Development of a Runway Veer-Off Location Distribution Risk Assessment and Reporting Template

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 107

Development of a Runway Veer-Off Location Distribution Risk Assessment Model and Reporting Template

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AIRPORT COOPERATIVE RESEARCH PROGRAM

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Dr. Manuel Ayres, Founding Principal at ASMC, was the Principal Investigator and Project Manager; Dr. Regis Carvalho, Principal Engineer at Dynatest, served as Co-Principal Investigator. The other authors of this report are Mr. Hamid Shirazi (ARA) and Mr. Robert David (RED).

A very important contribution to this study was provided by MITRE Corporation. MITRE made available its comprehensive database of accidents, and it significantly improved the availability of information to develop the risk models presented in this study. Finally, we want to thank Mr. Luiz Eduardo Sousa, airport engineer and former pilot, who was a key consultant to define the criteria used to draw inferences about the veer-off paths from report narratives.

AUTHOR DISCLAIMER

The Lateral Runway Safety Area Risk Analysis (LRSARA) software tool developed as a product of ACRP Project 04-14 is not intended for use in either determining runway safety area (RSA) dimensions or for justifying a modification to FAA design standards. Users are advised to consult the latest version of FAA Advisory Circular 150/5300-13 and to work with the FAA with respect to RSA determinations as appropriate.

The tool should not be used without adequate knowledge of the contents of this report.

Neither ACRP nor ASM Consultants shall be held liable for losses, injuries or damage which may arise from using the LRSARA tool, or be responsible for the accuracy or validity of data generated by the tool.

FOREWORD

By Joseph D. Navarrete
Staff Officer
Transportation Research Board

ACRP Report 107: Development of a Runway Veer-Off Location Distribution Risk Assessment Model and Reporting Template provides airports and their stakeholders with a method to assess the risk of lateral runway excursions, also known as veer-offs, and suggests ways to improve veer-off incident/accident reporting. The culmination of the research is the development of the Lateral Runway Safety Area Risk Analysis (LRSARA) tool that practitioners can use to determine the probability of runway veer-offs in specific areas at their particular airport.

Design standards for runway safety areas (RSAs) are provided in FAA's Advisory Circular 150/5300, *Airport Design*; however, many airports face financial or environmental constraints that limit their ability to meet these standards. While significant research has been done on aircraft runway overruns and undershoots, limited analysis has been done for veer-offs. Additionally, veer-off incident/accident data are limited and of varying quality. Research was therefore needed to develop risk-based models to assist airports and other stakeholders in assessing the relative risks associated with aircraft veer-offs and for developing guidelines for reporting and collecting runway veer-off incident/accident data.

This research, led by Airport Safety Management Consultants under ACRP Project 04-14, began with the development of a preliminary modeling approach in order to identify data requirements. This was followed by collecting data on runway veer-offs from multiple sources. The models were then developed and validated using information from more than 1,100 veer-off events. This led to a series of suggestions to improve veer-off reporting and future risk-based tools.

This report contains eight chapters. Chapter 1 provides a background for the study. Chapter 2 describes the research approach. Chapters 3 and 4 discuss veer-off reporting and data collection, availability, and limitations. Chapters 5 through 7 outline the approach taken to model veer-off risk and to develop and validate the analysis software. Conclusions and suggestions for improved veer-off reporting are provided in Chapter 8. A series of appendices complement the report and software tool, including a template for veer-off reporting, a summary of the data used in the study, and a user guide for the tool.

The LRSARA tool can be downloaded from the CD included with this report or from the Transportation Research Board website (www.trb.org, search for *ACRP Report 107*). Two types of analyses are possible with the tool: simplified and full. The simplified analysis uses default or user-defined values. The full analysis allows users to perform risk assessments based on runway dimensions, obstacles, fleet mix, weather data, field elevation, air temperature, and runway surface condition.

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

Development of a Runway Veer-Off Location Distribution Risk Assessment Model and Reporting Template

In the past, airport design standards have been established based on limited data and a significant amount of engineering judgment. However, in recent years the aviation industry has been challenged by the increased volume of operations and the need for operation of larger aircraft to accommodate more passengers. Many airports are constrained by natural barriers, such as rivers and topography, or by developments around the airport. Expanding runways and increasing the airfield separations are becoming more and more unfeasible to implement from a cost standpoint.

In recent years some ACRP studies have focused on the development of risk-based methodologies to evaluate runway safety areas (RSAs) and airfield separations. These methodologies may be applied when design standards cannot be met by the airport operator to assess the risk associated with a proposed action (e.g., the operation of larger aircraft).

Similar to previous ACRP studies, the basis of this risk-based methodology is a three-part model: probability of veer-off, location of veer-off, and consequences of the veer-off. Two sets of model were developed, one for landing veer-offs and another set for takeoff veer-offs. Improved location models account for both lateral and longitudinal distances in the RSA and are referenced to the runway edge and to the beginning of the runway, respectively. In addition, a new consequence model for veer-off is introduced. This consequence model was integrated to the frequency models developed in previous ACRP research and the new location models developed in this study. The main outcome of the analysis is a tool for the assessment of non-standard RSAs and estimation of the probability of veer-off incidents and risk of accidents involving runway veer-offs.

Data for development of veer-off location models involved accidents and incidents that have occurred over the past 30 years. Most events occurred in the U.S.; however, the data also included events that occurred in countries with accident rates similar to the U.S. Some data required for the development of the models were not available in the reports and it was necessary to either obtain from alternative sources, or to infer from the report narratives, when possible.

Software integrating the models and incorporating user-friendly interfaces for inputting data and outputting results has been developed in a Microsoft Windows platform supported by the commonly used Microsoft Excel and Microsoft Access Office applications.

The models and software tool were validated using independent samples, by comparing historical to estimated accident rates, and evaluating the models with probability distributions generated by an independent sample of veer-off events.

Another important outcome of this study was the identification of information required to develop risk models for veer-off events, as well as some deficiencies in reporting this type of event to obtain the required data. As a result, a template indicating the information that should be collected for veer-off events has been developed. The collection of the identified data for future accidents and incidents will allow the development of improved and more accurate models.

CHAPTER 1

Background

Introduction

Accident statistics show that from 1959 to 2011, 53% of the world's fatal commercial jet aircraft accidents occurred during landing and takeoff. These accidents accounted for 47% of all onboard fatalities (Boeing, 2012). Most of the aircraft accidents that occurred on or in the immediate vicinity of the runway were the result of undershoots, overruns, or veer-offs. The worldwide data for accidents and incidents from 1982 to 2008 collected for the *ACRP Report 50: Improved Models for Risk Assessment of Runway Safety Areas* showed that almost 50% of the events that have involved aircraft in RSAs were lateral runway excursions (veer-offs).

Although in many cases the causal factors involve some type of human error, the conditions at the airport may be an important contributing factor that may affect the severity of the accidents.

In an attempt to mitigate the severity of these accidents, the FAA developed standards for RSAs in the 1960s. The RSA is a graded and obstacle-free, rectangular-shaped area surrounding the runway that is "prepared or suitable for reducing the risk of damage to aircraft in the event of an undershoot, overshoot, or excursion from the runway" (FAA - AC 150/5300-13A, 2012).

By reducing the chance of damage to the aircraft, the RSA also reduces the chances of death or injury to the occupants of an aircraft that is involved in a runway undershoot, overrun, or veer-off. RSAs have resulted in many potentially catastrophic accidents becoming minor incidents. The rectangular dimensions of the RSA are dependent on the type and size of aircraft using the runway.

To meet aviation's continuous growth, airlines are operating larger aircraft with greater seating capacity. However, for many airports, airfield configurations were established many years ago and it is impracticable to meet the current RSA standards that have been established for these larger aircraft. The question arises as to what is the risk if these larger aircraft are allowed to operate in these airports with non-standard RSA dimensions. Currently there are no approved methodologies for assessing these risks and each situation is considered separately.

Another issue that has challenged the aviation industry, particularly airport planners, is how much risk is associated with the presence of certain obstacles inside the RSA. Although most navigational aids (NAVAIDs) are mounted on frangible structures, some of those larger structures may cause damage to aircraft, such as glideslope antennas, runway visual range (RVR) masts, or VHF Omnidirectional Range (VOR) structures. A queue of aircraft waiting for takeoff on a parallel taxiway, rough terrain, drainage structures, and other obstacles may also be present in the vicinity of runways and may represent hazards to aircraft that veer off the runway.

A tool to quantitatively estimate the risk of aircraft veering off runways and assess risk of aircraft operations under specific conditions in a uniform manner will be very beneficial to airport operators and governmental agencies.

The proposed approach is based on *ACRP Report 50* and includes the factors that impact the level of risk for airport operations. This approach also provides a rational probabilistic methodology for the analysis of areas contiguous to the sides of the runway. The approach is based on data collected from accidents and incidents for the past 30 years. The analysis also utilizes historical data from the specific airport being evaluated. This allows the user to take into consideration particular operational conditions to which aircraft are subject to at the airport, as well as the actual RSA conditions in terms of dimensions, configuration, type of terrain, and existing obstacles.

Despite the advances achieved with *ACRP Report 50*, the veer-off models developed for that project have some limitations, particularly in addressing the probability distributions of wreckage location for veer-off events over the length of the runway.

This project further enhances the models described in *ACRP Report 50* by considering adjusted (normalized) location data, as well as veer-off location relative to the beginning of the runway. Such factors were not included within the scope of the previous work.

The location models were integrated into the analysis methodology and software with the capability of assessing RSA lateral areas, the areas contiguous to the longitudinal sides of the runway. The analysis was validated and took into consideration the RSA boundaries and existing obstacles within the existing or proposed RSA.

This report summarizes the tasks, results, conclusions, and recommendations for the entire study. In addition, a software tool is included that may be utilized by the industry to assess risk associated with the lateral portions of the RSA.

