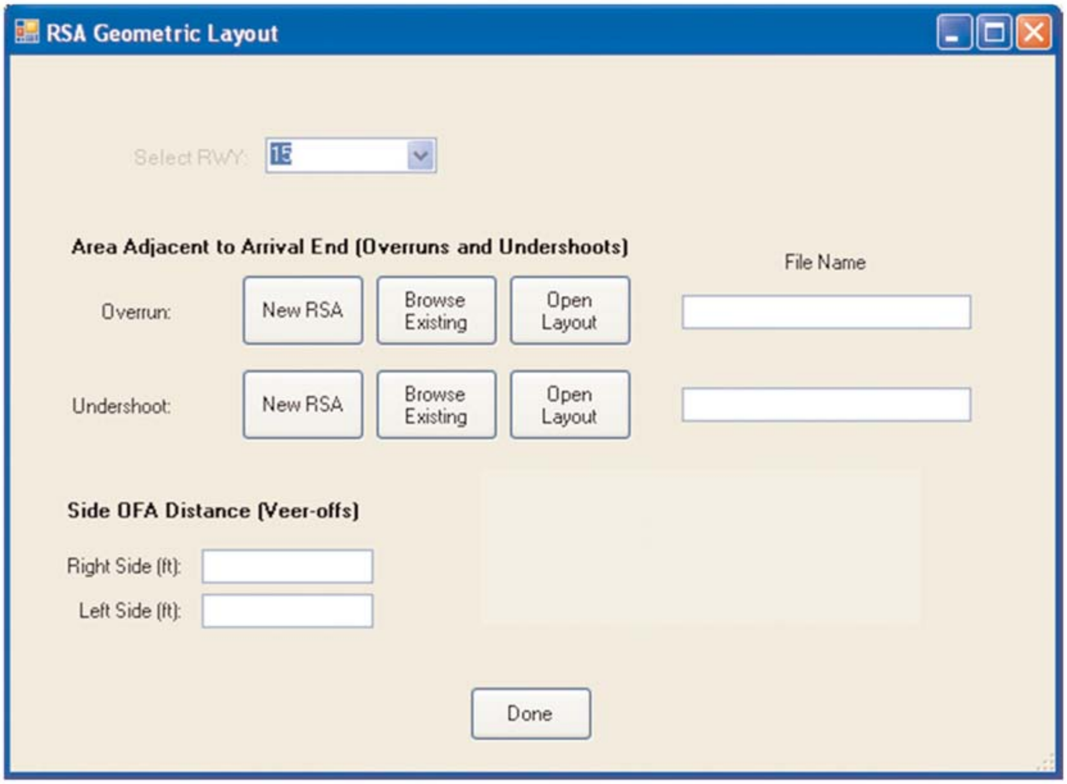
For runway configuration, enter all the runways that will be evaluated. The analysis provides results for each runway and for all runways as the total risk for the airport. **For this model, each runway pavement is treated as two runways**. To enter the runway information, click on *Add RWY* to enable the runway fields. The information required is the following:

Field	Description	Example	Meaning
RWY ID	Enter the runway designation	14R	This is the designation for runway 14R
ASDA (ft)	Accelerate-Stop Distance Available for takeoff, in feet	8300	Runway 14R has an ASDA of 8,300 feet
LDA (ft)	Landing Distance Available, in feet	7900	Runway 14R has an LDA of 7,900 feet
Category	Type of instrument approach available	CAT I	Runway 14R approach category is precision level 1. Other possibilities are: V (visual), NP (non-precision), CAT II and CAT III

Once the runway fields are filled, save the information by clicking *Save RWY*. You may continue adding the basic information for each runway before defining the RSA geometry for the runway. Changes to runway declared distances can be made directly in the table and the program will automatically save the changes.

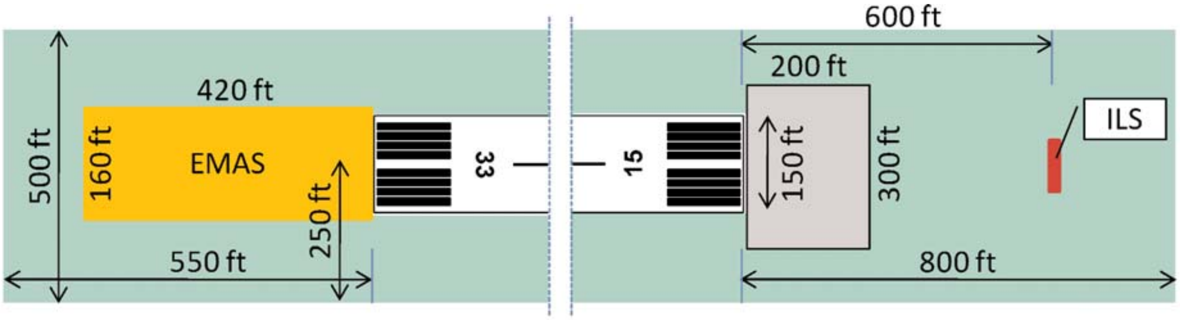
Defining RSA Geometry and Obstacles

Next, enter the RSA information, including the geometry and existing obstacles. To perform this step, click *Edit RSA Geometric Layout* and the following screen will appear.



The dropdown list includes all runways entered. In the example above, runway 15 is selected. The screen contains two sets of buttons: one set to define RSA geometry for overruns and one set for undershoots. It is important to note that these two geometries may be different when the threshold is displaced. The runway that is selected defines the RSA to be characterized. The two fields for *Side OFA Distance* are used to define the **distance from the runway edge** (not from the runway centerline) to the closest obstacle.

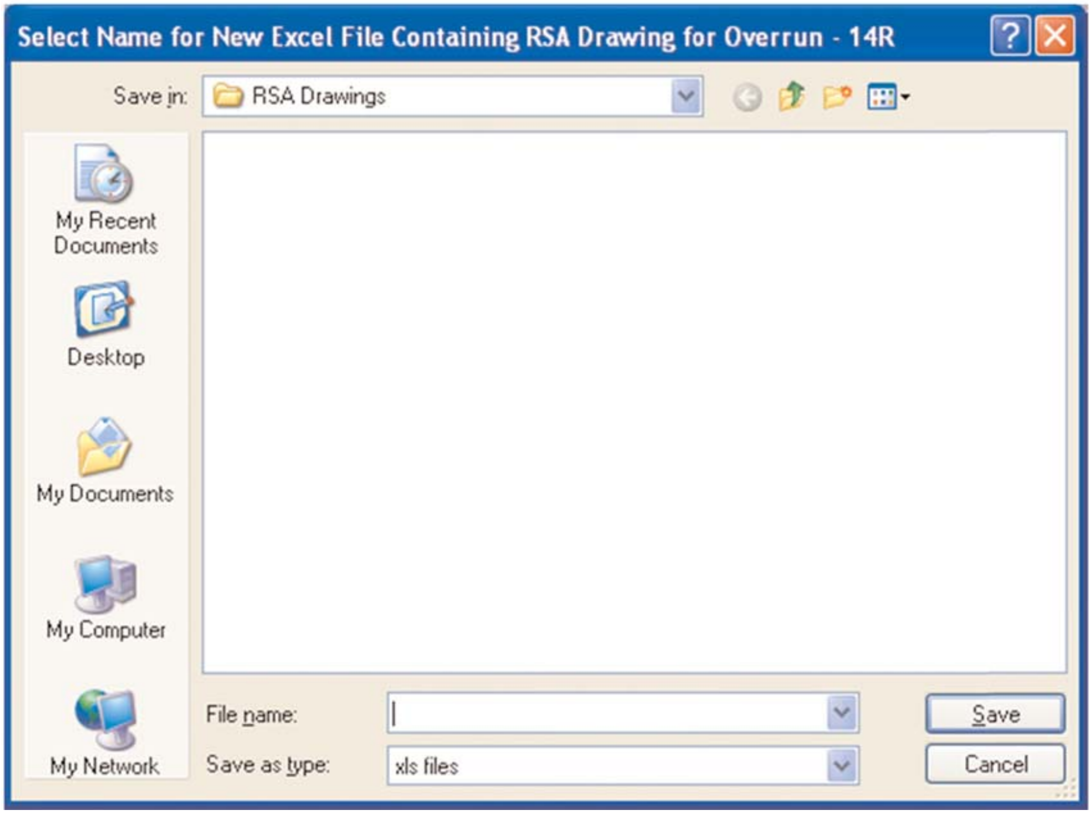
There are two stages to define the safety area for each runway. The example shown in the following figure illustrates how to define the RSA dimensions.



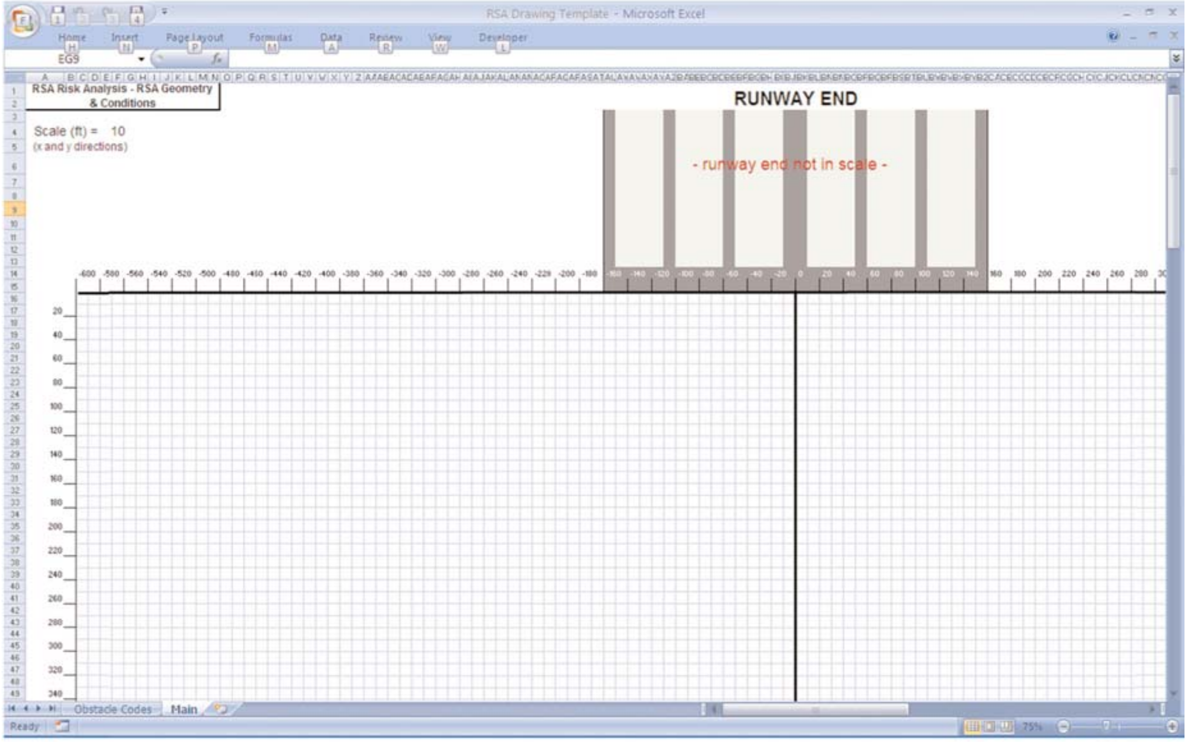
The runway in the example is 150 ft wide, and the total width of the RSA is 500 ft. The RSA adjacent to the runway 15 arrival end extends to 800 ft, with part of the RSA (200 x 300 ft) being paved and there is a Localizer 600 ft from the runway end. The RSA adjacent to runway 33 arrival end extends to 550 ft and has an EMAS bed measuring 420 x 160 ft.

The first step is to define the RSA geometry next to the runway ends. This area helps protect aircraft overrunning runway 33 or undershooting runway 15. The designation **RSA 15** means the RSA section adjacent to the runway 15 arrival end.

To define this area, click on *New RSA* next to the label *Overrun* to define the RSA geometry. A dialog box prompting you to create a Microsoft Excel spreadsheet will appear, as shown below.

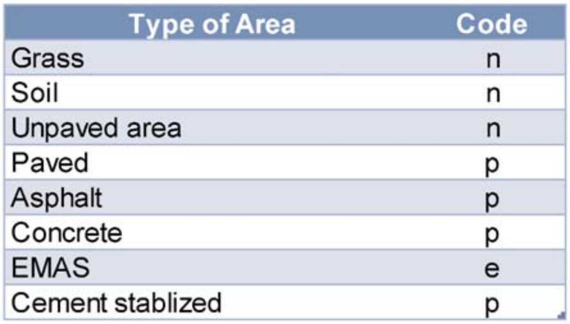


It is recommended that you name the file for the RSA 15 overrun (e.g., RSA 15 OR). Click *Save* and the Excel spreadsheet will open, as shown in the following screen.

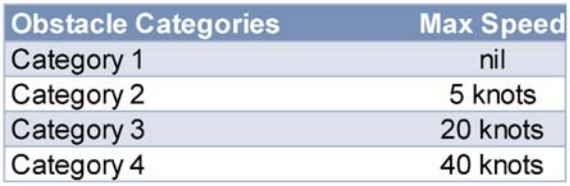


Initially, the spreadsheet contains an "empty" RSA. The template has two folders: *Main* and *Obstacle Codes*. The *Main* folder is where you will define the RSA geometry and obstacles. The second folder, *Obstacle Codes*, is where you may obtain information on codes to define the areas and obstacles, and contains three tables, as shown below.