Project Objectives

This project was aimed at identifying the subareas of the RSA where runway veer-offs are most likely to occur and develop quantitative analysis capability to evaluate the risk of runway veer-offs. Three goals were set to achieve this objective:

- Identify the probability of an aircraft that veers off the runway traversing various areas that are contiguous to the sides of the runway and determine how obstacles located within these areas may impact risk.
- Develop quantitative analysis capability and software tool to evaluate the risk of runway veer-offs and the probability distribution of veer-off locations in the vicinity of the runway.
- Identify deficiencies in data availability to characterize the location distributions and make suggestions for future improvements to the models developed in this study.

CHAPTER 2

Research Approach

The research project included 10 tasks that were divided into two phases, as shown in Figure 1. In Phase 1, the initial task was to develop a preliminary modeling approach to identify which data would be required for developing the location models. Following this initial task, accident and incident reports from various databases were identified as runway veer-offs. Required versus available data was compared. Alternative sources and approaches were used to obtain required data, or to support the inferences made based on report narratives. For many of the veer-off events included in the study, the inferences drawn from the report narratives and supporting data allowed the path of aircraft involved in the veer-off to be determined.

With reports of 1,144 veer-off events that occurred in the U.S. and elsewhere, the available information about the airport, runway used, flight (e.g., type of aircraft involved), weather conditions, runway surface conditions, and causes of damage to aircraft was stored in a database designed for this study. Veer-off paths were represented using two linear segments and were also saved in the database.

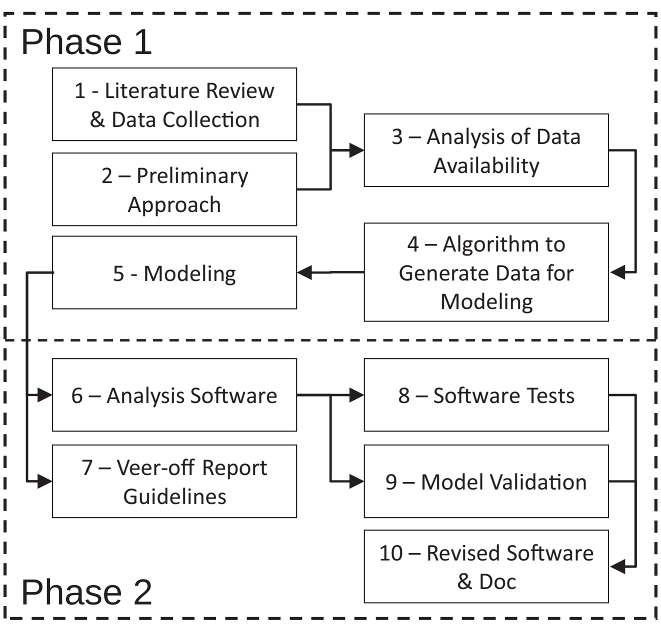

Figure 1. Project tasks.

The runway distance available was divided into ten segments or subareas for each normalization process used and described in ensuing chapters. An algorithm was developed in MS Excel to calculate, for each veer-off event, the lateral distances in each subarea of the runway. The automation was essential to obtain information and build the probability distributions for longitudinal and lateral distances for each normalization process investigated in this study. The process and the algorithm generated the data required for development of veer-off location models.

For the modeling, probability distributions were derived from data generated in the previous step and mathematical models were developed to represent those probability distributions in the longitudinal and lateral directions. One lateral location model was developed for each segment/subarea of the runway.

In Phase 2, a new algorithm was developed with the models and incorporated into analysis software that includes an interface for inputting information, a module incorporating the approach and models for analysis, and an interface for outputting results in report format. The tool was tested under various analysis scenarios.

A series of validation efforts were carried out to ensure the robustness of the new analysis tool and to check if results were rational and consistent with historical evidence of veer-off accidents and incidents. An independent sample of events not used for modeling was used to compare the models with the probability distributions for longitudinal and lateral distances generated with the sample.

Guidance for improving veer-off reporting was then developed from the lessons learned from previous tasks, particularly emphasizing the importance of recording information on the aircraft path during the veer-off.

CHAPTER 3

Veer-Off Reporting and Data Collection

As noted earlier, the basis for developing veer-off location models was information obtained from aircraft accident and incident reports available from several databases in the U.S. and countries with aviation accident rates comparable to those verified in the U.S.

The most important information collected was the characterization of the aircraft path during the runway veer-off. The pathway information was essential to develop the probability distributions associated with the longitudinal and lateral deviations when the plane was off the runway. This chapter presents the sources and type of information collected for the development of risk models.

Data Required for Modeling Veer-Off Distances

Previous mathematical models developed in the U.S. and elsewhere to characterize the probability of an aircraft deviating a certain distance from the runway during the veer-off have used either the final location of the aircraft or the largest deviation during the runway excursion.

The basic approach in this effort was to describe the aircraft veer-off path and use this information to characterize the subareas contiguous to the runway and that were challenged by the veer-off rather than using a single location. The proposed approach is a significant improvement to veer-off modeling. It required an in-depth evaluation of report narratives to obtain the aircraft travel path for as many events as possible. More importantly, this approach also helped to characterize the probability distribution of the subareas over the length of the runway.

The veer-off path of the aircraft and its stopping location depend on several factors that can be divided into the following categories:

- Location where the aircraft departed the runway;
- Speed of aircraft when leaving the runway;
- Runway surface conditions (e.g., dry, wet, contaminated, etc.);
- RSA surface conditions;
- Presence of obstacles (e.g., NAVAIDs, ditches, uneven terrain, snow banks);
- Condition of landing gear (e.g., retracted, partially collapsed);
- Aircraft direction during the veer-off (e.g., straight, sideways, ground looped);
- Bearing capacity of RSA terrain during the incident; and
- Pilot role in contributing to the event or in attempting to avoid it.

A combination of factors is usually present in all events making it very difficult to accurately model these events. In particular, human factors are extremely complex to model. For this reason, this study did not focus on the causal factors of the particular veer-off. Rather, the focus was placed on identifying evidence to characterize the chances that an aircraft veering off the runway will travel over certain subareas of the RSA. The data obtained on aircraft veer-off paths from actual veer-off accidents and incidents were used to characterize the probability distribution of the aircraft veer-off path occurring in segments of the RSA.

The aircraft veer-off path usually cannot be completely characterized from the data provided in the accident/incident report. The investigation reports do not always provide specific location references. Some reports may provide the excursion pathway in a diagram or a picture, while others do not. It was necessary to make assumptions and make inferences based on information contained in the narrative of the report when possible. For example, average aircraft deceleration and narrative of the aircraft speed when going off the runway helped identify the subarea in which the plane may have departed the runway.

As expected, the information required to depict the actual wreckage path was rarely available. For this reason, report narratives were reviewed and interpreted. All available references, including historical satellite pictures, were used to infer the approximate veer-off path of the aircraft.

Location References Used

Longitudinal Distances

Longitudinal distances were measured from the runway threshold for landing and from the beginning of the takeoff roll for takeoff operations. These two points normally coincide except for cases in which the threshold may be displaced. In a few cases the aircraft started its takeoff roll from an existing taxiway intersection other than at the beginning of the runway and in these cases the distance was measured from the taxiway intersection with the runway.

Lateral Distances

The reference for measuring the lateral distances is the side edge of the runway. Justification to use the edge instead of the runway axis is presented below.

Why Aren't Lateral Deviations Measured from the Centerline?

Another reference alternative evaluated for measuring lateral distances was the runway centerline; however, there were no data on aircraft wander that could be used to characterize the probability distribution both on the runway area and in the RSA. Moreover there is another important justification to use the runway edge, rather than the runway centerline.

It is important to note that the runway and the RSA may have very different types of surface and that the transition between the two areas may have a discontinuity in the pavement. Because aircraft control and braking can be significantly different whether the aircraft is moving on the runway paved surface or outside on the unpaved RSA, it is fair to assume that the probability distribution characterizing aircraft wander on the runway should not be extrapolated to outside the paved area.

Therefore, as illustrated in Figure 2, there may be two very different probability distributions for the characterization of lateral distances, one covering the runway paved area, and another covering the RSA. In Figure 2, one of the distributions may be used to characterize aircraft wander during normal operations. The flat curve represents the probability distribution if the aircraft departs the runway paved area. Even if there is a paved shoulder area, it may have a small drop and most importantly, it is the area where runway lights are installed and in many cases struck by aircraft veering off the runway.

In summary, a probability distribution to represent aircraft wander with distances measured from the runway centerline would incorporate an error due to the aircraft response on two different types of surface, on and off the runway. In addition, the purpose of this study is to model veer-offs and it is not necessary to model aircraft deviations in the paved area of the runway. Therefore, the edge of the runway was selected to measure lateral deviations during the lateral runway excursions.

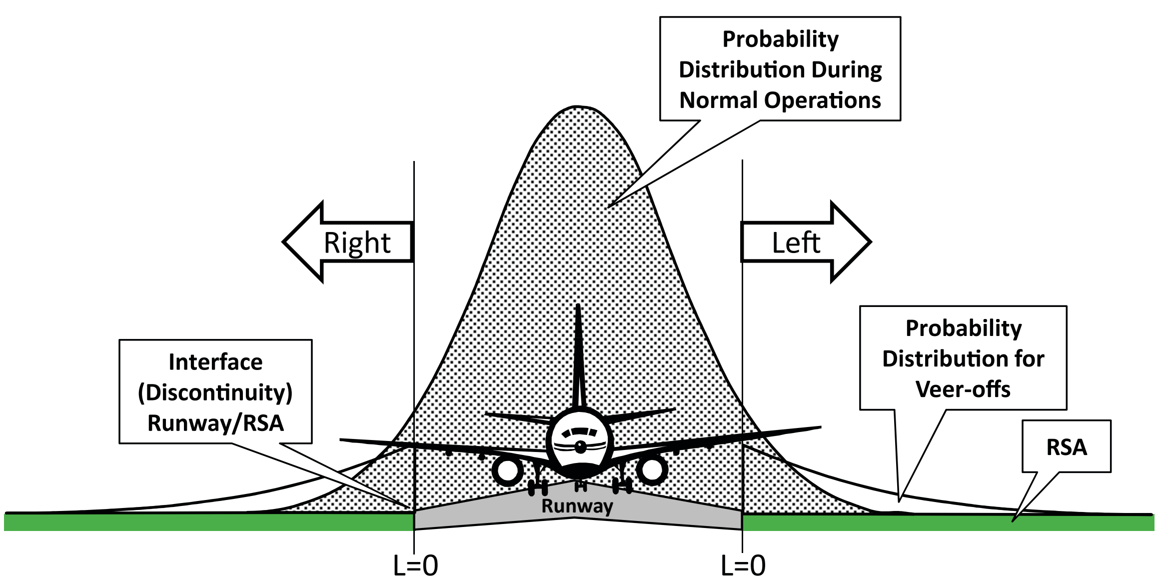

Figure 2. Use of runway edge to measure lateral distances (L = deviation from runway edge).