Codes for RSA Surface



Type of Area	Code
Grass	n
Soil	n
Unpaved area	n
Paved	p
Asphalt	p
Concrete	p
EMAS	e
Cement stablized	p



Obstacle Categories	Max Speed
Category 1	nil
Category 2	5 knots
Category 3	20 knots
Category 4	40 knots

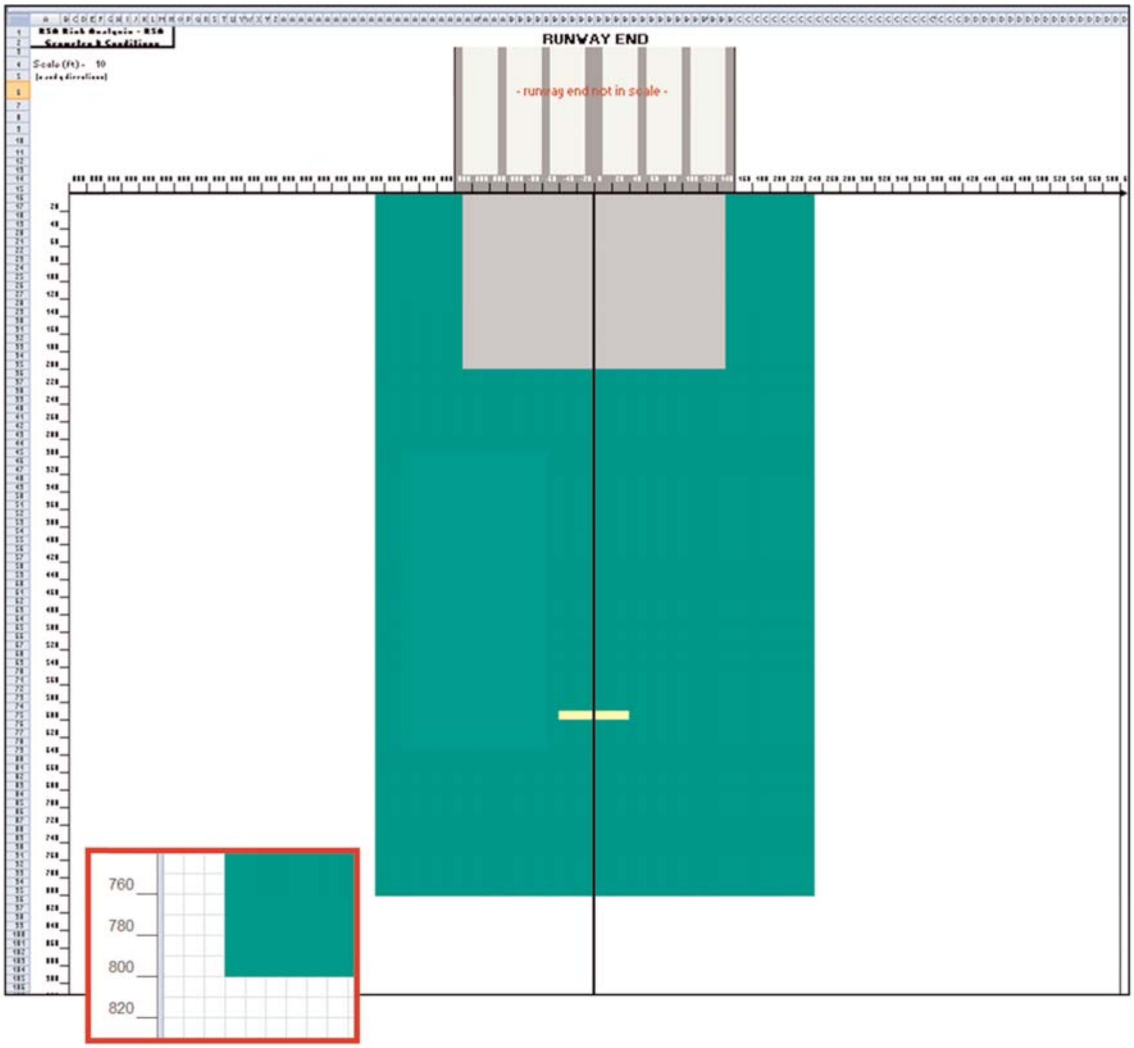
Codes for Obstacles

Type of Obstacle	Code
Concrete buildings	1
Concrete walls	1
Cliffs	1
Large holes	1
Body of water (undershoot)	1
Stockpiles	1
Highways	1
Flammable material pipeline	1
Gas station	1
Body of water (overrun)	2
Brick wall	2
Non frangible blast fences	2
Large ditches	2
Small ditches	3
Fences	3
Irregular terrain	3
Small depressions	3
Large frangible structures	4
Localizer	4
ALS	4
Frangible blast fences	4
Non prepared areas	4
Lights	no code
Signs (frangible)	no code

The runway end is represented at the top of the spreadsheet. Please note the runway section shown is only a representation to facilitate locating its position and is not on the same scale as the RSA. On the top left (line 4), you may select an appropriate scale for representation of each cell; the runway width will not match the coordinates used to define the RSA geometry. In this case, the scale selected was 10 ft, meaning that each cell in the RSA is a 10 x 10 ft square in the terrain.

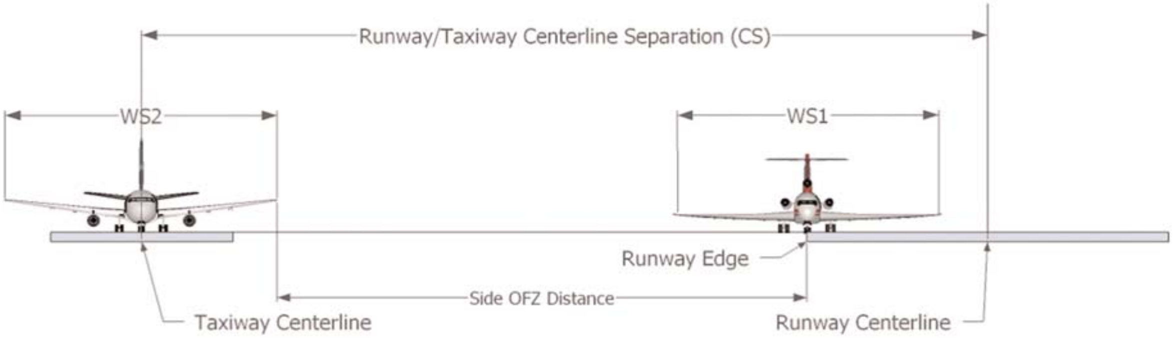
To define the area, select the appropriate code for the type of Area/Obstacle from the tables shown above and available in folder *Obstacle Codes*. In this case part of the area is paved and the remaining is grassy. For grass, you should use the letter "n". To define the grassy areas, insert an "n" (non-paved) in each cell that comprises the grassy area. In this example, the width of the RSA is 500 ft and the RSA is centered on the runway, so you should mark 250 ft to the right of the runway centerline and 250 ft to the left, and 800 ft from the runway end (please note it is easier to copy and paste the cells, rather than manually entering one "n" at a time). When an "n" is entered in a cell, the cell will change color (in this case, to green). After marking the grassy area, the same process is used to define the paved area using the letter "p".

Finally, you should define the ILS location. The same process is used to enter an obstacle. For this example, a 90-ft long Localizer is located 600 ft from the runway end, the code to enter for a Localizer is "4," and this number should be entered in the cells located 600 ft from the runway end for a total length of 80 ft, centered at the extended runway centerline. The total length should be 40 ft to the right and 40 ft to the left of the centerline.



Use the Excel menu to save the RSA geometry for overruns on RSA 15, and close the spreadsheet. The action will take you back to the *RSA Geometric Layout* screen. Define the RSA 15 geometry for undershoot using the same process; in many cases the RSA area for undershoot will be the same for overrun. It is important to note that depending on the runway declared distances (includes displaced thresholds), the RSA for overrun may be different from the RSA for undershoot in the same runway end.

The next step is to define the *Side Obstacle Free Area (OFA) Distance*. This distance is the clearance from the runway edge to the nearest obstacle, fixed or movable. In some cases, the object may be a hangar or another fixed object; however, in most cases it will be an aircraft located in a parallel taxiway. In this latter case, the Side OFA Distance will be the distance between the runway edge and the wingtip of the taxiing aircraft, as shown below. The location of the wingtip is associated with the Aircraft Design Group (ADG), or it may be the aircraft with the largest wingspan operating at the airport.



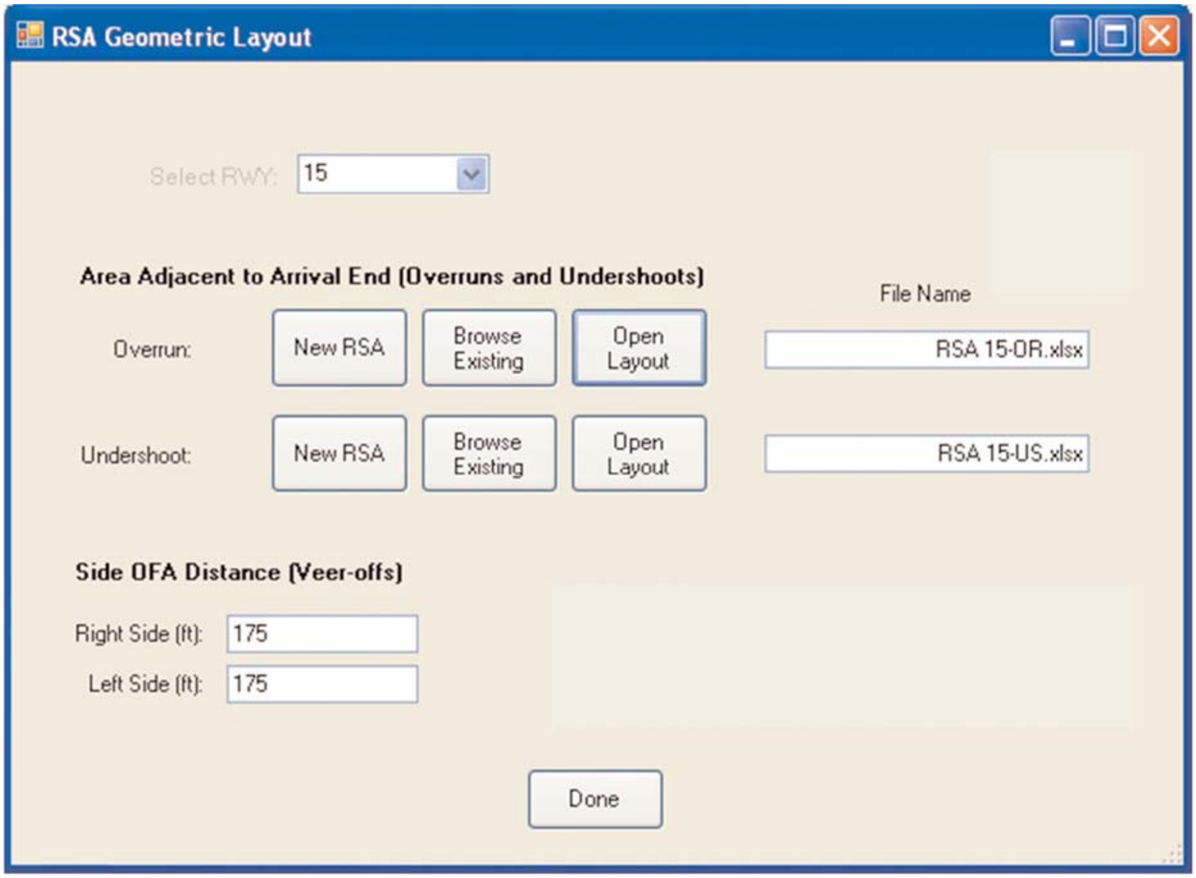
In the figure, WS2 is the wingspan of the taxing aircraft and WS1 is the wingspan of the aircraft in the runway. The *Side OFA Distance* can be calculated as follows:

$$SOFAD = CS - RW/2 - WS2/2$$

Where:

- SOFAD is the Side OFA Distance
- CS is the runway/taxiway centerline separation
- RW is the runway width
- WS2 is the wingspan of the aircraft in the taxiway, usually characterized by the largest wingspan of the Aircraft Design Group of the airfield

Because of the symmetry, the Side OFA Distance to the right and to the left is the same. In the example, the width of the OFA is 500 ft and the Side OFA Distance is simply half the OFA width minus half of the runway width, or 250 ft minus 75 ft, equal to 175 ft. The RSARA software takes into consideration the wingspan of the aircraft landing or taking off and uses the actual wingtip clearance to estimate the probability of collision when large lateral deviations take place during the veer-offs.



Select RWY: 15

Overrun: RSA 15-OR.xlsx

Undershoot: RSA 15-US.xlsx

Right Side (ft): 175

Left Side (ft): 175

When the RSA characteristics are entered for each runway available in the drop down list, you may click *Done* to exit the screen, taking you back to the *Airport Characteristics Input* screen. The program will automatically save the information entered.

Historical Operations Data (HOD)

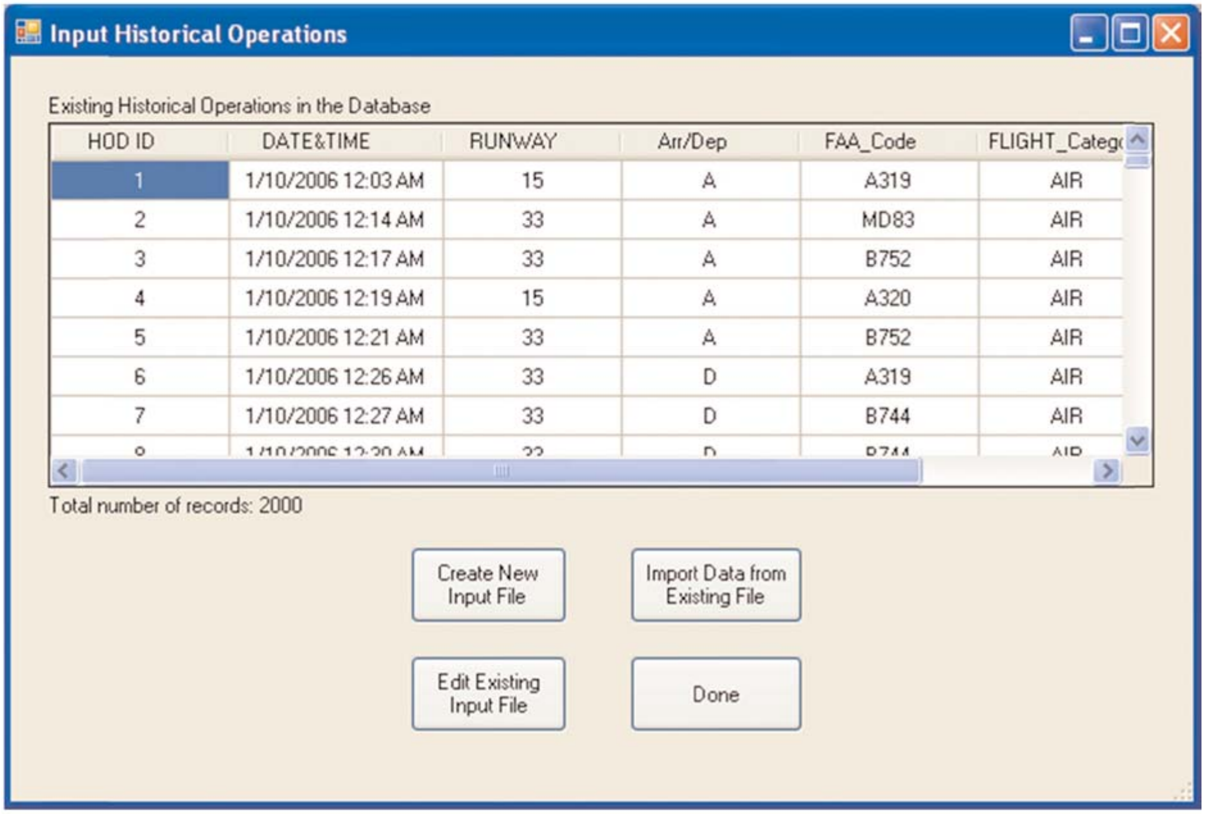
The next step is to enter HOD. Ideally historical data for the airport should be collected for one year. The information is placed in the template spreadsheet for this type of data. The columns, the field, and the format to save this data in the spreadsheet are presented in Attachment A to this guide. To enter the historical data into the analysis, click *Analysis/Input Data/Historical Operations Data* to open the screen to load the file.

Please note that the HOD can be edited using Microsoft Excel, however you **should not change the name of column headers or the tab name that contains the data**. RSARA uses the labels to identify the type of data to load into the program.

For towered airports it is possible to retrieve the records for operational data from the tower log or from the FAA's Aeronautical Information Management Lab. In some cases, the records are available however the runway used is not identified. For airports in the Aviation System Performance Metrics

(ASPM), it is possible to identify the runway configuration used in an hourly basis. The information is available online at *aspm.faa.gov*.

For non-towered airports, a sample of operations during one month may be repeated over the one-year period of records for the analysis. The information will be matched to the weather data retrieved for the airport to create a representative sample for analysis.



Existing Historical Operations in the Database

HOD ID	DATE&TIME	RUNWAY	Arr/Dep	FAA_Code	FLIGHT_Categ
1	1/10/2006 12:03 AM	15	A	A319	AIR
2	1/10/2006 12:14 AM	33	A	MD83	AIR
3	1/10/2006 12:17 AM	33	A	B752	AIR
4	1/10/2006 12:19 AM	15	A	A320	AIR
5	1/10/2006 12:21 AM	33	A	B752	AIR
6	1/10/2006 12:26 AM	33	D	A319	AIR
7	1/10/2006 12:27 AM	33	D	B744	AIR

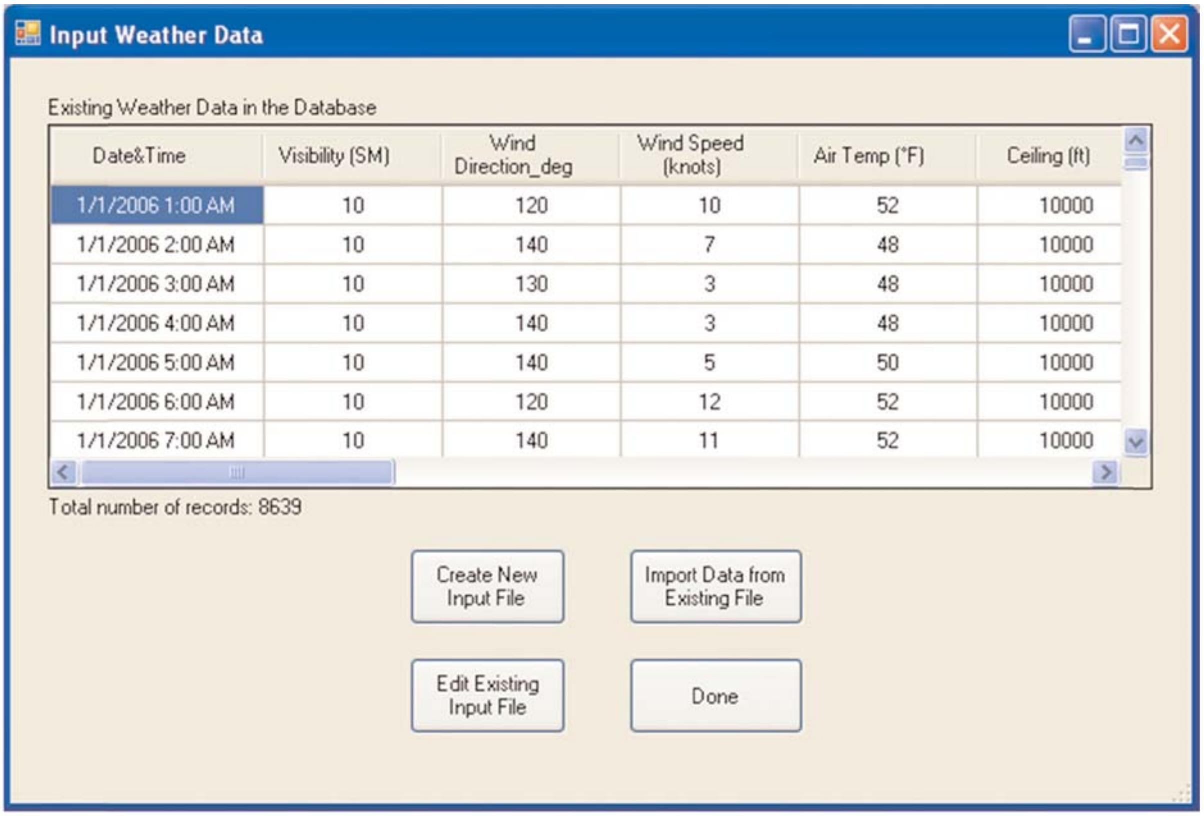
Total number of records: 2000

The screen allows the user to create, edit, import, or view the HOD required to run the analysis.

Historical Weather Data (HWD)

The file containing the HWD data will be loaded using a similar process to that used to load the HOD. The period for the weather data must match the period of operational data. The RSARA program will match the operational and weather data to characterize the actual weather conditions for each operation. The preparation of weather data is described in Attachment B to this guide.

It is important to note that the HWD can be edited using Microsoft Excel, however you **should not change the name of column headers or the tab name that contains the data**. RSARA uses the labels to identify the type of data to load into the program. The screen to enter the file containing weather data is the following.



Existing Weather Data in the Database

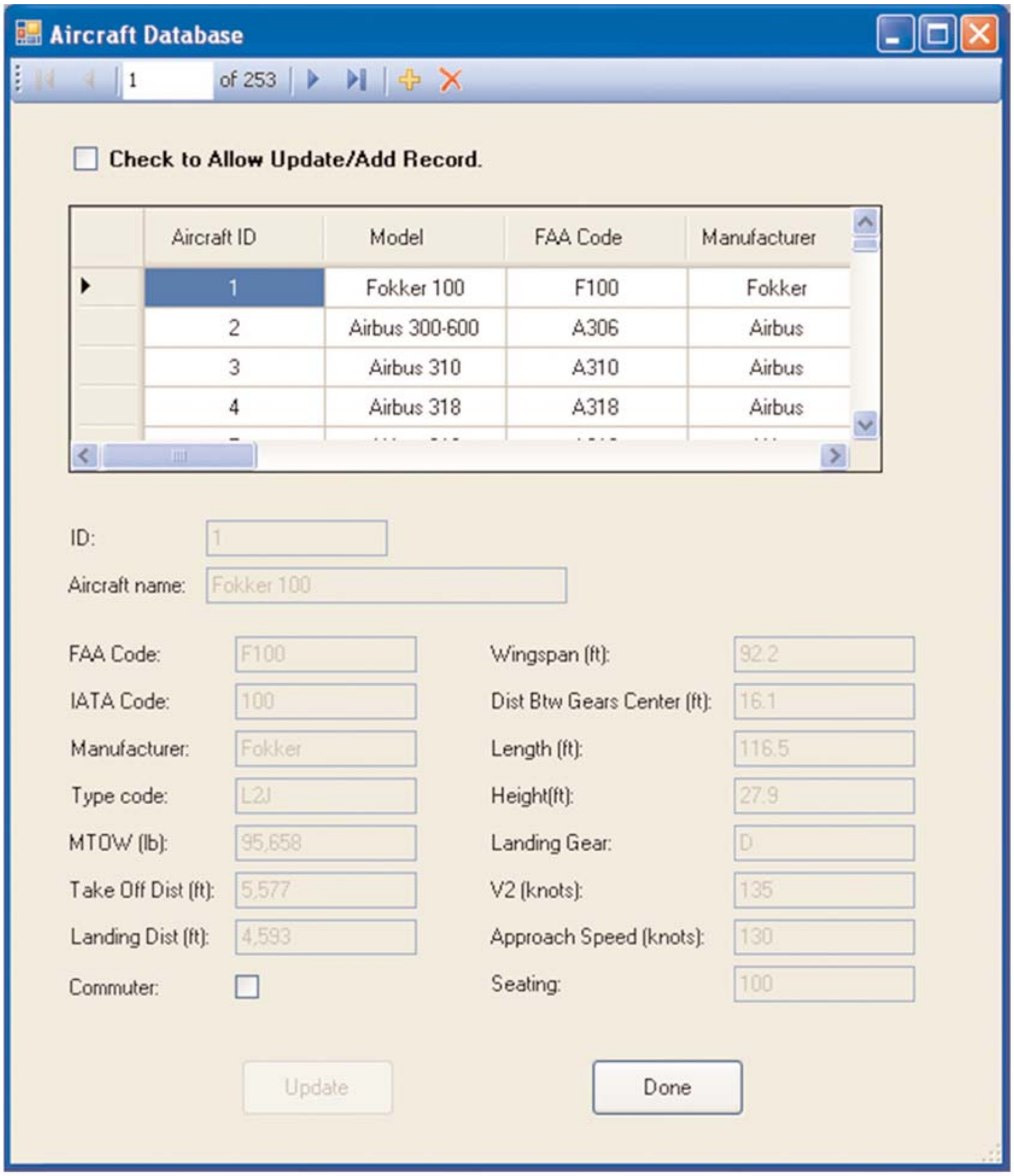
Date&Time	Visibility (SM)	Wind Direction_deg	Wind Speed (knots)	Air Temp (°F)	Ceiling (ft)
1/1/2006 1:00 AM	10	120	10	52	10000
1/1/2006 2:00 AM	10	140	7	48	10000
1/1/2006 3:00 AM	10	130	3	48	10000
1/1/2006 4:00 AM	10	140	3	48	10000
1/1/2006 5:00 AM	10	140	5	50	10000
1/1/2006 6:00 AM	10	120	12	52	10000
1/1/2006 7:00 AM	10	140	11	52	10000

Total number of records: 8639

The screen allows the user to create, edit, import, or view the HWD required to run the analysis. The spreadsheet may be opened using RSARA or directly in Excel and saving without changing the file name.

Aircraft Library

The software contains a basic database of aircraft that may be updated to run the analysis. Click *Software Parameters/Aircraft Database* to access the database. The following screen will appear.



☐ Check to Allow Update/Add Record.

Aircraft ID	Model	FAA Code	Manufacturer
1	Fokker 100	F100	Fokker
2	Airbus 300-600	A306	Airbus
3	Airbus 310	A310	Airbus
4	Airbus 318	A318	Airbus

ID: 1

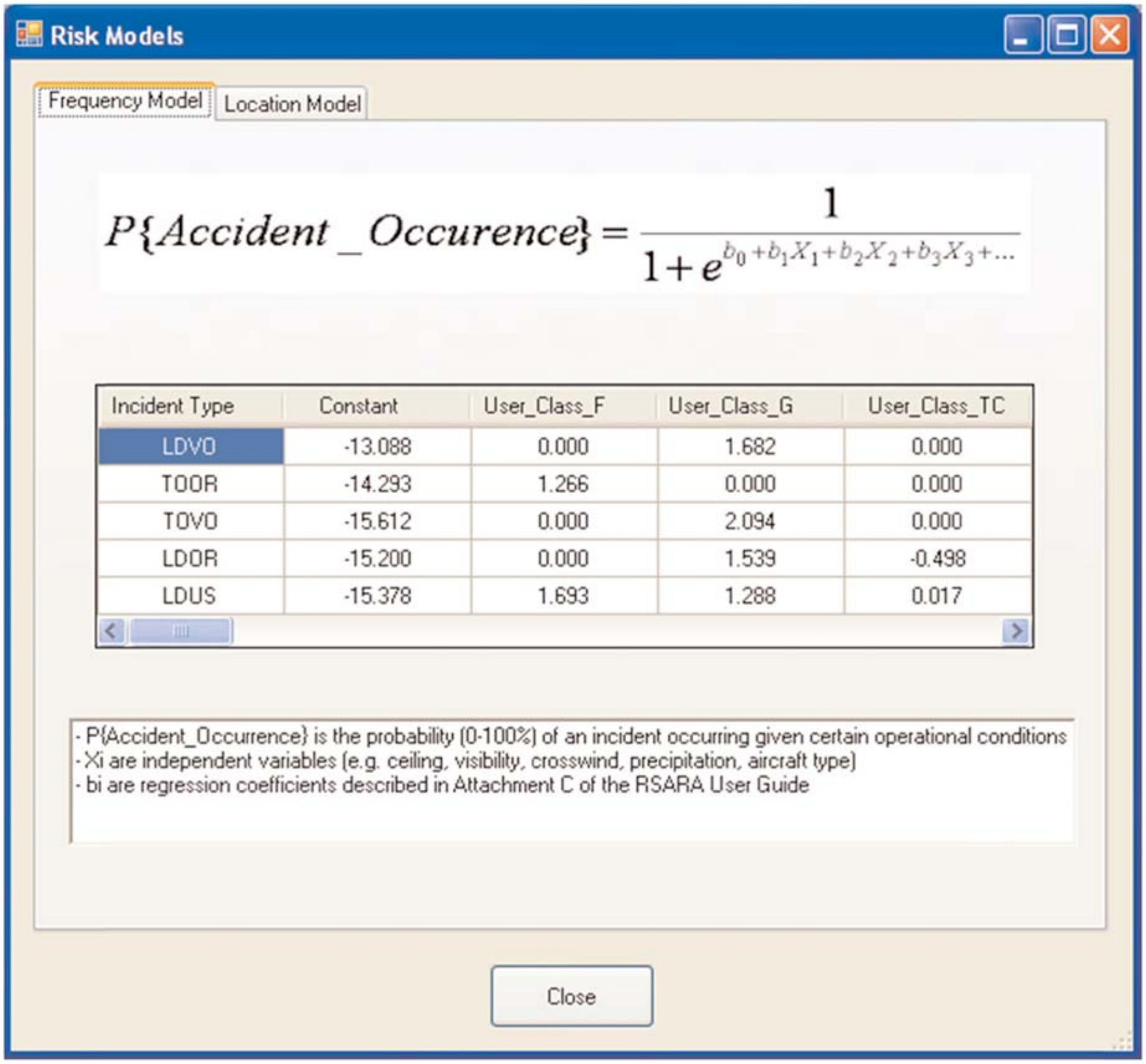
Aircraft name: Fokker 100

FAA Code:	F100	Wingspan (ft):	92.2
IATA Code:	100	Dist Btw Gears Center (ft):	16.1
Manufacturer:	Fokker	Length (ft):	116.5
Type code:	L2J	Height(ft):	27.9
MTOW (lb):	95,658	Landing Gear:	D
Take Off Dist (ft):	5,577	V2 (knots):	135
Landing Dist (ft):	4,593	Approach Speed (knots):	130
Commuter:	☐	Seating:	100

You may edit, update, or add records by clicking the check box on the top left of the screen. By checking that box the fields will be enabled for editing. It is important to note that RSARA identifies the type of aircraft in the historical information by the aircraft FAA Code shown in the third column.

8. Model Parameters

The user may view the frequency and location models used in the program by clicking *Software Parameters/Model Parameters*. The model parameters cannot be edited. The models incorporated to the software were those developed under project ACRP 4-08 – Improved Models for Risk Assessment of Runway Safety Areas (RSA). They will be available in the corresponding report, when published by the TRB.



$$P\{Accident\_Occurence\} = \frac{1}{1+e^{b_0+b_1X_1+b_2X_2+b_3X_3+\dots}}$$

Incident Type	Constant	User_Class_F	User_Class_G	User_Class_TC
LDVO	-13.088	0.000	1.682	0.000
TOOR	-14.293	1.266	0.000	0.000
TOVO	-15.612	0.000	2.094	0.000
LDOR	-15.200	0.000	1.539	-0.498
LDUS	-15.378	1.693	1.288	0.017

- P{Accident_Occurrence} is the probability (0-100%) of an incident occurring given certain operational conditions
- Xi are independent variables (e.g. ceiling, visibility, crosswind, precipitation, aircraft type)
- bi are regression coefficients described in Attachment C of the RSARA User Guide

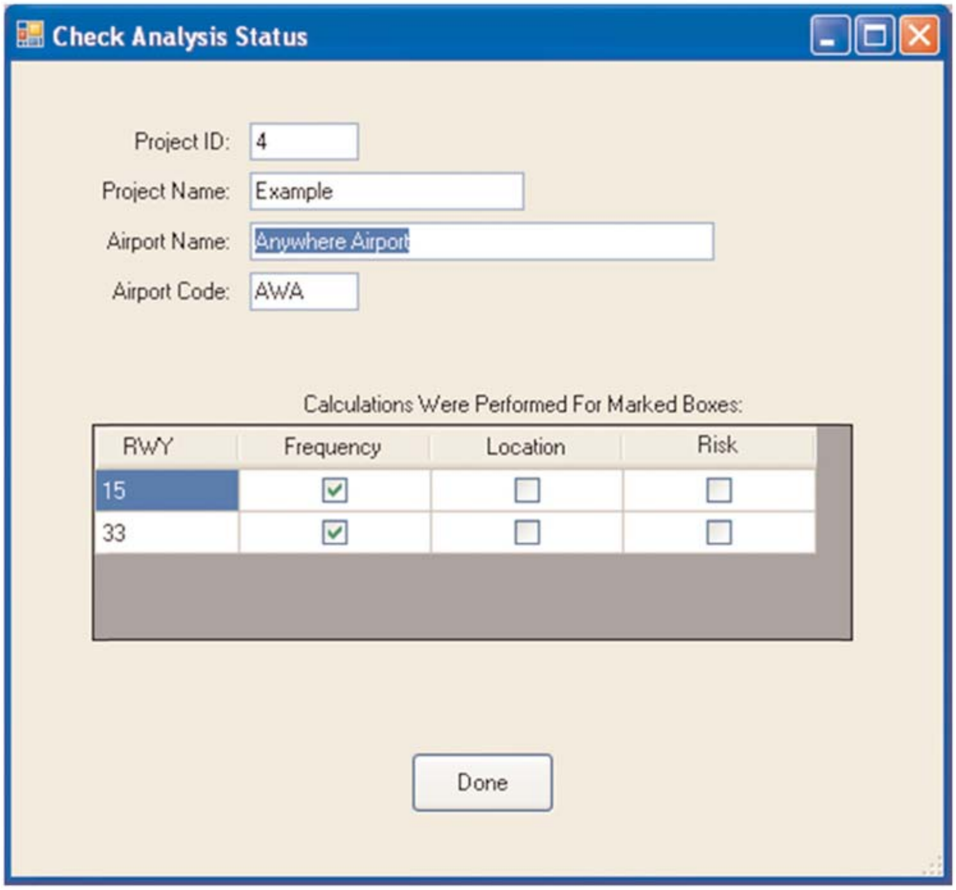
This screen contains two folders. The first shows the frequency models for landing overruns (LDUR), landing undershoots (LDUS), takeoff overruns (TOOR), landing veer-offs (LDVO), and takeoff veer-offs (TOVO). The second folder presents the location models for longitudinal and transverse distances relative to the runway axis for the same types of events.