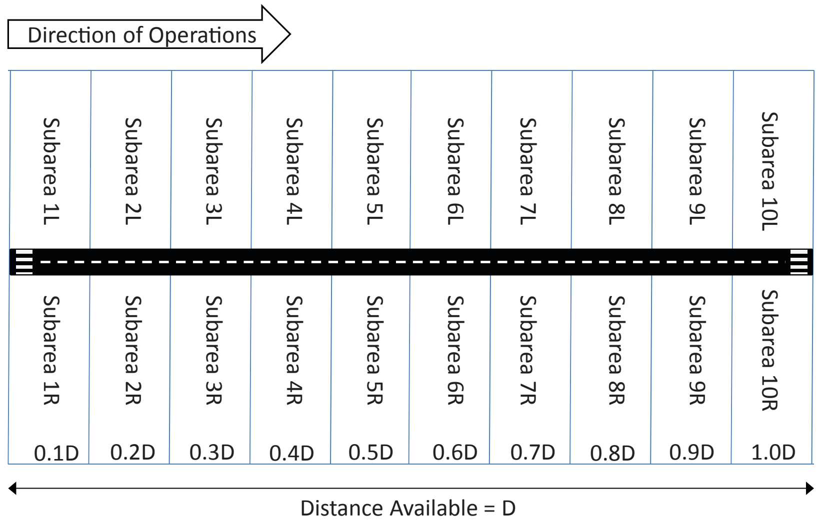

Figure 3. Subsections of the RSA – example for normalization with runway distance available.

In addition, the runway distance available was divided into 20 subsections, 10 on each runway side, as shown in Figure 3. The length of each subsection varied according to the normalization procedure used for measuring longitudinal distances, as explained later in Chapter 5. The procedure was necessary to characterize the lateral probability distributions for each subsection evaluated and obtain the probability distribution for the entire runway.

Aviation Accident and Incident Databases

Veer-off data was collected from several databases in the U.S. and abroad; however, close to 90% of the information was retrieved from U.S. sources, particularly from the databases managed by the NTSB, FAA and NASA. International databases managed by accident investigation bureaus of ten different countries were also sources of information for major incidents and accidents. These countries have aviation accident rates similar to that of the U.S. The following is a list of the databases from which data were collected:

- National Transportation Safety Board (NTSB)—Aviation Database,
- Federal Aviation Administration (FAA) Accident/Incident Data System (AIDS),
- FAA/NASA Aviation Safety Reporting System (ASRS),
- Transportation Safety Board of Canada (TSBC)—Aviation Investigation Reports,
- Australian Transport Safety Bureau (ATSB)—Aviation Safety Investigations and Reports,
- France Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA)—Rapports d'Enquête,
- UK Air Accidents Investigation Branch (AAIB) - Publications and Search Reports,
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- Air Accident Investigation Bureau of Singapore (AAIBS)—Reports Available,
- Ireland Air Accident Investigation Unit (AAIU)—Investigation Reports,
- Spain Comisión de Investigación de Accidentes e Incidentes de Aviación Civil (CIAIAC)—Investigación,
- South African Civil Aviation Authority (SACAA)—Accidents and Incidents, and
- Dutch Safety Board (DSB)—Investigation and Publication.

Additional information about these databases is provided in Chapter 4.

Database Statistics

Veer-off records were identified from various sources and information was collected to develop the location probability models in this study. Records were consolidated, duplicate records were removed and, even during the modeling process, additional data to fill the gaps were collected, when possible.

A summary of data used for modeling is provided below:

- Period: 1982 to 2011;
- A total of 1,144 veer-off records were identified in the databases: 345 veer-off accidents and 799 veer-off incidents;
- 901 veer-offs occurred during landing and 243 veer-offs during takeoffs;
- There were 1,072 records from U.S. databases (NTSB, AIDS, and ASRS) and 72 records from 10 international databases; and
- There were 577 records with sufficient information to characterize or infer the veer-off path.

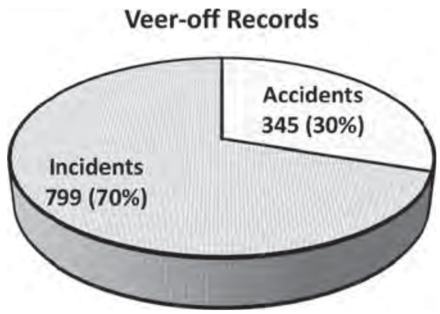


Figure 4. Veer-off accident and incident records from 1982 to 2011.

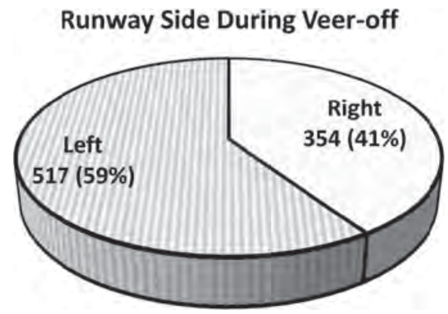


Figure 6. Veer-off records from 1982 to 2011—runway side.

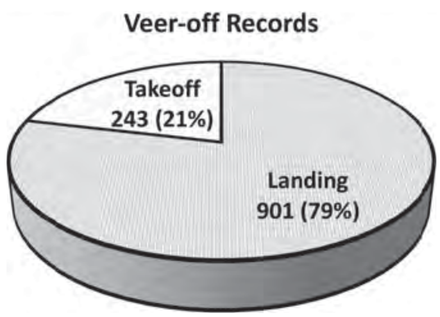


Figure 5. Veer-off records from 1982 to 2011—type of operation.

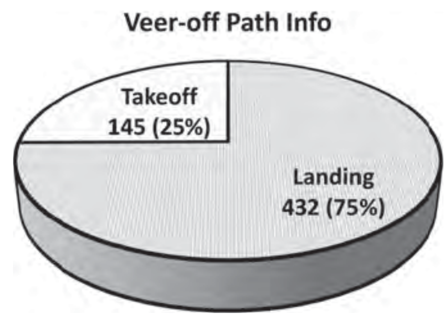


Figure 7. Records with information on veer-off path.

Figures 4 through 7 provide a summary of veer-off categories for the records identified by the research team. Please note that the total number of records for a certain category depends on whether the information was available for the record. For example, the total number of records with veer-off path information is 577, which represents approximately 50% of the total number of events identified and included in the accident/incident database.

As seen in Figure 6, most veer-offs occurred on the left side of the runway. A hypothesis test indicated that the difference between left and right is statistically significant.

CHAPTER 4

Availability of Data for Modeling Veer-Off Risk

The ultimate objective of this project was to characterize the risk of aircraft veer-off within segments or subareas of the RSA, and areas outside of, but contiguous to the RSA. To achieve these goals, it was necessary to develop risk models based on information collected from accident and incident reports. One of the main concerns during the planning for this study was the availability of information required for modeling veer-off risk, particularly data related to the characterization of longitudinal and lateral distances relative to the runway.

The analysis of data availability involved a few steps. Initially, it was necessary to develop a general modeling approach to identify what type of data would be required. Following, it was necessary to review accident and incident records screened as veer-offs to identify major gaps in data availability/usability.

With the analysis, alternative sources of information were evaluated to close the gaps by either extracting information from these alternative sources, or using it to support inferences based on each report narrative, particularly to characterize the veer-off pathway. Even using this approach, approximately 50% of the records were not used for modeling lateral and longitudinal distances during the veer-off, both because the information was not presented in the report and the narrative did not allow inferences on the veer-off pathway to be made.

It is recognized that these inferences may have some impact on the accuracy of the models developed; however, the study has resulted in the development of an analysis methodology available to the aviation industry that is a vast improvement over current status. The research has brought to light the identification of key information that is needed to develop the models and, moreover, to identify the deficiencies that exist in reporting key data. Collection of this data for future veer-offs enhances the accuracy of the models developed in this study.

In addition, as part of this project, guidance is provided for improving reporting procedures. This chapter describes the major gaps in data availability and describes additional sources of information used to characterize or infer the veer-off pathway and other parameters.

U.S. Databases

Three federal databases currently contain information to various degrees on runway veer-offs that have occurred at airports within the United States. Each of these databases is discussed in this section.

NTSB

The NTSB is the federal agency charged with investigating aircraft accidents and determining probable and contributing causes. As such, the NTSB can do an onsite investigation of any aircraft accident or incident it chooses. In reality, budget and staffing limitations result in the NTSB generally choosing to do onsite investigations of accidents/incidents that they believe will have the most impact on improving aviation safety.

If an aircraft veer-off results in an air carrier accident involving substantial damage to the aircraft and/or fatalities/serious injuries to the occupants, the NTSB will normally send a team to the site and conduct a major investigation to determine the probable causes and contributing factors of the accident. An RSA that does not meet the FAA standards may be cited as a contributing factor to the accident. The final resting place of the aircraft relative to the runway will usually be documented, along with any of the non-standard aspects of the safety area that contributed to the accident. The location at which the aircraft left the runway and the path that aircraft traveled off the runway may or may not be documented.