9. Running the Analysis

The analysis menu has three submenus:

- Check Analysis Status
- Run Analysis
- Output Missing Data

The user may select *Analysis/Check Project Status* to check the status of calculations on one or more runways.



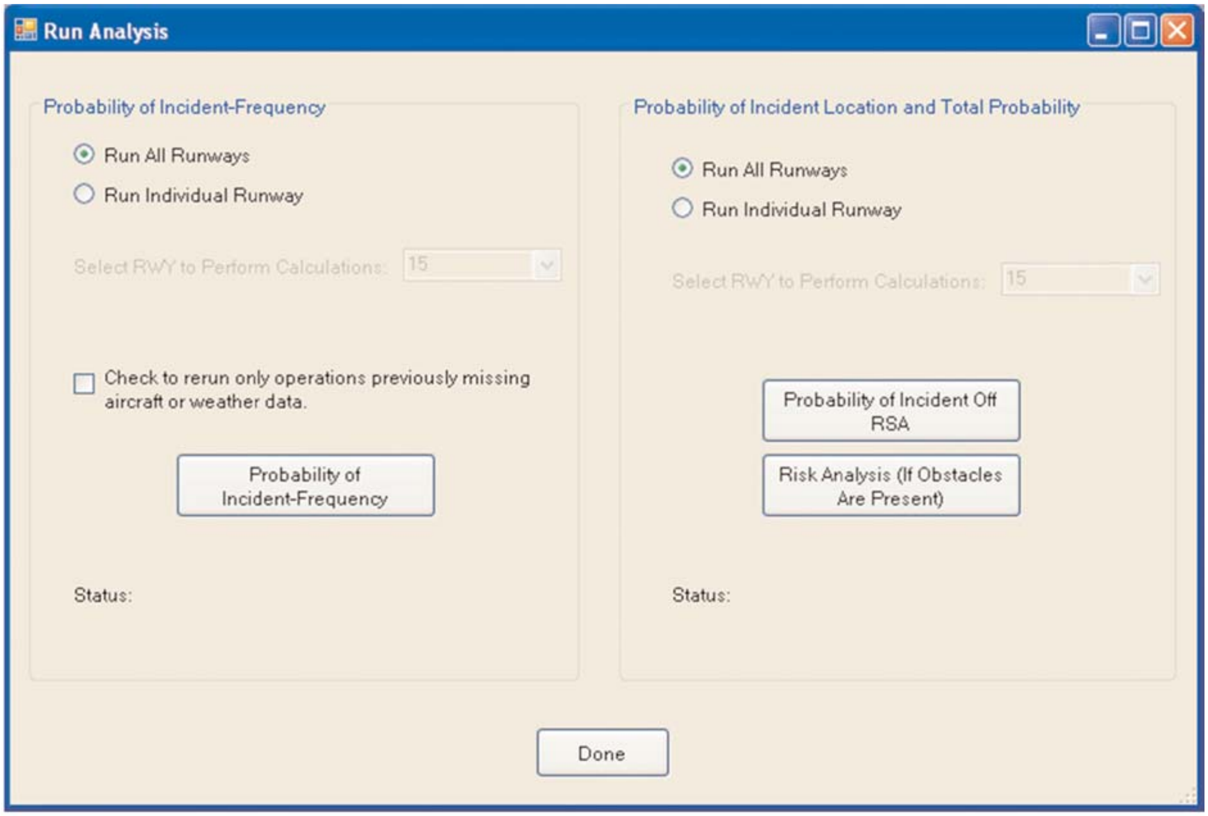
Project ID: 4
Project Name: Example
Airport Name: Anywhere Airport
Airport Code: AWA

Calculations Were Performed For Marked Boxes:

RWY	Frequency	Location	Risk
15	☑	☐	☐
33	☑	☐	☐

In the example presented, only the frequency probabilities for runways 15 and 33 were estimated.

To run the desired analysis, select *Analysis/Run Analysis*, and the following screen will appear.



Run Analysis

Probability of Incident-Frequency

● Run All Runways
○ Run Individual Runway

Select RWY to Perform Calculations: 15

☐ Check to rerun only operations previously missing aircraft or weather data.

Status:

Probability of Incident Location and Total Probability

● Run All Runways
○ Run Individual Runway

Select RWY to Perform Calculations: 15

Status:

You may run the analysis for individual runways or for all runways entered in the project. The selection is made on the top left of the screen, and if *Run Individual Runway* is selected, the list of runways is enabled for user selection.

After selecting *Run Individual Runway* or *Run All Runways*, the user must select one of the following three buttons to run the analysis:

- Probability of Incident-Frequency
- Probability of Incident Off RSA
- Risk Analysis

The analysis is conducted in two steps. First, click on *Probability of Incident-Frequency*. The program will only estimate the probability of individual incidents occurring. In this case, only the frequency model will be used to calculate the probability of overruns, undershoots, and veer-offs, no matter where the aircraft stopped or touched down. The program will store the results internally, and this step will allow the user to identify missing data on the historical records. **Running the *Probability of Incident-Frequency* is required before running the next steps**.

This step saves time when running the second step – when the actual RSA dimensions and obstacles will have an influence on the risk estimates. If you want to evaluate different RSA conditions, it will not be necessary to run the frequency model again.

The *Probability of Incident Off the RSA* button is used to estimate the probability that aircraft will overrun, veer-off, or undershoot the runway and that it will stop or touch down outside the limits of the existing or planned RSA. This analysis will not consider the risk of severe consequences, only the risk that the aircraft will stop outside the bounds of the RSA. Again, this analysis can be performed only after the user has run the *Probability of Incident*.

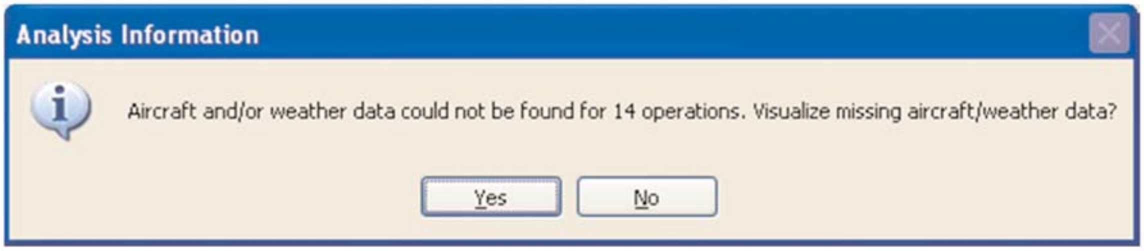
The *Risk Analysis* button allows the user to consider the interaction between the aircraft and the obstacles present within the RSA or its vicinity. The analysis will consider the type, location and size of the obstacles and will assume catastrophic consequences for cases when the aircraft is still moving when reaching the obstacle location. The speed of the aircraft to cause such serious consequences depends on the category of the obstacle. The end of the RSA for risk analysis is always assumed to be an obstacle of category 1 (maximum collision speed is nil, see below). **When clicking the *Risk Analysis* button, please wait a few minutes before the progress bar is shown**. The program is performing internal calculations before the progress bar is activated.

The approach to estimate the risk of catastrophic consequences uses the following assumptions:

1. Aircraft overrunning, undershooting, or veering-off the runway will strike the obstacle in paths parallel to the runway direction. This assumption is necessary to define the area of influence of the obstacle.
2. Four categories of obstacles are defined as a function of the maximum speed with which an aircraft may collide with an obstacle that produces small chances of causing hull loss and injuries to the occupants.
   a. Category 1: Maximum speed is nil (e.g., cliff at the RSA border, body of water for undershoots)
   b. Category 2: Maximum speed is 5 knots (e.g., brick buildings, non-frangible blast fences)
   c. Category 3: Maximum speed is 20 knots (e.g., small ditches, fences)
   d. Category 4: Maximum speed is 40 knots (e.g. large frangible at ground level structures such as Localizers and approach lighting systems (ALS))
3. Severe damage and injuries are expected only if the aircraft collides within the central third of the wingspan and with a speed higher than the maximum for that obstacle category.
4. The lateral distribution is random and does not depend on the presence of obstacles. This is a conservative assumption because there are events when the pilot will avoid the obstacles if he has some directional control of the aircraft. The accident/incident database contains a number of cases in which the pilot avoided a Localizer or some ALS structures in the RSA.

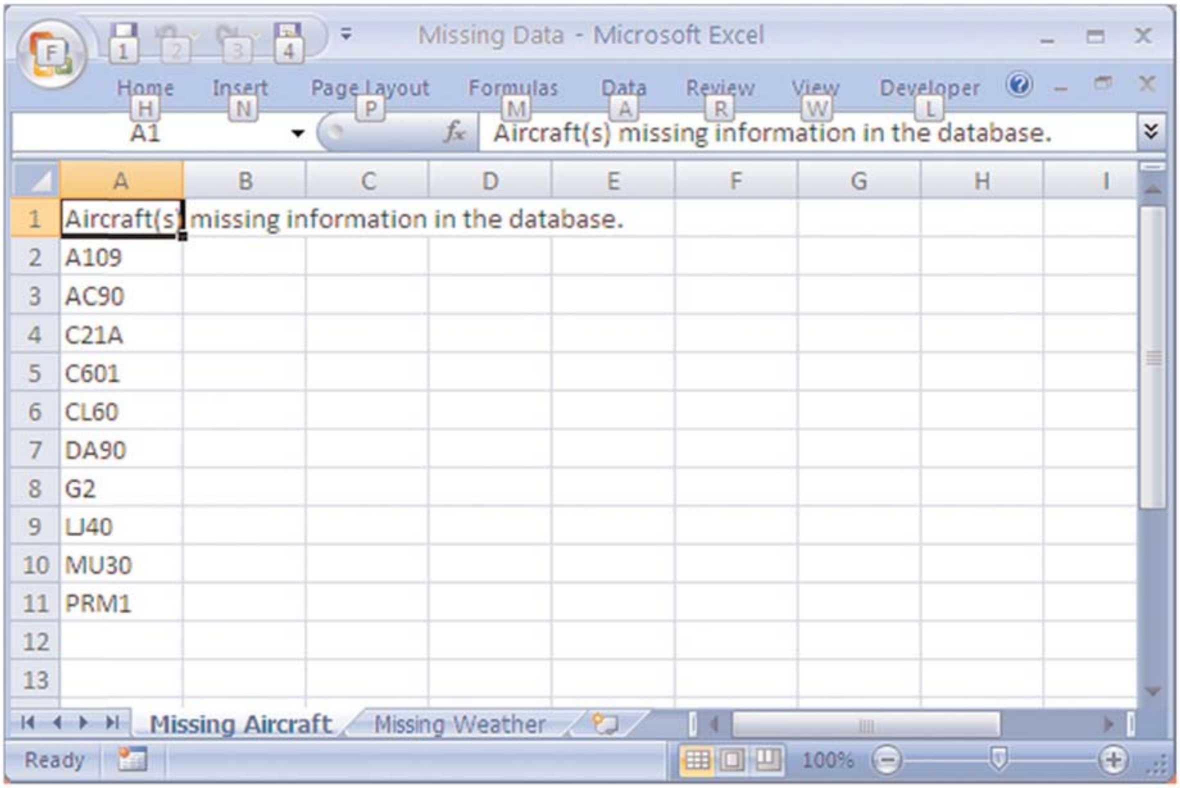
Output Missing Data

When running the analysis for a given runway for the first time, the program checks for records missing either aircraft or weather information. The analysis cannot be completed for specific records that have missing information. One common occurrence is a record for an aircraft that is not listed in the aircraft database. In most cases, the Federal Aviation Administration (FAA) code for the aircraft is a variation of the normal code; it is an aircraft that isn't widely used and is not in the default aircraft database; or it is an aircraft with maximum takeoff weight lower than 5,600 lbs. If missing records were identified during the run, the following screen will appear.



Aircraft and/or weather data could not be found for 14 operations. Visualize missing aircraft/weather data?

If the user selects *Yes*, an Excel spreadsheet will appear as shown below, showing the records with missing information. These records will be stored during the analysis and can be retrieved by the user at any time by clicking *Analysis/Output Missing Data*.



	A
1	Aircraft(s) missing information in the database.
2	A109
3	AC90
4	C21A
5	C601
6	CL60
7	DA90
8	G2
9	LJ40
10	MU30
11	PRM1
12	
13	

The user may ignore the list of records with missing data if the list contains only a few records; however it is possible to fix the problems with such records and rerun the analysis for all runways or individual runways with only the missing records.

There are two ways to correct missing data for aircraft. If the information for the aircraft is not in the aircraft database, the user should click *Software Parameters/Aircraft Database* and add the aircraft information to the database. If the information is available and the code does not match the FAA code in the aircraft database, the user may simply edit the code by clicking *Analysis/Input Data/Historical Operations Data* and then *Edit Existing Input File*. Information on FAA codes for aircraft can be obtained from FAA Order JO 7110.65T (Feb 2010). All the mismatching codes should be replaced with the code matching the code available in the aircraft database.

If weather data is missing, the user may correct the file by clicking *Analysis/Input Data/Weather Data*base and then *Edit Existing Input File* to make the necessary corrections.

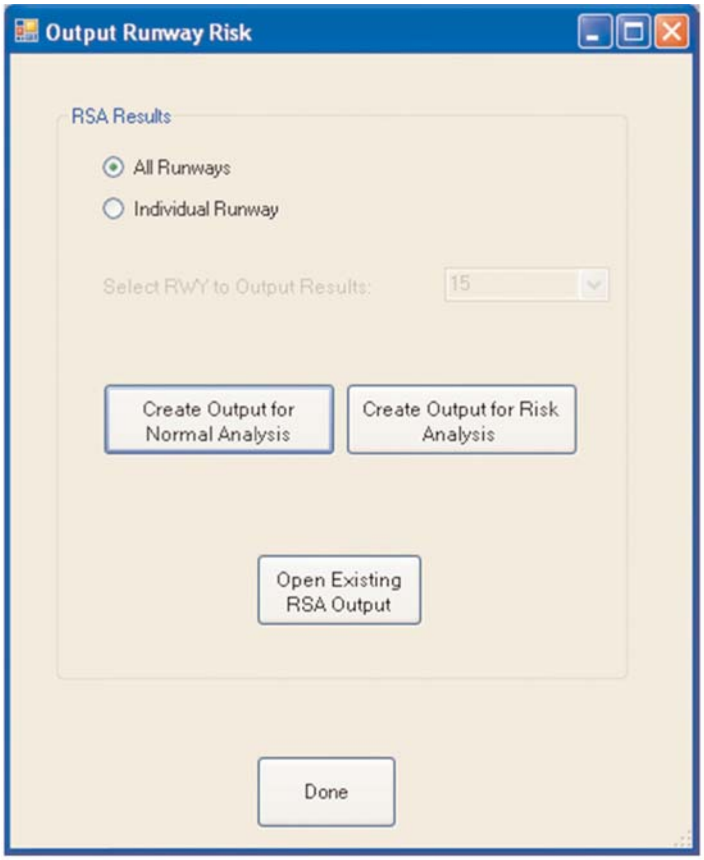
After the corrections are made, the user may run the analysis only for the missing records. This will save time, particularly for the analysis of larger airports with many historical records. To rerun the analysis for missing records, the user must check the option *Check to rerun fixed missing data* in the *Run Analysis* screen. The estimates after rerunning the analysis will consider both the previous and the new analysis of records recovered.

10. Output Results

When the analyses are completed, the user may see the results using the *Output* option of the main menu. There are two types of results: individual runways or the consolidated results for the whole airport. Within each of these options, the user can view the results for risk of events taking place outside the RSA or view the analysis output for the risk of catastrophic accidents.

Results for Runways

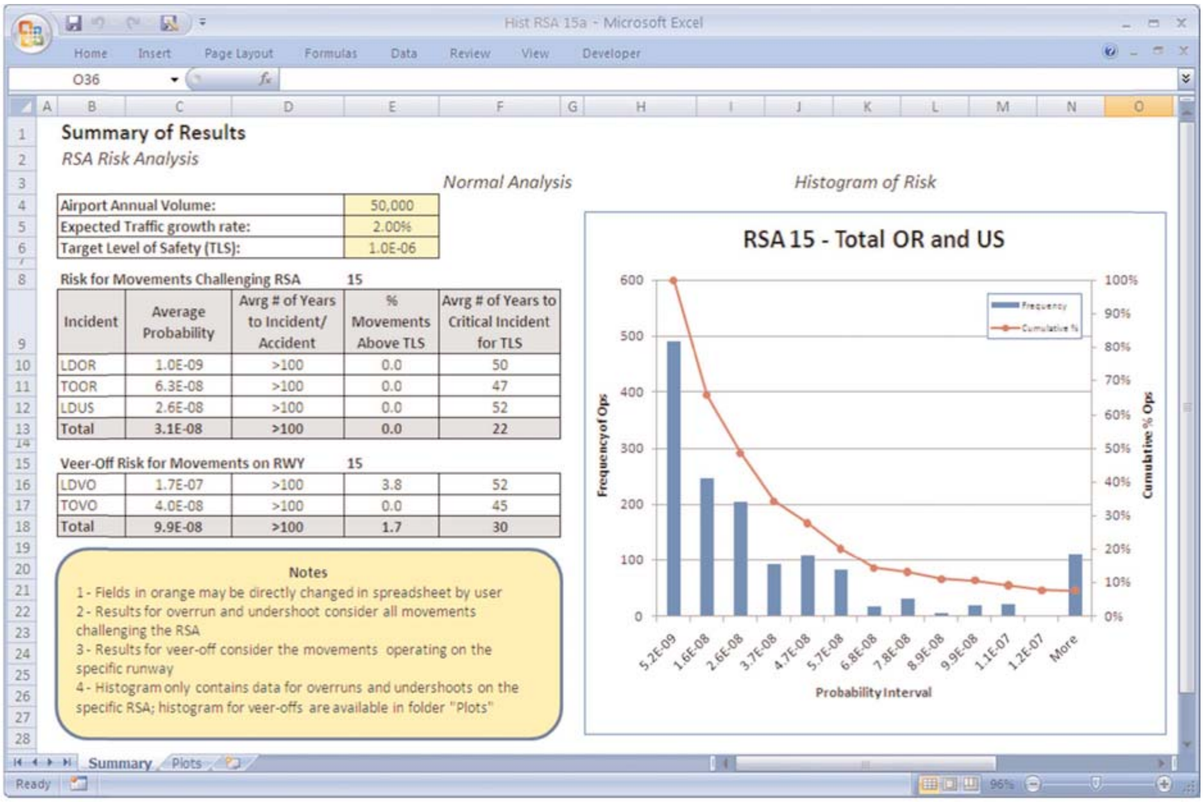
To see the results for all or individual runways, select *Output/Runway* and the following screen will appear.



The first step is to create the output and there are two alternatives, depending on the type of analysis that the user ran in the *Analysis* option of the main menu. The results are stored internally in the program and the need to create the output in this step is because the data will be transferred to an Excel spreadsheet to facilitate visualization of results.

Since this screen is for runways, the user may select one specific runway to output results, or to see the results for all the runways. In the latter case, the number of spreadsheets created will be the same as the number of runways analyzed.

The first option is to create the output for the analysis of RSA dimensions. To perform this procedure click *Create Output for Analysis of RSA Geometry* and a progress bar will open and show when the output is completed. Next, click *Open Results*, and an Excel spreadsheet will open as shown below. Please note that the *Open Results* button will only open the last output created.



Summary of Results

RSA Risk Analysis

Normal Analysis

Airport Annual Volume:	50,000
Expected Traffic growth rate:	2.00%
Target Level of Safety (TLS):	1.0E-06

Risk for Movements Challenging RSA 15

Incident	Average Probability	Avrg # of Years to Incident/ Accident	% Movements Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.0E-09	>100	0.0	50
TOOR	6.3E-08	>100	0.0	47
LDUS	2.6E-08	>100	0.0	52
Total	**3.1E-08**	**>100**	**0.0**	**22**

Veer-Off Risk for Movements on RWY 15

LDVO	1.7E-07	>100	3.8	52
TOVO	4.0E-08	>100	0.0	45
Total	**9.9E-08**	**>100**	**1.7**	**30**

Notes

1 - Fields in orange may be directly changed in spreadsheet by user
2 - Results for overrun and undershoot consider all movements challenging the RSA
3 - Results for veer-off consider the movements operating on the specific runway
4 - Histogram only contains data for overruns and undershoots on the specific RSA; histogram for veer-offs are available in folder "Plots"

Results are presented in both tabular and graphical format. Each folder contains the risk estimates for each type of incident and individual operation and the total risk during landings and takeoffs. A summary of the results is presented in the *Summary* folder shown in the previous screen. The summary table is shown below. It is very important to understand the information contained in the three tables shown.

The first table contains the *Airport Annual Volume* and the expected *Annual Traffic Growth Rate* and these values may also be modified by the user in the output spreadsheet. By changing these values, the average number of years between incidents will also change to reflect the new volume of traffic estimated for future years. The second information, the *Target Level of Safety (TLS)*, may also be modified in the spreadsheet and the value will impact on the percentage of movements above the TLS (4th column in the large table).

Airport Annual Volume:	50,000
Expected Traffic growth rate:	2.00%
Target Level of Safety (TLS):	1.0E-06

The second table is titled *Risk of Movements Challenging the RSA* and contains results for the RSA adjacent to the arrival end of the runway selected per type of event (column 1). For example, if the user selected to output results for runway 15, this table presents the analysis results for overruns and undershoots occurring in the area adjacent to the arrival end of runway 15. These incidents are those associated with the movements challenging this RSA, and may take place when aircraft land on runway 15 (undershoots) or when aircraft land or takeoff on runway 33 (overruns).

Risk for Movements Challenging RSA 15

Incident	Average Probability	Avrg # of Years to Incident/ Accident	% Movements Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.0E-09	>100	0.0	50
TOOR	6.3E-08	>100	0.0	47
LDUS	2.6E-08	>100	0.0	52
Total	**3.1E-08**	**>100**	**0.0**	**22**

The second column shows the average probability of incident outside the RSA and the third column contains the average number of years expected between events; in this case, when the result is greater than 100, the ">100" value is informed. The fourth column provides the percentage of movements with risk higher than the adopted TLS. The fact that some operations are subject to such higher risk does not means that the operations are unacceptable. However it is desired that the percentage of such flights be minimized for each runway and for the whole airport.

The third table titled *Veer-Off Risk for Movements* on the selected runway contains results for veer-off only. This is necessary because it is a different area and comprises the lateral safety areas between the runway ends. The configuration of this table is similar to that presenting the results for the RSA (second table).

Veer-Off Risk for Movements on RWY 15

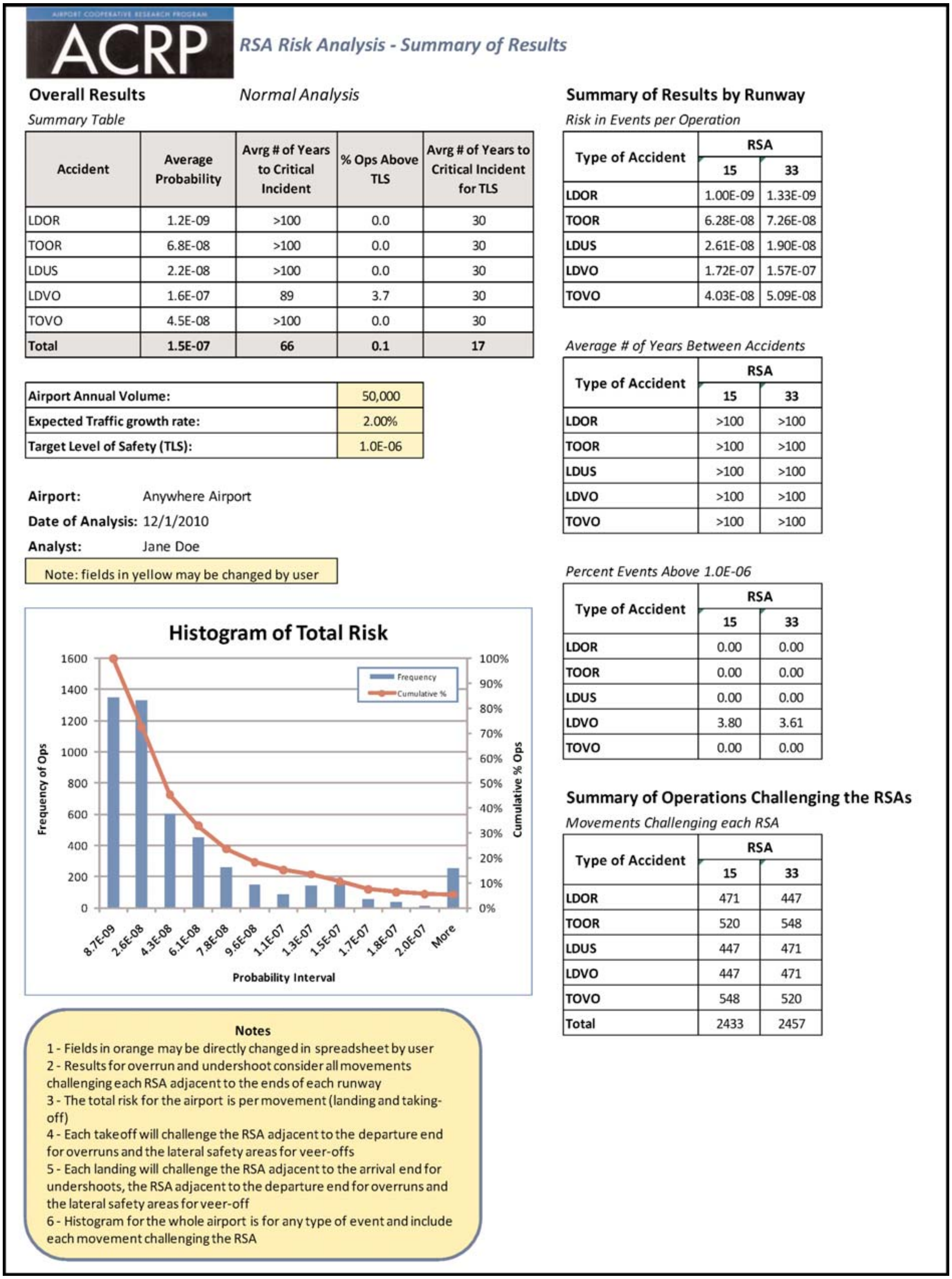
LDVO	1.7E-07	>100	3.8	52
TOVO	4.0E-08	>100	0.0	45
Total	**9.9E-08**	**>100**	**1.7**	**30**

The histogram shown in the *Summary* folder contains the data for each movement challenging the RSA adjacent to the arrival end of the runway selected. Therefore the data is only for overruns and undershoots only. Similar histograms for each individual type of incident are available in the *Plots* folder. Please note the total number of movements is higher than the number of movements for the airport and the reason is that one landing will challenge the arrival end RSA for undershoot, the departure end for overrun, and the lateral safety areas for veer-off.

Results for the Airport

To see the results for the airport as a whole, select *Output/Airport* and the following screen will appear.

Again, it is necessary to create the output if this procedure has not been performed earlier. The user may select the type of output and click *Open Summary for Airport* to view the results in a spreadsheet as shown in the screen below.



AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP

RSA Risk Analysis - Summary of Results

Overall Results

Normal Analysis

Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.2E-09	>100	0.0	30
TOOR	6.8E-08	>100	0.0	30
LDUS	2.2E-08	>100	0.0	30
LDVO	1.6E-07	89	3.7	30
TOVO	4.5E-08	>100	0.0	30
Total	**1.5E-07**	**66**	**0.1**	**17**

Airport Annual Volume:	50,000
Expected Traffic growth rate:	2.00%
Target Level of Safety (TLS):	1.0E-06

Airport: Anywhere Airport

Date of Analysis: 12/1/2010

Analyst: Jane Doe

Note: fields in yellow may be changed by user

Notes

1 - Fields in orange may be directly changed in spreadsheet by user
2 - Results for overrun and undershoot consider all movements challenging each RSA adjacent to the ends of each runway
3 - The total risk for the airport is per movement (landing and taking-off)
4 - Each takeoff will challenge the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-offs
5 - Each landing will challenge the RSA adjacent to the arrival end for undershoots, the RSA adjacent to the departure end for overruns and the lateral safety areas for veer-off
6 - Histogram for the whole airport is for any type of event and include each movement challenging the RSA

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA	
	15	33
LDOR	1.00E-09	1.33E-09
TOOR	6.28E-08	7.26E-08
LDUS	2.61E-08	1.90E-08
LDVO	1.72E-07	1.57E-07
TOVO	4.03E-08	5.09E-08

Average # of Years Between Accidents

Type of Accident	RSA	
	15	33
LDOR	>100	>100
TOOR	>100	>100
LDUS	>100	>100
LDVO	>100	>100
TOVO	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA	
	15	33
LDOR	0.00	0.00
TOOR	0.00	0.00
LDUS	0.00	0.00
LDVO	3.80	3.61
TOVO	0.00	0.00

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA	
	15	33
LDOR	471	447
TOOR	520	548
LDUS	447	471
LDVO	447	471
TOVO	548	520
Total	2433	2457

The tables are similar to those presented for individual runways, except that results for all types of incidents/accidents are consolidated and data for individual risk for any type of event are consolidated into the histogram. In addition, individual tables containing results for each runway are also presented.

Similar to the output for individual runways, the spreadsheet also provides a *Plots* folder containing histograms for individual types of incidents/accidents for the airport as a whole.

An example of the first table is shown below. It contains in the second column the average probabilities for each type of event and the total average probability for the airport. In the third column, the average number of years between incidents or accidents is calculated. This number is estimated based on the event probability, the annual volume of operations challenging the RSA for the given event, and the expected growth rate. Please note that this number is not to predict how many years it will take for that accident to happen; rather, it is an indication on how frequently the event can take place if the same conditions of operations are kept for a very long period of activity at the airport.