If an event involves an air carrier incident, the NTSB may or may not send an investigator to the site. For an event involving a general aviation aircraft with fatalities, the NTSB will probably send an investigator; however, site visits would likely not occur for non-fatal general aviation accidents and general aviation incidents.

The data collected onsite by the NTSB or received from other organizations, such as the FAA, is entered into the NTSB database. Although some incidents are reported in this database, most of the records available involve accidents and are used to support the NTSB's determination of probable causes and contributing factors.

FAA AIDS

The FAA is also charged with investigating aircraft accidents in conjunction with the NTSB. However, the FAA does not have the authority to determine probable causes. The FAA will make site visits to any accidents that the NTSB visits; however, the FAA may also make site visits to many of the accidents and incidents the NTSB does not. In these cases, the NTSB will use the information gathered by the FAA in determining probable causes.

The information gathered by the FAA is used to populate the AIDS database, which is primarily collected by FAA personnel having a pilot, airworthiness, or flight procedures background. Most of the information collected by them is related to these areas. The information may also be used by the NTSB to populate its database.

Although the FAA is a larger organization and more geographically dispersed than the NTSB, there are still a large number of accidents/incidents that do not result in an onsite visit from either organization. In these cases, the NTSB and FAA may conduct a desk investigation during which they gather information through telephone calls, e-mail, and written correspondence. This information may be provided by parties such as pilots, controllers, airport officials, state aviation agency employees, and local/state police investigators.

Most of the incidents in the AIDS database do not contain explicit information on veer-offs that would be desirable for this study, particularly the veer-off path. In some cases, it is possible to infer some of the necessary information from the write-up (e.g., aircraft came to a stop about 50 feet from the runway just short of Taxiway Bravo). More explicit information on where the aircraft exited the runway, the aircraft veer-off path, and final resting place would be extremely helpful for the development of risk models.

FAA/NASA ASRS

NASA administers the ASRS, which is funded by the FAA. Although submitted reports primarily come from pilots and controllers, anyone can report an unsafe condition, incident, procedure, practice, or safety concern through the ASRS. The reporter is assured that he or she will remain anonymous. Also, pilots receive immunity if they report an inadvertent violation to the regulations.

The intent of this reporting system is to identify deficiencies and discrepancies that can be corrected before they become accidents. The report narrative is made in a free flowing prose style. The information contained in each report will vary depending upon the reporter. The report represents the reporter's perspective of what occurred. It is not independently validated by anyone, which would be very difficult to do so since the identifying information has been parsed from the report.

International Databases

International databases are obtained from the aviation accident investigation bureau of the country where the accident occurred. The information is particularly comprehensive for major accidents and the availability is similar to that provided by NTSB when the full accident investigation report is available. Data from international databases made up less than 10% of the veer-off records used in this study.

Why Should Data Collection Be Improved?

Over the years, the FAA has reviewed accidents and incidents involving undershoots, veer-offs, and overruns for commercial aircraft and found that approximately 90 percent of them come to rest within the prescribed safety area (FAA, 1990). However, the question has never been addressed as to how much risk is involved if a full safety area cannot be obtained for a runway. For example, if a safety area should extend to 250 feet on either side of the runway centerline but on one side, it is cost prohibitive to obtain more than 200 feet of RSA, what is the risk implication if the safety area is narrowed on one side?

In this situation the 90 percent figure that the FAA cites addresses the entire safety area and here (in the case of the narrower safety area on one side) only one small section is being considered. The models and the analysis approach developed under this ACRP effort allow one to assess the risk for this situation. However, the results and accuracy of the models would improve if additional data were included from actual veer-off events. At some airports, achieving the standard safety area may require the expenditure of large sums of money and may result in very little reduction in risk. Better data would allow one to more confidently assess the risk associated with the modified safety area to determine if the investment to meet the standard is worth the benefit in terms of improved level of safety.

Potential Improvements to Veer-Off Reporting

The intent of this study is not to identify deficiencies or to criticize the procedures used by agencies that manage civil aviation accident and incident databases. However, some conclusions derived from this study have allowed the identification of potential improvements in data collection that may, in the future, enhance the accuracy of veer-off risk models developed in this research.

Most of the improvements that may be achieved are associated with including information to characterize the veer-off path during the runway excursion. The following paragraphs describe each of the three U.S. databases (NTSB, AIDS and ASRS) and the desirable improvements to reporting aircraft veer-off events.

NTSB

As mentioned earlier, characterization of the veer-off path is not available in many investigation reports from NTSB. Pictures and sketches showing the path would certainly help to characterize the veer-off path and support development of risk models. In most cases, when veer-off location information is available, it is descriptive and included in the section describing the wreckage of the accident.

In other cases, an investigator may not visit the site and little information is collected. For such cases, the pilot or the airport operator may be able to help the NTSB investigator by providing a sketch, pictures, and/or a narrative describing the veer-off path and touchdown location, if the veer-off occurred during landing.

With the availability of accident dockets online for events occurring after 1996, sometimes it is possible to find additional information on veer-off path in documents other than the investigation report, particularly for major accidents.

Although comprehensive information on weather conditions is not available for many events involving non-fatal accidents and incidents, it is possible to retrieve METARs when location, date and time are reported.

FAA AIDS

Veer-off reporting in the AIDS database can be significantly improved. Although the reports are very objective, details on the veer-off path through the narrative are seldom provided.

Local time of the incident isn't available in many reports; however, this data is very important because it allows the weather conditions under which the incident took place to be identified through the associated METAR for the airport at the date and time of the event.

Another important parameter that is rarely reported is the approximate touchdown location for landing veer-offs. This information is most likely obtained from the pilots of the aircraft involved in the incident. Moreover, few reports contain information on runway surface conditions, which may be used to estimate the distance required for the operation.

NASA/FAA ASRS

ASRS database reports have information only on the month and year that the event occurred. Moreover, the reports only contain the 6-hour interval when the veer-off took place and it may be difficult to relate weather conditions to the event, if not included in the report.

Another difficulty with ASRS database is that the information on the runway used may not be available. In this case it is not possible to assess the runway distance available for the operation or to associate wind direction and wind components during the operation.

The aircraft veer-off path during the runway excursion is not available for most of the reports; however, it is sometimes possible to infer from the narrative, particularly if it provides information on aircraft speed and location references (e.g., aircraft departed runway 200 ft from Taxiway D intersection).

What Data Needs to Be Collected?

In this section, the data that ideally should be collected are identified. Two categories of data can be characterized according to the need and availability from alternative sources. The first category of information entails data that is essential for developing and improving risk-based approaches and risk models for aircraft veer-off events. The second category involves data that can be helpful to improve models; however, this type of data may be obtained from alternative sources, if necessary.

For example, in some cases weather conditions may not be reported, but this information can be obtained from METARs if the airport, the date, and time of the event are reported. Key information with no alternative sources (e.g., the characterization of the veer-off path) is considered essential data for reporting purposes. Some of this information is already collected as part of the accident investigation (e.g., runway identification) but is not always explicitly included in the accident documentation. Knowing the runway designation allows one to use other databases to find other parameters, such as the runway length and wind components.

A template for reporting veer-offs was created and is included in Appendix A. The purpose of the template is to identify key information for reporting veer-off events and describe the distances that may be used to characterize the aircraft path during the runway excursion. Figures have been included in Appendix A to illustrate the measurements needed to document the travel path of the aircraft from where it leaves the runway to where it stops or reenters the runway.

The measurement of the various distances should be as accurate as possible but by no means is the accuracy obtained by a surveyor expected. If engineering plans of the airport layout are available, it may be possible to make the field measurement from a known point and then add or subtract the distance to that point found on the engineering drawing. For example, "aircraft left the runway pavement, 150 feet beyond the north edge of the Taxiway Sierra intersection with the runway." The 150 feet measured in the field would be added to the distance from the beginning of the runway to the north edge of Taxiway Sierra that is measured on the engineering drawing. Although not required, a sketch of the veer-off path is always very helpful.

The purpose is to require the minimum data to avoid, as much as possible, overwhelming the investigator or reporter with inputting information that may be optional. For all veer-offs, it is important from a risk analysis perspective to document the aircraft travel path from where it departs the runway to where it comes to a stop. The figures presented in Appendix A depict the various types of veer-off travel paths.

Essential Data

- Aircraft model (e.g., B737-400).
- Airport code (e.g., DVT).
- Date and time of event.
- Runway used (e.g., 27R).
- Type of operation (landing or takeoff).
- Runway surface condition: dry, wet, contaminated with water, ice, slush, snow, or other.
- Begin roll location:
  - Longitudinal distance for begin roll (*DBR*):
    - Landing: approximate touchdown location measured from the beginning of the runway.
    - Takeoff: only if different from the beginning of the runway (always measured from beginning of runway).
  - Lateral distance for beginning roll (*LBR*): distance from runway edge, only if touchdown occurred off the runway.
- Veer-off path:
  - Longitudinal distance from the beginning of the runway where the first wheel of the aircraft departed the runway and runway side (*DExit*).
  - Longitudinal distance from the beginning of the runway where maximum veer-off occurred (*DMax*).
  - Lateral distance from runway edge (not pavement edge) where the maximum veer-off occurred (*LMax*).
  - Longitudinal distance from the beginning of the runway where aircraft stopped or reentered the runway after veering off (*DStop*).
  - Lateral distance from runway edge where aircraft stopped (*LStop*). Use zero if aircraft reentered runway.
- Runway side: right or left relative to direction of operation.
- Cause(s) of aircraft damage, if any.

The distances defined above are applicable to the aircraft path during the veer-off only. If an aircraft crossed the RSA and entered a taxiway, the stop location should be assumed to be the point where the aircraft entered the taxiway before initiating normal taxiing operation. *All distances are measured to the center of the main gears of the aircraft.*

The template in Appendix A contains figures to illustrate the veer-off distances that will ideally be reported. These figures depict four different veer-off scenarios that are shown as either a left or a right veer-off.

Supporting Data

In addition to the essential information described in the previous section, it is always beneficial to include the following data in the report for sake of accuracy:

- Runway distance available for the operation.
- Runway distance required for the operation.
- Weather conditions (temperature, ceiling, visibility, wind speed and direction, gusts, type of precipitation), if any.
- Was runway grooved? Yes or No.
- RRSA conditions at time of the veer-off: dry, wet, snow, soft terrain, rough terrain.

Implementation of Veer-Off Data Collection Procedures

One of the main problems with attempting to collect accurate data for future runway veer-offs is that in many cases a representative from the NTSB or the FAA may never do an on-site investigation. This is especially true for veer-off incidents with minor consequences—in these cases, the RSA with its graded slopes and cleared areas have prevented the aircraft from incurring substantial damage and the aircraft occupants have not been seriously injured. From an accident-prevention perspective there is not much to be gained by sending someone to conduct an on-site investigation, especially during times when budgets are limited.

The reason for collecting additional information such as aircraft veer-off path is for the purpose of risk analysis. As mentioned earlier, the FAA is moving toward a risk-based decision-making processes; however, with the exception of funding, some ACRP studies like this one, the available tools for the industry are still very limited.

The prime beneficiary of collecting information on future veer-offs to support risk assessments would be the airport operator who either cannot obtain the full safety area or perhaps needs to modify the current safety area for one reason or another. The airport operator generally has an employee that has access to the airfield after a veer-off occurs, either on duty or subject to call back. Consequently, the cost and time of traveling to the airport that other parties would incur would be minimized if an airport employee takes the measurements and collects the information described in this report.

A simple self-administered, computer-based training program to explain the data that needs to be collected for the various types of veer-offs and how it will be used may be the tool to implement data collection. Also, a standardized data collection form or the template shown in Appendix A could be used by airport operators. In establishing a program for this type of data collection, it would be essential to coordinate this data collection approach at the national level with NTSB, FAA and NASA, so the data may be saved in their respective accident and incident databases.

The main question with this type of approach would be what happens to the data once it is collected. If NTSB and FAA were agreeable, it could be sent to them for incorporation into their databases. ASRS information may be entered directly in the narrative of the incident by the reporter. Since NTSB's database primarily consists of accidents, they may be reluctant to include so many incidents where the only entries would be information from the airport operator's effort. The FAA would have to either modify the AIDS database to accommodate this data in a uniform fashion or establish a new database, which may represent a major challenge.

Alternative Sources of Information

The explicit data contained in accident and incident reports for veer-offs rarely provided all the information necessary to develop risk models. In many cases it was possible to infer some of the missing information from the report narratives. Often, information on weather conditions during the incident, if not included in the narrative, was obtained from historical METARs for the specific location, date, and closest time of the event.

In ASRS reports, the airport where the event occurred may not be reported and the specific day and time are never reported. If the airport was identified, the mean temperature during the specific month for the time period of the accident was used. The temperature is an important factor needed to adjust the required runway distance for the operation.

Runway distances during an incident are seldom disclosed. Only the total runway length is normally available, even for NTSB reports. Historical satellite pictures from Google Earth can be used to measure the landing distance available (LDA) or the accelerate-stop distance available (ASDA). Although the information is available for existing conditions at websites like Airnav.com, runway extensions or reductions may have changed the available distances at the time of the incident.

In some reports, the narrative describes airfield components and structures such as taxiways, hangars, ditches, markers, etc. Identification of specific taxiways was obtained from airport diagrams available at airnav.com. Satellite images were used to identify the location distances associated with these structures.

In addition to the official websites with access to accident and incident reports, alternative databases were used to help screen relevant records and to check information inferred from the report narratives. The main sources used were:

- Aircraft Owners and Pilots Association (AOPA) Air Safety Institute Accident Database, and
- MITRE Corp. Aviation Accident Database.

In summary, other sources of information to complement missing data are presented in Table 1.

Appendix B of this report presents a summary of veer-off records screened from the listed sources.

Summary of Data Available/Usable

Table 2 summarizes the data available and usable obtained for this research. The first and second columns list the database source and the number of veer-off events screened that are relevant to this study. The following columns contain the number of events that contained some level of information, or none, to characterize the veer-off path of the aircraft during the veer-off.

Assumptions Made

As indicated in Table 1, comprehensive information required to characterize the veer-off path is seldom explicitly available in accident and incident reports, except for major accidents when a full investigation report was prepared.

To overcome this shortcoming, the research team made inferences and assumptions based on the narratives provided and used the additional data sources listed in previous sections. Although some accuracy was lost due to the assumptions made, the information developed in this study will assist the industry in understanding the mechanisms and the relationship between risk, available safety areas, and the presence of obstacles associated with aircraft veer-off accidents and incidents.

The approach will certainly improve knowledge of the relationship between airfield design standards and the risk level involved when standards cannot be met. When necessary, some assumptions were adopted, particularly to estimate the pathway during the runway excursion. In many cases, it was necessary to use the narrative to infer the phase of the roll-out at which the veer-off occurred.

When information required was not available in the report narrative, the procedures presented in Table 3 were used to obtain the data.

In some cases, based on the aircraft speed reported and type of aircraft, the distance from the beginning of the

Table 1. Complementary sources of information for modeling.

Source	Type of Information Retrieved
Google Earth www.googleearth.com	Historical satellite pictures, measurement of distances, and terrain profiles
Weather Underground www.wunderground.com	Historical METARs to complement weather conditions during the accident/incident
Airnav airnav.com	Information on runway slope, airport diagrams, airport identifier for U.S. airports
Landings www.landings.com	Information on world's airports
FAA Aircraft Characteristics Database www.faa.gov/airports/engineering/aircraft_char_database/	Aircraft data
Eurocontrol Aircraft Performance Database V2.0 elearning.ians.lu/aircraftperformance	Aircraft performance
AOPA Air Safety Institute Accident Database http://www.aopa.org/asf/ntsb/search_ntsb.cfm	Screening NTSB records for smaller general aviation (GA) aircraft
MITRE Corporation Accident Database Microsoft Access database file	Comprehensive information screened from U.S. accident records (NTSB and FAA AIDS)

runway was inferred based on average acceleration and deceleration under the runway conditions reported. Other information and references available in the narrative, such as runway markers, taxiways, and other structures (e.g., ditches, hangars) were identified in satellite pictures to infer the distances.

In most cases, the runway declared distances are not reported in the accident reports. Current web sources only provide existing declared distances. Historical satellite images were used to measure the declared distance for the operation at the time of the event. Distance measurements when using Google Earth are quite accurate for the purpose of this study.

Table 2. Summary of data available and usable.

Source	Total Number of Events	Complete Veer-Off Pathway Available		Partial Veer-Off Pathway Available	No Veer-Off Pathway Available
		Actual	Estimates	Actual or Estimate	
NTSB	283	77	94	66	46
AIDS	545	8	38	75	424
ASRS	243	0	142	14	87
AAIB	21	3	9	5	4
SACAA	5	0	2	0	3
ATSB	7	1	2	2	2
TSBC	18	9	5	3	1
BEA	8	8	0	0	0
TAIC	1	1	0	0	0
AAIBS	2	2	0	0	0
AAIU	4	2	2	0	0
CIAIAC	4	0	3	1	0
DSB	3	2	0	1	0
TOTAL	**1144**	**113**	**297**	**167**	**567**

Table 3. Procedures to obtain missing data.

Information Available	Temperature	Wind (Speed and Direction)
Airport, date and time	Historical METAR information for time of event	Historical METAR information for time of event
Only date and time (no identification of airport)	No assumption was made	No assumption was made
Airport and date (no time)	Average air temperature at the airport for the date	Wind speed equal to zero if indicated that weather was not a factor
Airport and month, with time range (ASRS reports)	Average monthly temperature for the time range	Assumed zero wind if weather was not a factor. In a few cases, the day of the month was identified based on specific weather conditions reported in narrative (e.g., strong gusts, precipitations, etc.) and time range reported
Airport and month, but no information on runway used	Average monthly temperature for the time range	Assumed zero wind if weather was not a factor

CHAPTER 5

Modeling Veer-Off Risk

General Approach

Enhanced lateral runway excursion risk location models that reflect how RSA configuration and the presence of obstacles or unprepared terrain may impact veer-off risk are presented in this chapter. The enhanced location models are integrated to a three-part modeling approach. Event probability, location probability, and veer-off consequence are shown in Figure 8. This is similar to the approaches used under previous ACRP studies in this area.

The first component is the Event Probability (Frequency Model). The likelihood of an aircraft veer-off incident depends on the operation conditions, including airport characteristics, weather conditions, and aircraft performance. This also includes the interaction between the runway distance required by the aircraft for the given conditions and the runway distance available at the airport.

The probability of an accident is not equal for all locations around the runway. The probability of a veer-off close to the edge of the runway is higher than at larger distances from the runway edge. Also, the probability may be different over the length of the runway. This dependence is represented by the Location Probability Model, which is the second main element of the current methodology. Its development was one of the key goals of this study.

The last component is the Veer-Off Consequence Model. The basic approach uses the location models to assess the probability that an aircraft strikes an obstacle in the vicinity of the runway or departs the RSA leading to an accident.

Each of these three components is discussed in greater detail in the ensuing sections of this chapter.

Event Probability

The annual probability of an aircraft veer-off accident depends on the probability of an accident per aircraft movement and the number of movements (landings and takeoffs) carried out per year. This probability may be different for each operation at the airport because the conditions may change. To estimate the probability of an accident per movement at any specific airport, a sample of historical data for operations, including aircraft, flight, and weather data is applied to the probability model.