The fourth column indicates the percentage of movements challenging the RSA that have a risk higher than the selected TLS (e.g. for landing veer-offs (LDVO), 3.7% of the movements are under a risk higher than 1.0E-06, (one in one million movements).

Finally, column 5 contains the estimated number of years between events for the selected TLS. The results in this column are calculated using the same method used to estimate the results in the third column, except that the risk used is the TLS.

The table immediately below has the airport volume of operations (annual number of movements (landings and takeoffs), the expected annual growth rate of traffic, and the selected TLS. These numbers can be directly changed in the spreadsheet and new values will be calculated for the third, fourth and fifth columns of the main table.

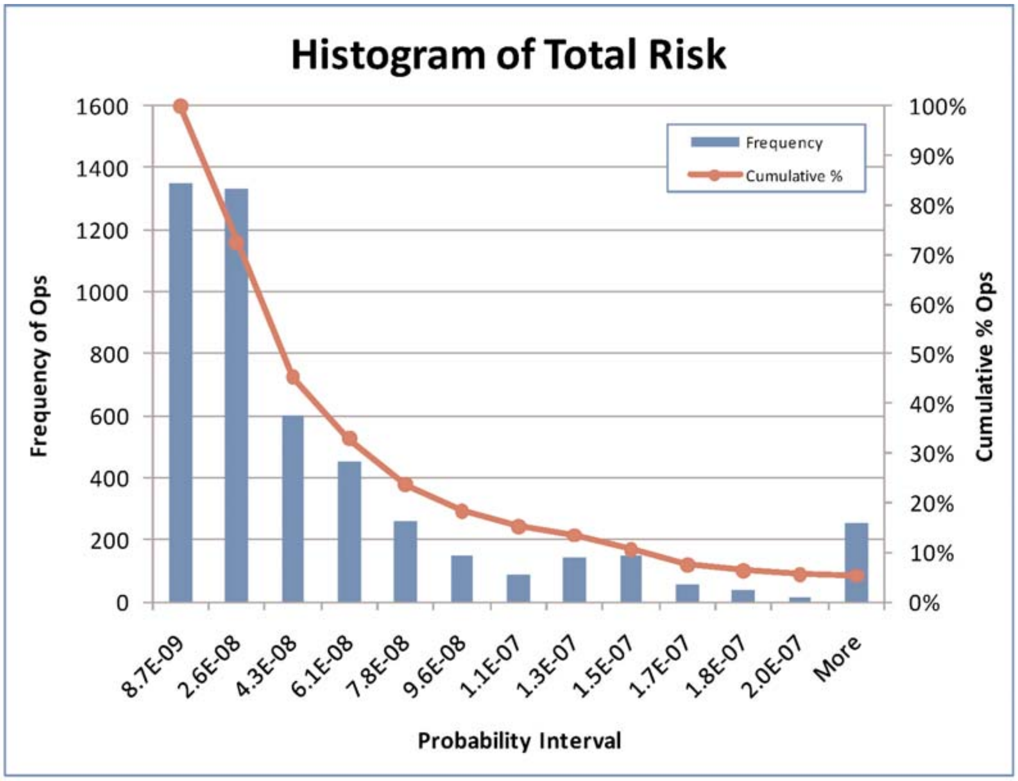
Overall Results *Normal Analysis*

Summary Table

Accident	Average Probability	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDOR	1.2E-09	>100	0.0	30
TOOR	6.8E-08	>100	0.0	30
LDUS	2.2E-08	>100	0.0	30
LDVO	1.6E-07	89	3.7	30
TOVO	4.5E-08	>100	0.0	30
Total	**1.5E-07**	**66**	**0.1**	**17**

Airport Annual Volume:	50,000
Expected Traffic growth rate:	2.00%
Target Level of Safety (TLS):	1.0E-06

Below the main table, a plot with the total distribution of risk is shown. Data used for this plot are originated from each type of event and two results are presented. The bars comprise the histogram of risk and each bar represents a given risk level shown in the x-axis. The percentage of operations for each bar is read on the left y-axis. The red line indicates the percentage of movements that have a risk higher than the value read in the x-axis (e.g. approximately 15% of movements are subject to risk higher than 1.1E-7 (or one event in 9,090,000 movements).



Additional tables are shown on the right of the main table. The first one is shown below and presents the average risk level for each type of event and the associated RSA challenged by the movements.

Summary of Results by Runway

Risk in Events per Operation

Type of Accident	RSA	
	15	33
LDOR	1.00E-09	1.33E-09
TOOR	6.28E-08	7.26E-08
LDUS	2.61E-08	1.90E-08
LDVO	1.72E-07	1.57E-07
TOVO	4.03E-08	5.09E-08

The table below presents the average number of years to occur one accident if the operational conditions were similar during a long period of activity. Similar to the previous table, the results are provided by RSA challenged by aircraft movements at the airport.

Average # of Years Between Accidents

Type of Accident	RSA	
	15	33
LDOR	>100	>100
TOOR	>100	>100
LDUS	>100	>100
LDVO	>100	>100
TOVO	>100	>100

The third table in the group shows the percentage of movements challenging each RSA that are subject to risk level higher than one accident in one million operations.

Percent Events Above 1.0E-06

Type of Accident	RSA	
	15	33
LDOR	0.00	0.00
TOOR	0.00	0.00
LDUS	0.00	0.00
LDVO	3.80	3.61
TOVO	0.00	0.00

The final table shows the total number of movements that challenge each RSA. These values are based on the HOD sample used for the analysis.

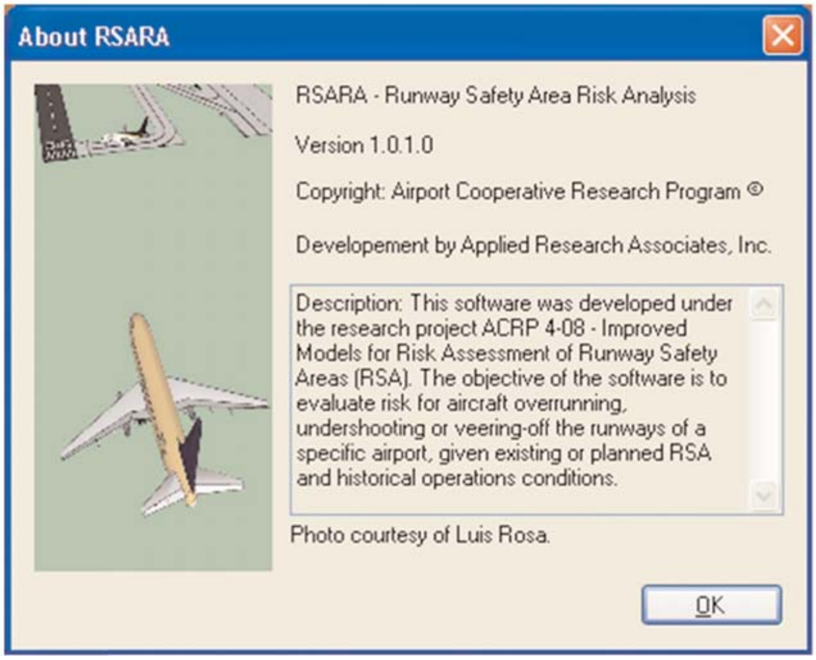
Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA	
	15	33
LDOR	471	447
TOOR	520	548
LDUS	447	471
LDVO	447	471
TOVO	548	520
Total	2433	2457

11. Help and Troubleshooting

The last option in the main menu is *Help*. When selecting this option *Help/Content*, a pdf version of this User Guide will open. If the user selects *Help/About*, the following screen will be presented.



RSARA - Runway Safety Area Risk Analysis

Version 1.0.1.0

Copyright: Airport Cooperative Research Program ©

Developement by Applied Research Associates, Inc.

Description: This software was developed under the research project ACRP 4-08 - Improved Models for Risk Assessment of Runway Safety Areas (RSA). The objective of the software is to evaluate risk for aircraft overrunning, undershooting or veering-off the runways of a specific airport, given existing or planned RSA and historical operations conditions.

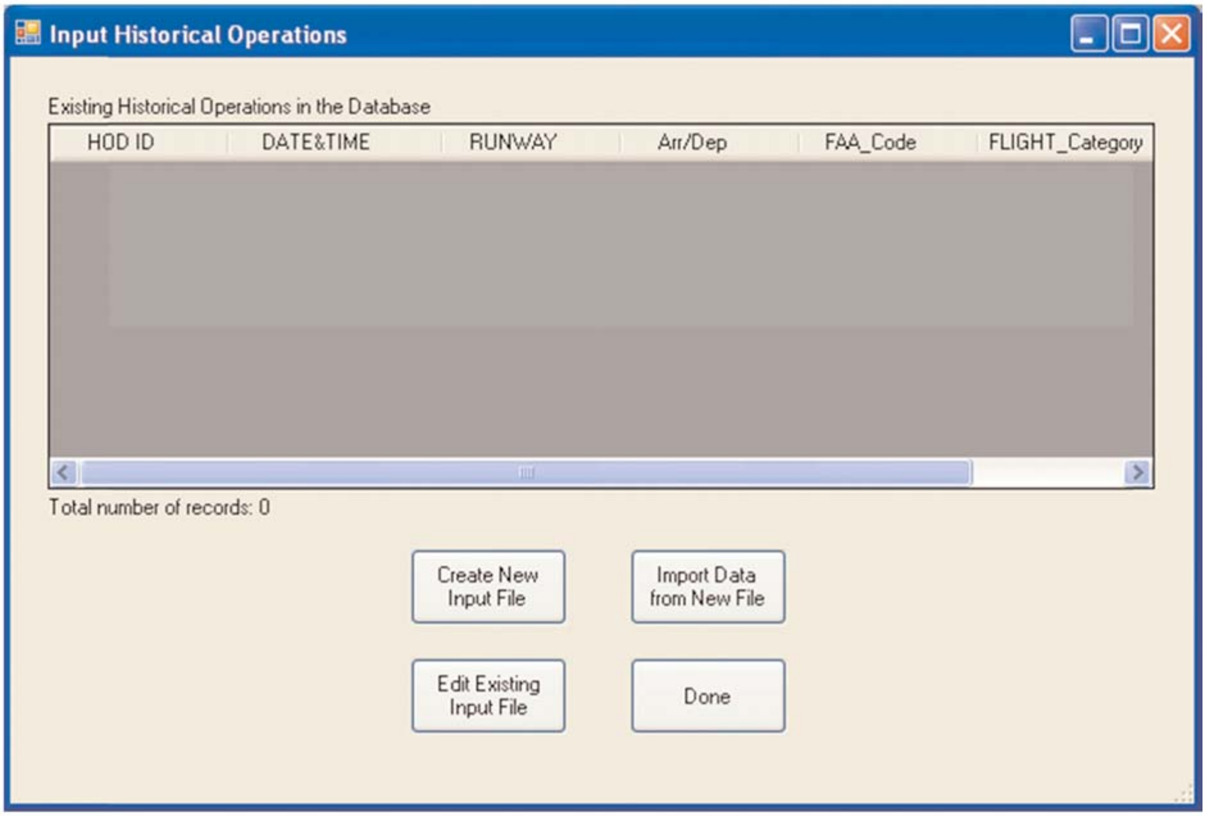
Photo courtesy of Luis Rosa.

Attachment A – Historical Operations Data

This section describes the procedure to prepare historical operations data for the airport. The historical operations data provided is consolidated internally in the program with the weather information provided (see Attachment B). The process is used to characterize the sample operations for the airport and weather conditions that these operations were subject.

Ideally a sample of data covering one full year of recent operations should be prepared to run the analysis. Having one year of data will help take into consideration seasonal weather and operational variations.

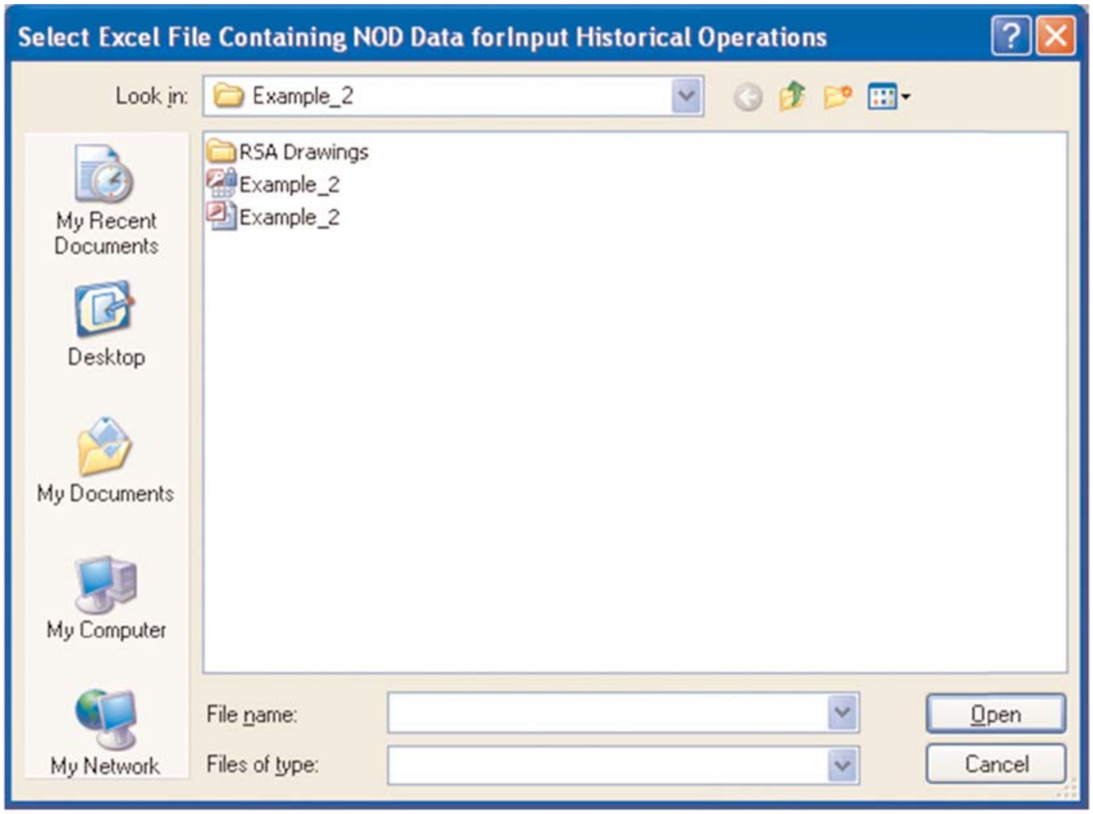
A Microsoft Excel (2007 or later) spreadsheet is used to enter the Historical Operations Data and create the sample. To create this database, select Input Data/Historical Operations Database and the following screen will open.