During the landing, after touchdown, or during the takeoff roll, the pilot may lose directional control. Some common causes and contributing factors include low runway friction, snow accumulation on the runway, mechanical failures, adverse weather conditions, and pilot deviations.

The basis of the approach used to model frequency in this study is presented in *ACRP Report 50* and *ACRP Report 51*. The likelihood of an aircraft veer-off incident depends on the operational conditions and human factors. It includes airport characteristics, weather conditions, and the aircraft performance, as well as the relationship between the runway distance required by the aircraft for the given conditions and the runway distance available at the airport.

The basic model structure is:

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

where

- $P\{Accident\_Occurrence\}$ is the probability (0–100%) of an accident type occurring given certain operational conditions;
- X_i are independent variables (e.g., ceiling, visibility, crosswind, precipitation, aircraft type); and
- b_i are regression coefficients.

One of the parameters is named runway criticality and represents the interaction between the runway distance required by the aircraft and the runway distance available at the airport. The distance required is a function of the aircraft performance under specific conditions. Therefore,

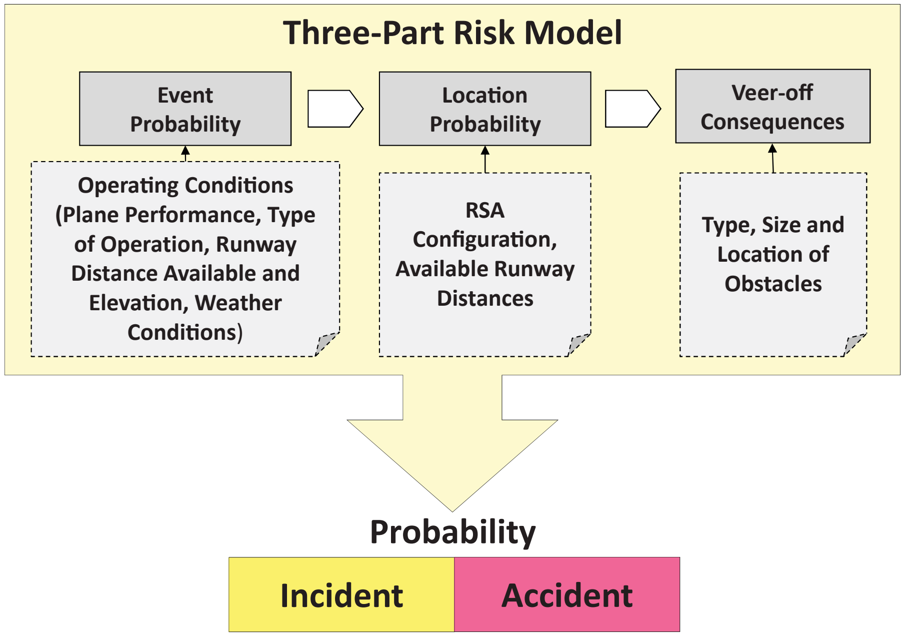


Figure 8. Risk modeling approach (adapted from* ACRP Report 50*).

every distance required under International Organization for Standardization (ISO) conditions (sea level, 15 degrees centigrade) is converted to actual conditions for operations. Moreover, the distances are adjusted for the runway surface condition (wet, snow, slush, or ice) and for the level of head/tailwind. The adjustment factors for runway surface condition are those recommended by the Flight Safety Foundation (FSF, 2009). Table 4 presents the factors applied to the distance required by the aircraft.

Parameters X_i are defined in Table 5, which summarizes the model coefficients obtained for each veer-off frequency model.

Table 4. Correction factors applied to runway distance required.

Local Factor	Unit	Reference	Adjustment
Elevation (E)[i]	1000 ft	E = 0 ft (sea level)	F_E = 0.07 x E + 1
Temperature (T)[i]	deg C	T = 15 deg C	F_T = 0.01 x (T – (15 – 1.981 E) + 1
Tailwind for Jets(TWLDJ)[iii]	knot	TWLDJ = 0 knot	F_{TWJ} = (RD + 22 x TWLDJ)/RD[ii]
Tailwind for Turboprops(TWLDT)[iii]	knot	TWLDT = 0 knot	F_{TWJ} = (RD + 30 x TWLDT)/RD
Headwind for Jets(HWTOJ)[iii]	knot	HWTOJ = 0 knot	F_{TWJ} = (RD + 6 x HWTOJ)/RD
Headwind (HWTOT) for Turboprops[iii]	knot	HWTOT = 0 knot	F_{TWJ} = (RD + 6 x 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]Temperature and elevation corrections used for runway design.
[ii]RD is the runway distance required.
[iii]Correction for wind are average values for aircraft type (jet or turboprop).
[iv]Runway contamination factors are those suggested by FSF.

where

Model Parameter	Ref/Unit	Comment/Description
Equipment Class	Ref: C	Large jet of maximum takeoff weight (MTOW) 41k-255k lb (B737, A320, etc.)
Heavy Aircraft	AB	Heavy jets of MTOW 255k lb+
Commuter Aircraft	D	Large commuter of MTOW 41k-255k lb (small RJs, ATR42, etc.)
Medium Aircraft	E	Medium aircraft of MTOW 12.5k-41k lb (biz jets, Embraer 120 Learjet 35, etc.)
Small Aircraft	F	Small aircraft of MTOW 12.5k or less (small, single or twin engine Beech90, Cessna Caravan, etc.)
User Class	Ref: C = Commercial, or F = Cargo, or T/C = Taxi/Commuter	
User Class G	G = GA	
Turboprop	Turboprop engine (yes/no) – Ref: Turbojet	
Ceiling Height	feet	
Visibility	statute miles	
Crosswind	knots	
Tailwind	knots	
Gusts	Yes/No – Ref: No	
Icing Conditions	Yes/No – Ref: No	
Snow	Yes/No – Ref: No	
Rain	Yes/No – Ref: No	
Frozen Precipitation	Yes/No – Ref: No	
Fog	Yes/No – Ref: No	
Air Temperature	Deg C	
Turboprop Aircraft	Yes/No – Ref: No	
Foreign Origin/Destination	Yes/No – Ref: No	
Non-hub Airport	Yes/No – Ref: Yes for hub airport	
Log Criticality Factor	Criticality Factor (CF) is defined as the ratio between the runway distance available and the runway distance required. A lower ratio means a lower safety margin and greater operation criticality.	
Night Conditions	Night, Dawn, or Dusk – Ref: Daylight	

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.

These event probability models require the use of historical information on operations and weather for the specific airport. The necessary information on operations includes the time of the flight, runway used, type of aircraft, type of flight, and if the operation was an arrival or departure. In addition, it is necessary to collect the weather information for the same period that operational data are available, usually for one year.

Weather information for U.S. airports can be acquired directly from the National Oceanic and Atmospheric Administration (NOAA) database for the weather station located at the airport. However, the information on operations, particularly for non-towered airports, may be harder to obtain, particularly the identification of the runway used. For towered airports operational data can be requested from the FAA. Another challenge is to run the analysis because computations can be made only with the help of a computer and specific software that incorporates these models.

To facilitate the analysis, average veer-off rates in the U.S. presented in *ACRP Report 51* may be used to simplify the application of the proposed approach. The rates are presented

Table 5. Independent variables for veer-off frequency models.

Variable	LDVO	TOVO
Adjusted Constant	-13.088	-15.612
User Class G	1.682	2.094
Aircraft Class A/B	-0.770	-0.852
Aircraft Class D/E/F	-0.252	-0.091
Visibility less than 2 SM	2.143	2.042
Visibility from 2 to 4 SM		0.808
Visibility from 4 to 8 SM		-1.500
Xwind from 5 to 12 kt	0.653	0.102
Xwind from 2 to 5 kt	-0.091	
Xwind more than 12 kt	2.192	0.706
Tailwind from 5 to 12 kt	0.066	
Tailwind more than 12 kt	0.98	
Temp less than 5 C	0.558	0.988
Temp from 5 to 15 C	-0.453	-0.42
Temp more than 25 C	0.291	-0.921
Icing Conditions	2.67	
Rain	-0.126	-1.541
Snow	0.548	0.963
Frozen Precipitation	-0.103	
Gusts	-0.036	
Fog	1.74	
Turboprop	-2.517	1.522
Foreign O/D	-0.334	-0.236
Hub/Non-Hub Airport		-0.692
Log Criticality Factor	4.318	1.707
Night Conditions	-1.36	

Note: LDVO = landing veer-off, TOVO = takeoff veer-off, SM = statute miles, kt = knot, OD = origin/destination.

in Table 6. The average incident rates are based on the number of accidents and incidents, and the total traffic of relevant operations from 1982 to 2009.

From Table 6, LDVOs are approximately 4 times more likely to occur than TOVOs.

Location Probability Models

There are two location probabilities that are modeled to incorporate in the analysis methodology:

- Longitudinal location: The probability that the veer-off occurs within a certain distance from the beginning of the runway, where *DExit* is the distance from the beginning of the runway to where the plane exited the runway, and *DStop* is the distance from the beginning of the runway to where the plane stopped or returned to the runway paved area. The "*D*" distances are measured parallel to the runway centerline; and
- Lateral location: The probability that the aircraft may travel beyond a certain distance from the runway edge, where *L* is a given lateral distance from the runway edge. This "*L*" distance is measured perpendicular from the runway edge.

Table 6. Average veer-off incident rates (ACRP Report 51)

Type of Incident	Event Rate per Operation	Operations per Event
LDVO	1.195E-06	837,000
TOVO	2.590E-07	3,861,000

The product of the previous probabilities provides the probability that the aircraft veers off within a certain subarea between *DExit* and *DStop* from the beginning of the runway and travels beyond a certain distance *L* from the runway edge. Such models will support the analysis and evaluation of RSAs of different widths and help estimate the probability that the aircraft strikes an obstacle located near the runway.

Three alternatives were evaluated to normalize the longitudinal distances for modeling. The normalized models use normalized distances, or distances transformed to a reference (e.g., the runway length). Whether or not the normalization of longitudinal distances could improve model accuracy was also investigated. The three normalization alternatives evaluated were as follows:

- Alternative 1—Normalization for the runway distance available (RDA),
- Alternative 2—Use of raw distances without normalization, and
- Alternative 3—Normalization for the runway distance required.

The results achieved from each of these three alternatives were evaluated for accuracy and the most accurate alternative was incorporated into the analysis software developed in this study.

As mentioned earlier, rather than solely using the aircraft stopping location, this study attempts to characterize the veer-off path of the aircraft. It was essential to obtain information on where the aircraft departed the runway and the path followed by the aircraft to help identify the subareas of the RSA affected by the excursion as well as its probability distribution over the runway length.

Main Challenges to Develop Location Models

The main challenge in developing probabilistic models for runway veer-offs was to find information to characterize the aircraft veer-off path, as most accident and incident reports lack this information. The alternative was to review the narrative and identify any clues that could be used to infer the pathway. Clue indications in the narrative included such things as:

- Runway lights and signs struck by the aircraft;
- Speed when aircraft departed the runway;
- Specific airfield components referenced (e.g., crossing of specific taxiways);
- Airfield structures and obstacles (e.g., ditches, hangars); and
- Phase of flight (e.g., "*upon touchdown the right landing gear collapsed and the aircraft swerved to the right*").

Another important challenge was to identify an approach that could use the veer-off path instead of using only the final location where the aircraft stopped after the veer-off. This feature was deemed critical as some of veer-off accidents and incidents may challenge several subareas of the lateral RSA. The veer-off path was approximated by two linear models and it was necessary to develop a specific code to automatically calculate the lateral deviations for each subarea of the lateral RSA.

Characterization of the Aircraft Veer-Off Path

The aircraft veer-off path is defined as the path of the aircraft from the point where the aircraft departs the edge of the runway to the place the aircraft either comes to a stop or reenters the runway.

The veer-off pathway was required to generate data to develop the location models. The path was referenced by the longitudinal distance from the beginning of the runway and the lateral distance from the runway edge. Usually, the path cannot be completely characterized from the information provided in the accident/incident report. Some reports may provide the veer-off path in a diagram or a picture; others do not. Some assumptions and inferences were made based on information contained in the narrative of the report, when possible.

Figure 9 shows the references used to measure distances to characterize the veer-off path. For takeoffs, the longitudinal distances are measured from the beginning of the takeoff runway, unless it is reported that an intersection takeoff occurred. The veer-off distances for landings are measured from the landing threshold (beginning of the runway for landing). The lateral distance is always measured from the runway side edge.

The following parameters were defined to characterize the veer-off path and are illustrated in Figure 10:

- *DExit* is the longitudinal distance measured from the beginning of the runway to the point where the plane crossed the runway edge and departed the runway;

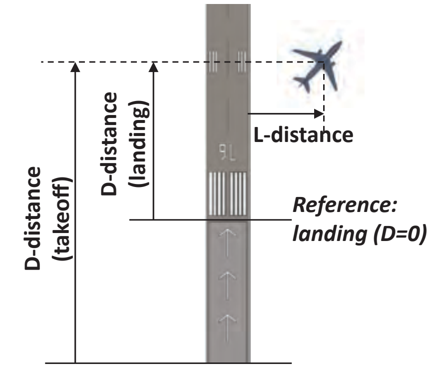


Figure 9. References to distances used to characterize veer-off path.

- *DStop* is the longitudinal distance measured from the beginning of the runway to the point where the plane stopped or returned to the runway;
- *LStop* is the lateral deviation where the plane stopped, or nil, if it returned to the runway surface;
- *LMax* is the maximum lateral deviation from the runway side edge; and
- *DMax* is the longitudinal distance measured from the beginning of the runway to where the plane had the *LMax*.

Figure 10 illustrates a veer-off for which the pilot tries to return the plane to the runway but stops prior to reaching the paved surface. In this situation, *LMax* is larger than *LStop*.

Implementing these parameters tries to mimic the actual veer-off path with some approximations. Figures 11 through 13

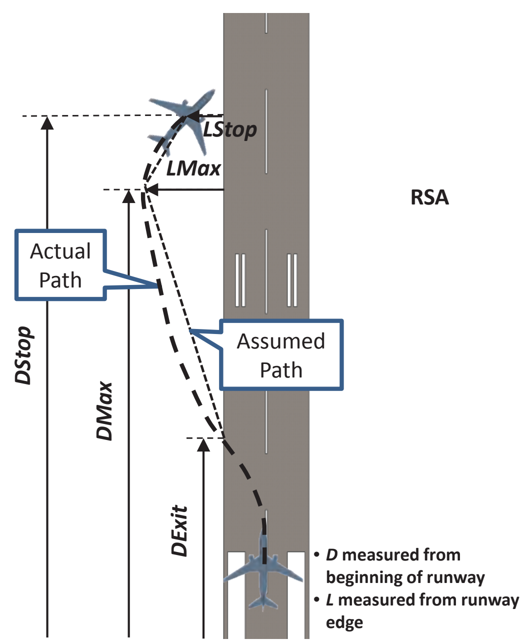


Figure 10. Characterization of veer-off path.

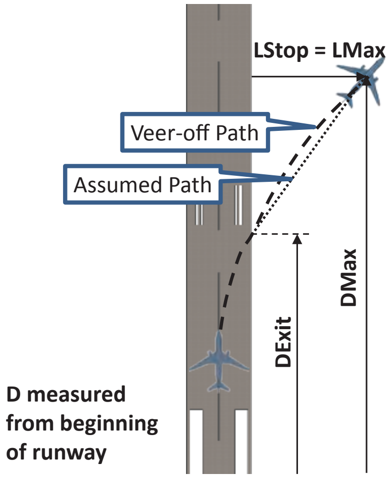


***Figure 11. Runway veer-off distances*—LStop = LMax.**

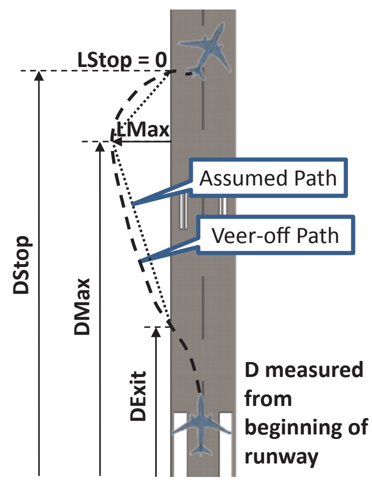


Figure 12. Runway veer-off* – LStop = *0.

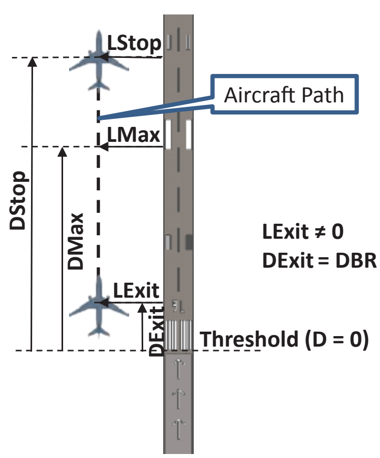


Figure 13. Runway veer-off*— LExit = *0.

show the type of approximation introduced for different types of veer-off path.

In Figure 11, the lateral deviation increases until where the plane stops. In this case, *DStop* is equal to *DMax*, and *LStop* is equal to *LMax*. As shown in the figure, the actual path is normally a curve, which is approximated by a straight line.

As shown in Figure 12, the plane veers off the runway and returns to the runway paved area. The location at which the plane has the maximum lateral deviation is characterized with *LMax* and *DMax*. The final lateral distance *LStop* is equal to zero because the plane returned to the runway. The likely curved veer-off path is again approximated with straight lines.

Another possible veer-off scenario considered in this study is represented in Figure 13. In this case, the lateral deviation occurs prior to the touchdown, which occurs off the runway. In this case, the runway exit distance X_e is assumed to be the touchdown distance X_{td}. In most cases, the aircraft has its veer-off path parallel to the runway, as depicted in the figure.

As mentioned earlier, in addition to the veer-off path, data on weather conditions affecting aircraft performance and on runway distance required, such as air temperature, runway elevation, runway surface condition, effective slope, wind direction, and speed were also important information. Finally, it was necessary to characterize the physical condition of the runway, particularly the distances available for landing or takeoff, depending on the type of incident.

Normalization of Longitudinal Distances

As indicated in earlier sections, the location models developed in this task used a D-L coordinate system where the D-origin was set at the beginning of the runway, and the L-origin was set at the runway edge, as shown in Figure 14, where D1 and L1 coordinates represent the aircraft location off the runway.

Three alternatives to transform, or, in other words, to normalize the longitudinal distances were evaluated in this study. The normalization procedure consisted of the transformation

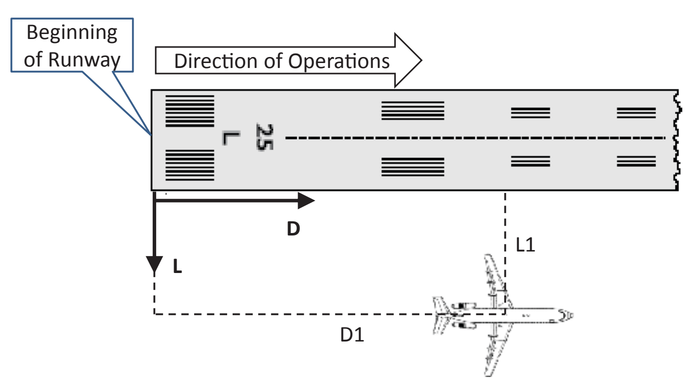


Figure 14. Reference coordinate System for veer-off location.

of the longitudinal distances to a reference length, as described below. The runway length was divided into 10 subareas and the location of each subarea is a function of the specific normalization procedure used, as follows:

- Alternative 1: Normalization for RDA:—actual longitudinal distances characterizing the veer-off pathway were divided by the runway distance available for each event. In this case, the beginning of the runway is the origin ($D = 0$) and the runway end is the maximum value ($D = 1$).
- Alternative 2: Raw Distances: Actual longitudinal distances from the beginning of the runway were used and the runway subareas were divided into 800-ft intervals with the last interval containing any distance greater than 7,200 ft.
- Alternative 3: Normalization for Runway Distance Required (RDR): The runway distance required by the aircraft involved in the event was estimated based on the actual aircraft model, runway elevation, air temperature, and effective runway slope. The subareas were composed of sections with 0.1 RDR in length, with the last interval containing any distance greater than 0.9 RDR.