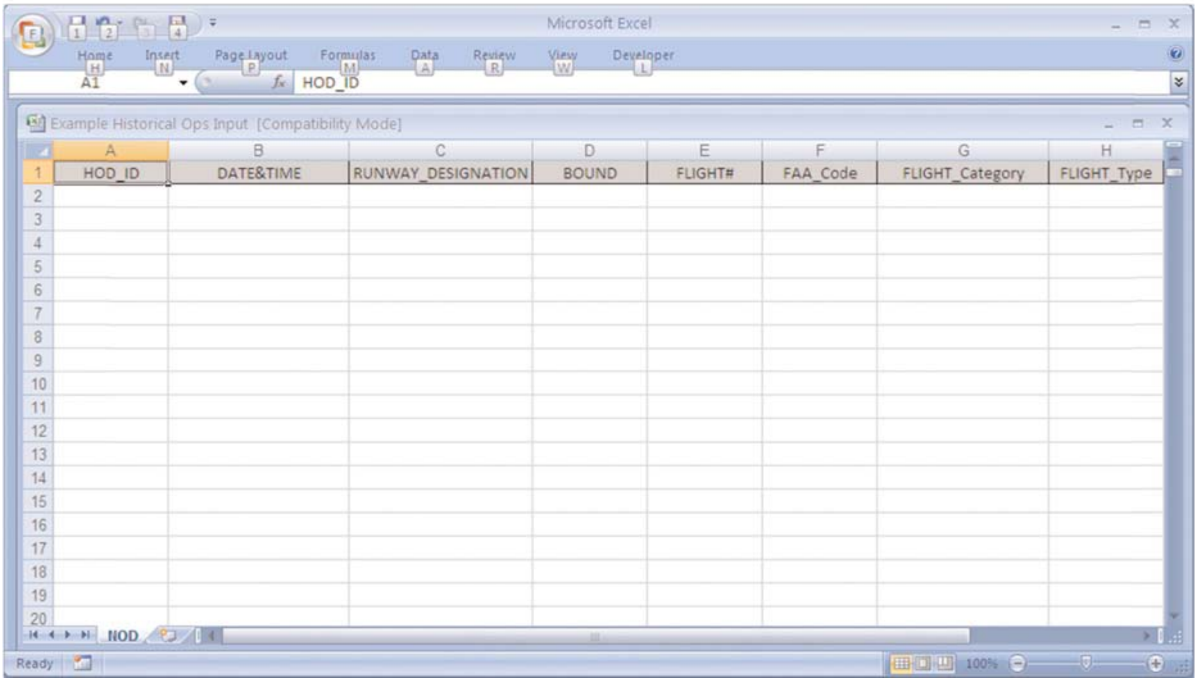
HOD ID	DATE&TIME	RUNWAY	Arr/Dep	FAA_Code	FLIGHT_Category

Total number of records: 0

To create the operations file, click on Create New and a dialog box will open.



Please enter a file name and the Excel spreadsheet will open with eight columns as shown below.



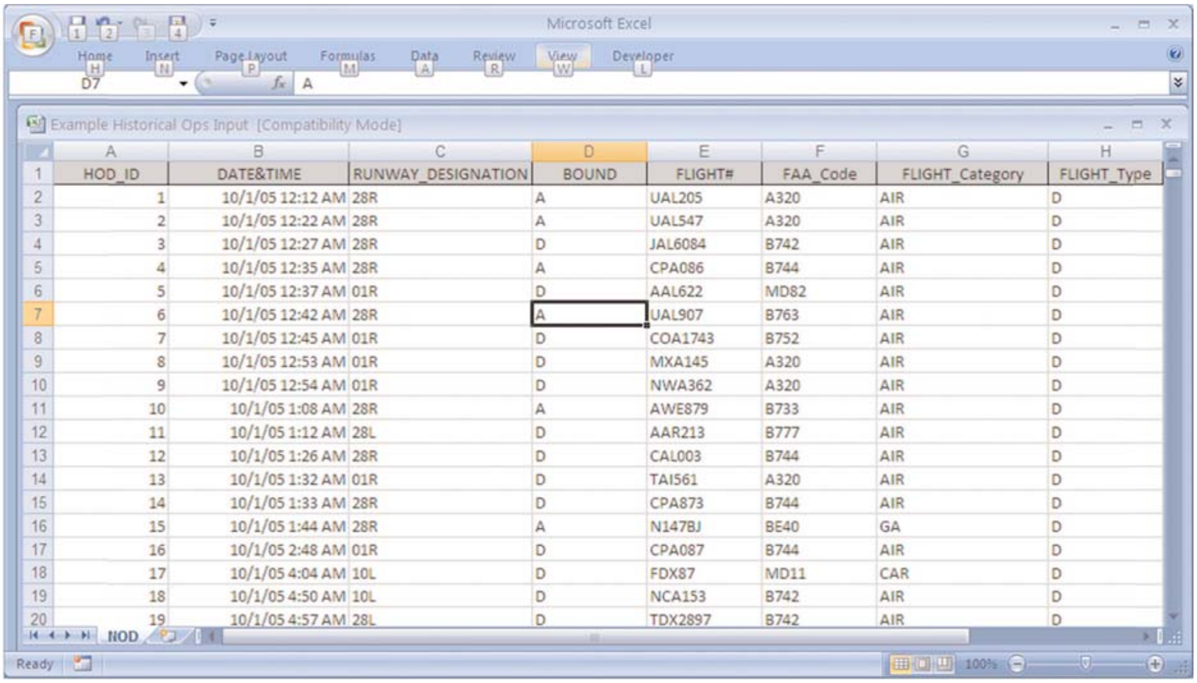
HOD_ID

	A	B	C	D	E	F	G	H
1	HOD_ID	DATE&TIME	RUNWAY_DESIGNATION	BOUND	FLIGHT#	FAA_Code	FLIGHT_Category	FLIGHT_Type

Each line in the spreadsheet should correspond to one record. The following table contains a description of each field.

Field	Description	Format
HOD_ID	This is an ID for the record and any reference may be used by the person creating the database. We suggest to enter a number, starting from 1 to the last record number, as shown in the example below.	Any format may be used. This information is not used by the program and is intended only to be a reference for the user.
DATE&TIME	This is the date and time when the aircraft movement took place	The format includes date and time, and is already set in the template provided with the program. Please see example below.
RWY_DESIGNATION	This is the runway designation where the movement took place.	The runway number and letter should be included (e.g. 14R or 23).
BOUND	If the movement is an arrival or departure.	Use ***A*** for arrival and ***D*** for departure
FLIGHT#	The flight number for the movement.	Any format can be used (e.g. AAL622). This information is for user reference only and does not need to be filled in because the program does not require it.
FAA_CODE	This is the code used by the FAA to characterize the aircraft type and model.	The code must match those available in the aircraft database. For example B733 is used for the Boeing 737-300 aircraft. When running the analysis, the program will attempt to match this code to one of the codes in the aircraft library. If the program is unable to match to an existing aircraft code, the record will be saved in a file for missing data and later the user can insert the new aircraft in the database and rerun the analysis for missing data records.
FLIGHT_CATEGORY	This field is used to characterize the type of flight: commercial, cargo, commuter/taxi or general aviation (GA)	Use ***AIR*** for commercial, ***CAR*** for cargo, ***COM*** for commuter/taxi and ***GA*** for general aviation
FLIGHT_TYPE	This is a code used to characterize if the flight is arriving from or departing to an international destination	Use ***D*** for domestic and ***I*** for international

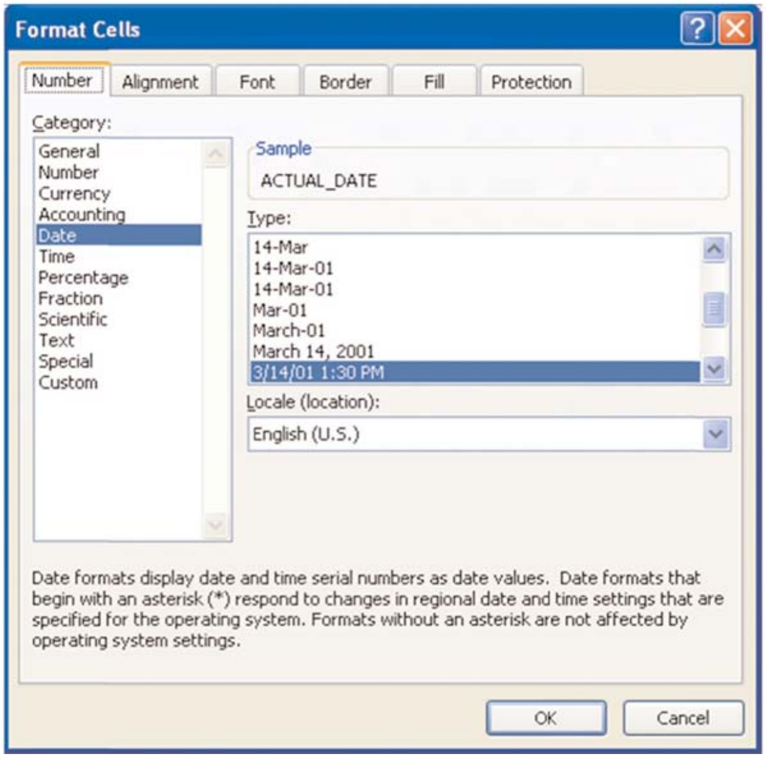
An example of the template filled with the information needed to run the program is shown below.



D7 *fx* A

HOD_ID	DATE&TIME	RUNWAY_DESIGNATION	BOUND	FLIGHT#	FAA_Code	FLIGHT_Category	FLIGHT_Type
1	10/1/05 12:12 AM	28R	A	UAL205	A320	AIR	D
2	10/1/05 12:22 AM	28R	A	UAL547	A320	AIR	D
3	10/1/05 12:27 AM	28R	D	JAL6084	B742	AIR	D
4	10/1/05 12:35 AM	28R	A	CPA086	B744	AIR	D
5	10/1/05 12:37 AM	01R	D	AAL622	MD82	AIR	D
6	10/1/05 12:42 AM	28R	A	UAL907	B763	AIR	D
7	10/1/05 12:45 AM	01R	D	COA1743	B752	AIR	D
8	10/1/05 12:53 AM	01R	D	MXA145	A320	AIR	D
9	10/1/05 12:54 AM	01R	D	NWA362	A320	AIR	D
10	10/1/05 1:08 AM	28R	A	AWE879	B733	AIR	D
11	10/1/05 1:12 AM	28L	D	AAR213	B777	AIR	D
12	10/1/05 1:26 AM	28R	D	CAL003	B744	AIR	D
13	10/1/05 1:32 AM	01R	D	TAI561	A320	AIR	D
14	10/1/05 1:33 AM	28R	D	CPA873	B744	AIR	D
15	10/1/05 1:44 AM	28R	A	N147BJ	BE40	GA	D
16	10/1/05 2:48 AM	01R	D	CPA087	B744	AIR	D
17	10/1/05 4:04 AM	10L	D	FDX87	MD11	CAR	D
18	10/1/05 4:50 AM	10L	D	NCA153	B742	AIR	D
19	10/1/05 4:57 AM	28L	D	TDX2897	B742	AIR	D

If the date and time format is not matching the format presented in the example above, the user may adjust by selecting the column, right-clicking and selecting *Format Cells*. In the dialog box, select Date in the *Category* box and selecting *3/14/01 1:30PM* in the *Type* box, as shown in the screen below.



Category: Date

Sample: ACTUAL_DATE

Type: 3/14/01 1:30 PM

Locale (location): English (U.S.)

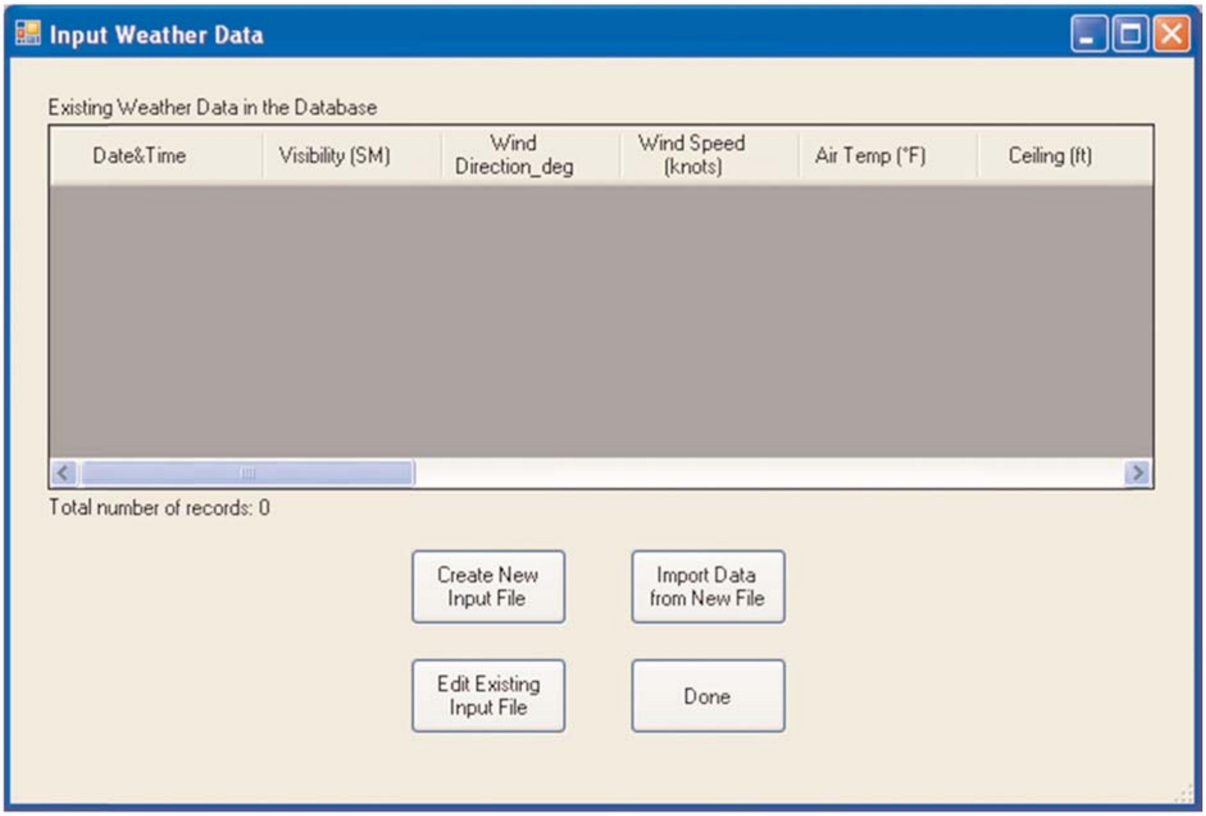
Date formats display date and time serial numbers as date values. Date formats that begin with an asterisk (*) respond to changes in regional date and time settings that are specified for the operating system. Formats without an asterisk are not affected by operating system settings.

Attachment B – Historical Weather Data

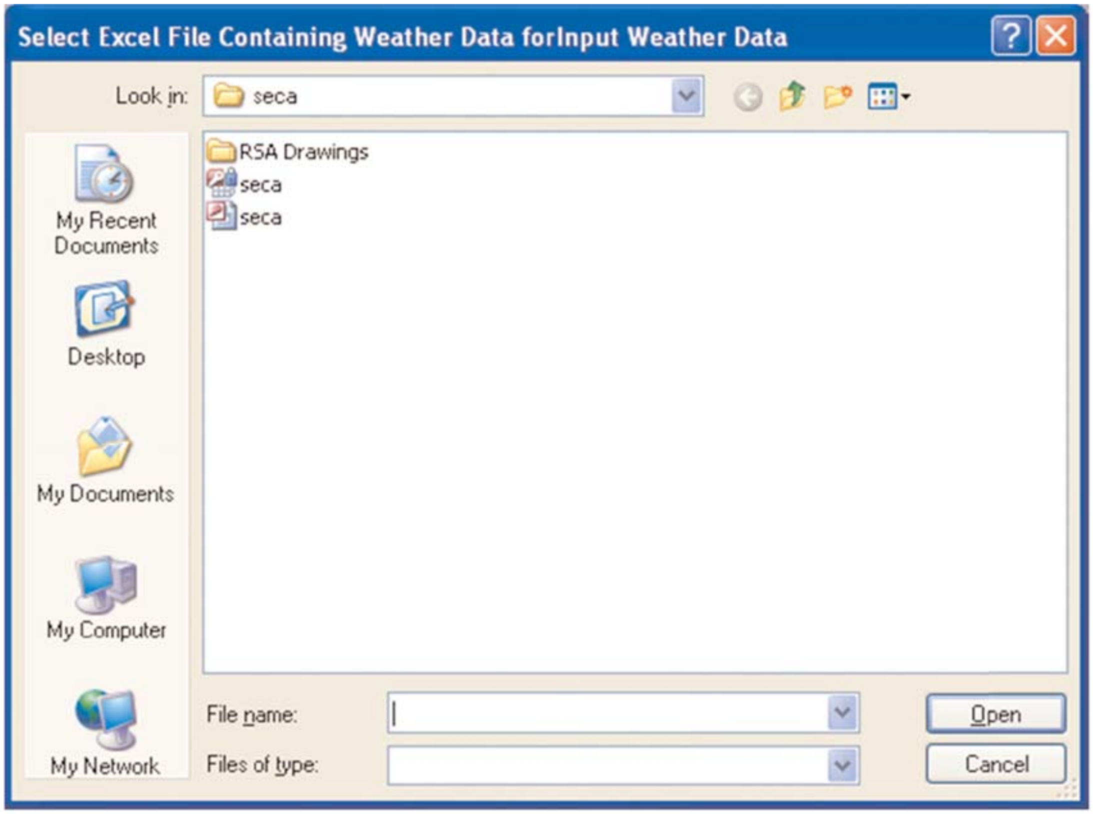
This section describes the procedure to prepare historical weather data for the airport. The historical weather data provided is consolidated internally in the program with the historical operations information provided (see Attachment A). The process is used to characterize the sample operations for the airport and weather conditions that these operations were subject.