As an illustration, the subareas used for Alternative 1, the normalization of longitudinal distances for the runway distance available, are shown in Figure 15. The runway distance available is divided into 10 sections of equal length and each section includes both the right and the left side subareas of the lateral runway area. Each subarea comprises 5% of the total lateral RSA.

It is important to note that the lateral distances were not normalized and only the raw distances in feet were used for modeling. The maximum lateral distance from the runway edge for the grid was set to 1,000 ft. The lateral distance for each event was computed for each subarea that includes any part of the veer-off path. The largest value of *L* in each subarea was selected to represent the lateral deviation at the subarea for the specific veer-off event, as illustrated in Figure 16. In this example, the aircraft departed the runway in *subarea 2R* and stopped in *subarea 6R*. *Subareas 1R, 7R, 8R, 9R, 10R* and none of the subareas on the left of the runway were challenged by the veer-off event. In subarea *2R*, the corresponding D_2 is the maximum value of the path in the subarea, which is equivalent to the deviation value when the aircraft crossed the interface between *subareas 2R* and *3R*.

An algorithm was developed and implemented in MS Excel to calculate the lateral distances for each event in each subsection, as a function of the normalization procedure used. The algorithm uses the veer-off distances to define the two linear segments representing the veer-off pathway and calculates the maximum lateral distance in each segment challenged by the veer-off. Data generated was used to develop lateral probability models for each subsection of the RSA.

It should be noted that the example presented is quite simple because the veer-off path was approximated with one straight line. For other cases, when the aircraft has a *LMax* that is greater than *LStop* (the plane stopping location), the path is represented by two straight lines and the same principle of using the maximum veer-off deviation in the subarea is applied.

Location Models

The development of a modeling approach for veer-off deviations was one of the key tasks in this study. The basic approach consisted of the following steps for the three normalization alternatives evaluated:

- Define the grid associated with the selected normalization procedure;

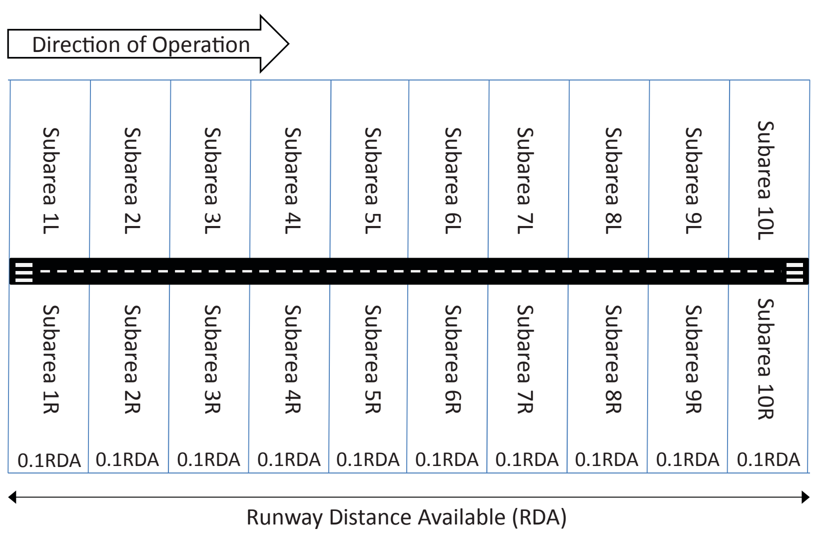


Figure 15. Normalization for RDA subareas.

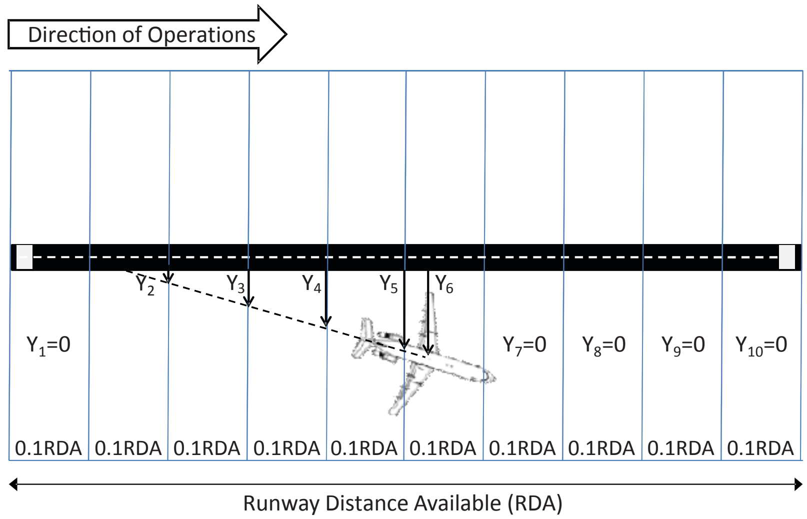


Figure 16. Representative deviation for each subarea—example.

- Conduct normalization for longitudinal veer-off distances;
- Identify which subareas were challenged by each event;
- Estimate the lateral deviation in each subarea challenged by each veer-off event;
- Repeat the process for each veer-off event and count the number of times that each subarea was challenged by all events to calculate the percentage of occurrences in each subarea;
- Using the lateral deviation values estimated for each subarea, develop mathematical models to estimate the probability that an aircraft exceeds a certain lateral deviation during the veer-off event in the specific subarea;
- Based on the probability that aircraft may challenge each subarea, develop cumulative probability curves for longitudinal distances covered during the veer-off event; and
- Develop risk contour curves based on the subarea probabilities and the lateral deviation models for each subarea.

It is important to note that the modeling effort presented in ensuing sections was developed based on the assumption that aircraft has an equal chance to veer off to the right or to the left side of the runway. However, out of 873 records containing information on the veer off side, in 518 events the aircraft departed the left side, in 354 cases the aircraft departed the right side, and in 1 case the aircraft departed one side, crossed the runway and departed the other side.

A Chi-Square statistical test was conducted and results demonstrated a statistically significant trend toward veer-offs to the left side of the runway. Despite this result, the models were still developed considering an equal split to the left and right side, since runways are used in both directions and splitting the data to model both sides would negatively impact model accuracy.

Lateral deviation and longitudinal distance models and risk contour curves were developed for three normalization alternatives described earlier: RDA, raw distances, and RDR; however, only the alternative using the RDA was selected to incorporate in the analysis approach because it was assumed to be the most accurate approach based on the stability of the contour lines generated with the models. High variability in the generated risk contour lines was assumed to be an indication that the models using the specific transformation may not be suitable or may lead to larger errors.

To a certain degree, the distance available is related to the aircraft performance during operations in the runway, including the adjustments for elevation, temperature, slope, wind, and surface conditions. The resulting contour lines using RDA for normalization were more stable and the technique was selected for use in the analysis software.

Only the models using the normalization for RDA will be presented in the body of this report. Results for the other two normalization alternatives are presented in Appendix G.

A set of lateral deviation models for veer-off was developed using the RDA to transform the longitudinal distances of the veer-off path for each event. The transformation is simply the ratio between the veer-off path distance and the RDA; therefore, the path distances are given as percentages of the RDA for landing or takeoff, depending on the type of operation. For example during a landing operation, *DExit* is equal to 0.25, which means that the aircraft exited the runway at 25% of the landing distance available (LDA), measured from the beginning of the runway.

Longitudinal Probability Distribution

Figure 17 illustrates the longitudinal probability distribution for both landing and takeoff veer-offs when distances are normalized with the RDA. Figures 18 and 19 depict the longitudinal probability distributions for LDVO and TOVO, respectively.

Based on the results presented in Figures 17, 18 and 19, the cumulative probability distributions for normalization with

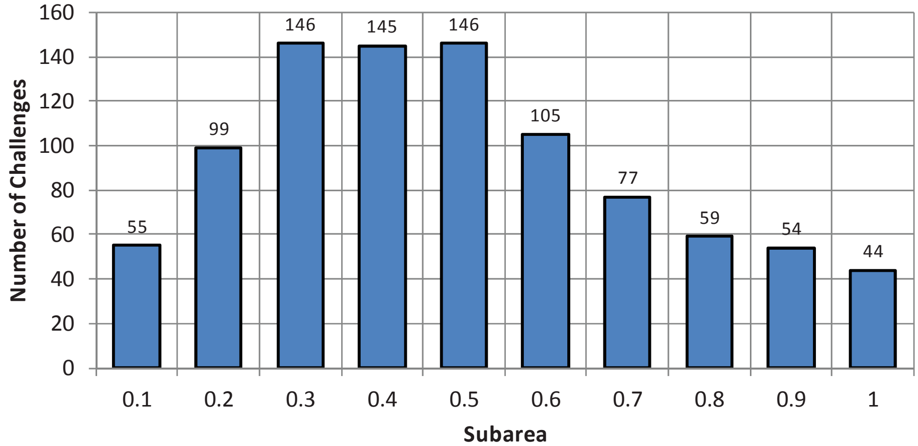


Figure 17. Longitudinal probability distribution—both LDVOs and TOVOs—distances normalized by RDA.