The period for weather data must match the same period for historical operations data. Having one year of data will help take into consideration seasonal weather and operational variations.

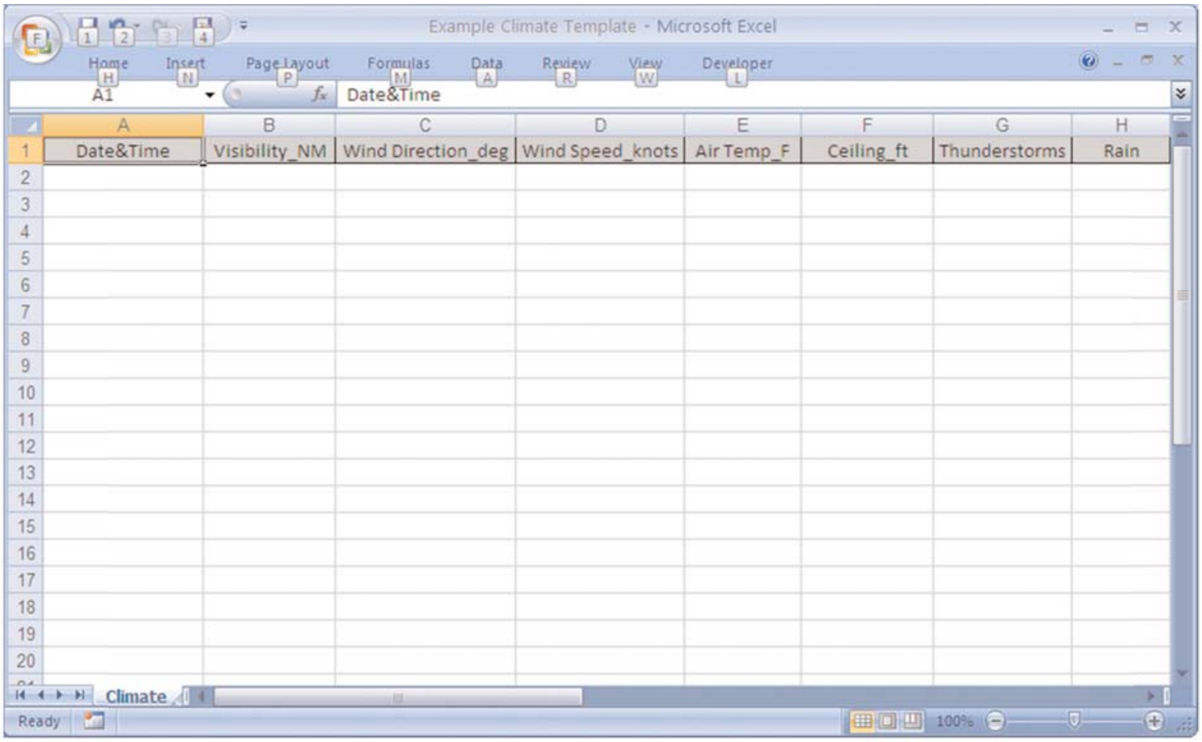
A Microsoft Excel (2007 or later) spreadsheet is used to enter the Historical Operations Data and create the sample. To create this database, select Input Data/Weather Database and the following screen will open.



To create the weather file, click on Create New and a dialog box will open.



Please enter a file name and the Excel spreadsheet will open with twenty columns as shown below.



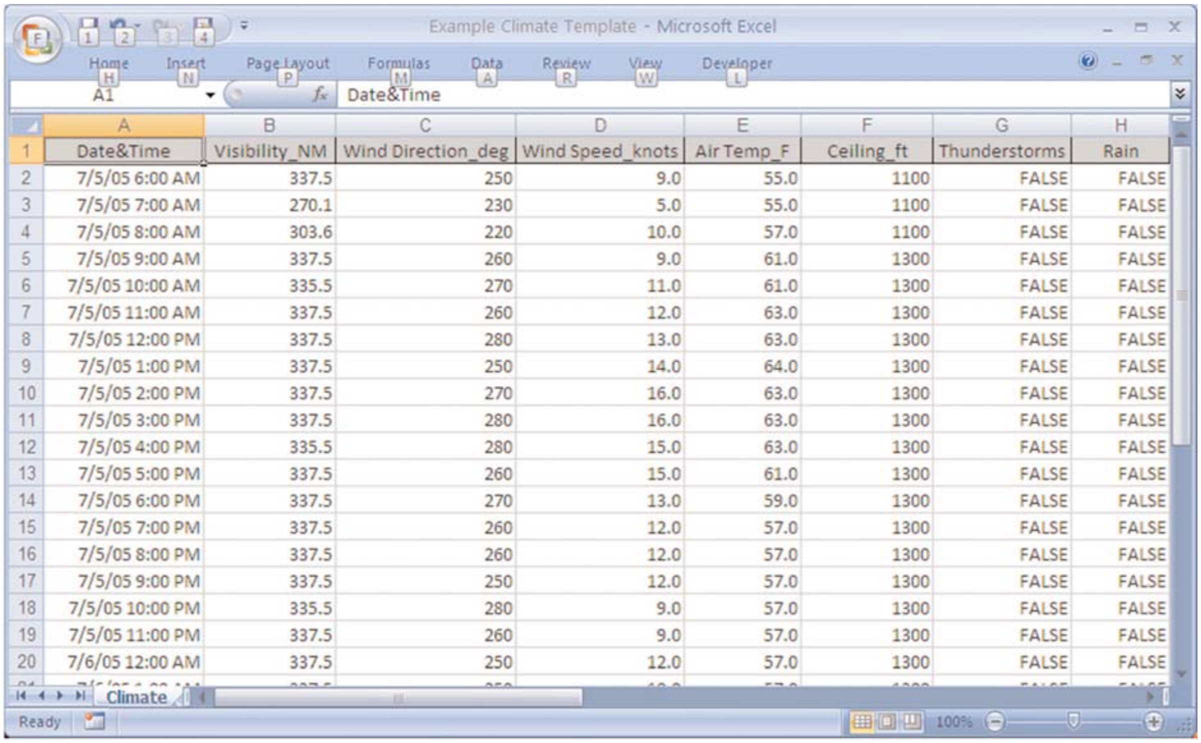
	A	B	C	D	E	F	G	H
1	Date&Time	Visibility_NM	Wind Direction_deg	Wind Speed_knots	Air Temp_F	Ceiling_ft	Thunderstorms	Rain

Each line in the spreadsheet should correspond to one record. The following table contains a description of each field.

Field	Description	Format
Date&Time	This is the date and time when the weather measures were taken	The format includes date and time, and is already set in the template provided with the program.
Visibility_NM	The distance at which a given standard object can be seen and identified with the unaided eye	Nautical Miles (NM)
Wind Direction_deg	The true direction from which the wind is blowing at a given location (i.e., wind blowing from the north to the south is a north wind). A wind direction of 0 degrees is only used when wind is calm.	In degrees clockwise through 360 degrees. North is 360 degrees.
Wind Speed_knots	The rate at which air is moving horizontally past a given point. It may be a 2-minute average speed (reported as wind speed) or an instantaneous speed (reported as a peak wind speed, wind gust, or squall).	Knots (kts)
Air Temp_F	The ambient temperature indicated by a thermometer exposed to the air but sheltered from direct solar radiation.	Degrees Fahrenheit (F)
Ceiling_ft	The height of the cloud base for the lowest broken or overcast cloud layer.	Feet (ft)

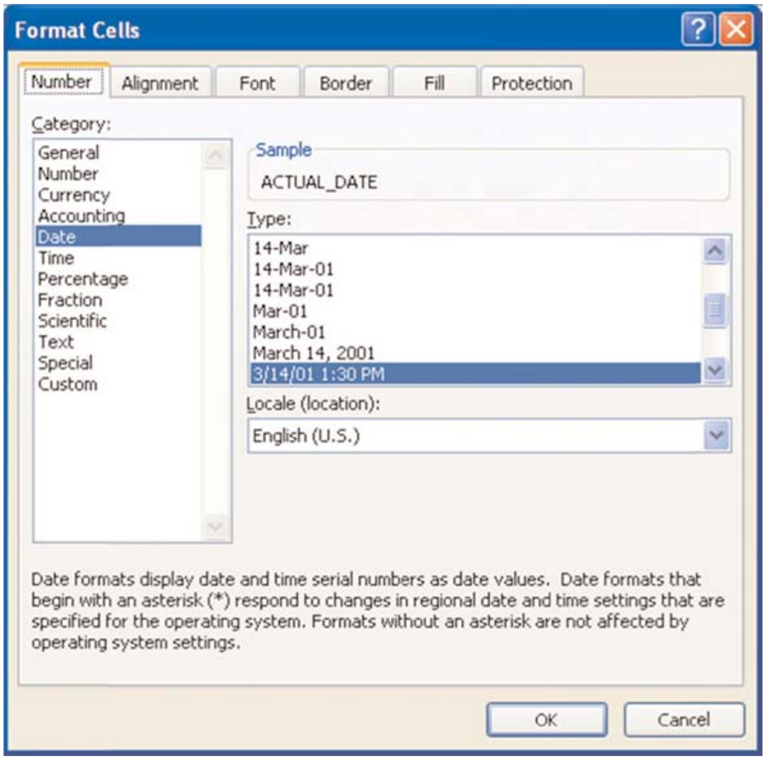
Field	Description	Format
Thunderstorm	A local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder	Presence (TRUE) or not (FALSE)
Rain	Precipitation that falls to earth in drops more than 0.5 mm in diameter.	Presence (TRUE) or not (FALSE)
Rain Showers	A brief period of rain	Presence (TRUE) or not (FALSE)
Freezing Rain	Rain that falls as a liquid but freezes into glaze upon contact with the ground.	Presence (TRUE) or not (FALSE)
Freezing Drizzle	A drizzle that falls as a liquid but freezes into glaze or rime upon contact with the cold ground or surface structures.	Presence (TRUE) or not (FALSE)
Snow	Precipitation in the form of ice crystals, often agglomerated into snowflakes, formed directly from the freezing [deposition] of the water vapor in the air.	Presence (TRUE) or not (FALSE)
Snow Pellets	Precipitation, usually of brief duration, consisting of crisp, white, opaque ice particles, round or conical in shape and about 2 to 5 mm in diameter. Same as graupel or small hail.	Presence (TRUE) or not (FALSE)
Ice Crystals	A barely visible crystalline form of ice that has the shape of needles, columns or plates. Ice crystals are so small that they seem to be suspended in air. Ice crystals occur at very low temperatures in a stable atmosphere.	Presence (TRUE) or not (FALSE)
Snow Showers	Short duration of moderate snowfall. Some accumulation is possible.	Presence (TRUE) or not (FALSE)
Ice Pellets	Same as Sleet; defined as pellets of ice composed of frozen or mostly frozen raindrops or refrozen partially melted snowflakes. These pellets of ice usually bounce after hitting the ground or other hard surfaces. Heavy sleet is a relatively rare event defined as an accumulation of ice pellets covering the ground to a depth of ½" or more.	Presence (TRUE) or not (FALSE)
Ice Pellet Showers	Short duration of ice pellet precipitation.	Presence (TRUE) or not (FALSE)
Fog	Fog is water droplets suspended in the air at the Earth's surface. Fog often degrades the visibility.	Presence (TRUE) or not (FALSE)
Gusts	A rapid fluctuation of wind speed with variations of 10 knots or more between peaks and lulls.	Presence (TRUE) or not (FALSE)

An example of the template filled with the information needed to run the program is shown below.



	A	B	C	D	E	F	G	H
1	Date&Time	Visibility_NM	Wind Direction_deg	Wind Speed_knots	Air Temp_F	Ceiling_ft	Thunderstorms	Rain
2	7/5/05 6:00 AM	337.5	250	9.0	55.0	1100	FALSE	FALSE
3	7/5/05 7:00 AM	270.1	230	5.0	55.0	1100	FALSE	FALSE
4	7/5/05 8:00 AM	303.6	220	10.0	57.0	1100	FALSE	FALSE
5	7/5/05 9:00 AM	337.5	260	9.0	61.0	1300	FALSE	FALSE
6	7/5/05 10:00 AM	335.5	270	11.0	61.0	1300	FALSE	FALSE
7	7/5/05 11:00 AM	337.5	260	12.0	63.0	1300	FALSE	FALSE
8	7/5/05 12:00 PM	337.5	280	13.0	63.0	1300	FALSE	FALSE
9	7/5/05 1:00 PM	337.5	250	14.0	64.0	1300	FALSE	FALSE
10	7/5/05 2:00 PM	337.5	270	16.0	63.0	1300	FALSE	FALSE
11	7/5/05 3:00 PM	337.5	280	16.0	63.0	1300	FALSE	FALSE
12	7/5/05 4:00 PM	335.5	280	15.0	63.0	1300	FALSE	FALSE
13	7/5/05 5:00 PM	337.5	260	15.0	61.0	1300	FALSE	FALSE
14	7/5/05 6:00 PM	337.5	270	13.0	59.0	1300	FALSE	FALSE
15	7/5/05 7:00 PM	337.5	260	12.0	57.0	1300	FALSE	FALSE
16	7/5/05 8:00 PM	337.5	260	12.0	57.0	1300	FALSE	FALSE
17	7/5/05 9:00 PM	337.5	250	12.0	57.0	1300	FALSE	FALSE
18	7/5/05 10:00 PM	335.5	280	9.0	57.0	1300	FALSE	FALSE
19	7/5/05 11:00 PM	337.5	260	9.0	57.0	1300	FALSE	FALSE
20	7/6/05 12:00 AM	337.5	250	12.0	57.0	1300	FALSE	FALSE

If the date and time format is not matching the format presented in the example above, the user may adjust by selecting the column, right-clicking and selecting *Format Cells*. In the dialog box, select *Date* in the *Category* box and selecting *3/14/01 1:30PM* in the *Type* box, as shown in the screen below.



Category: Date

Sample: ACTUAL_DATE

Type: 3/14/01 1:30 PM

Locale (location): English (U.S.)

Date formats display date and time serial numbers as date values. Date formats that begin with an asterisk (*) respond to changes in regional date and time settings that are specified for the operating system. Formats without an asterisk are not affected by operating system settings.

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation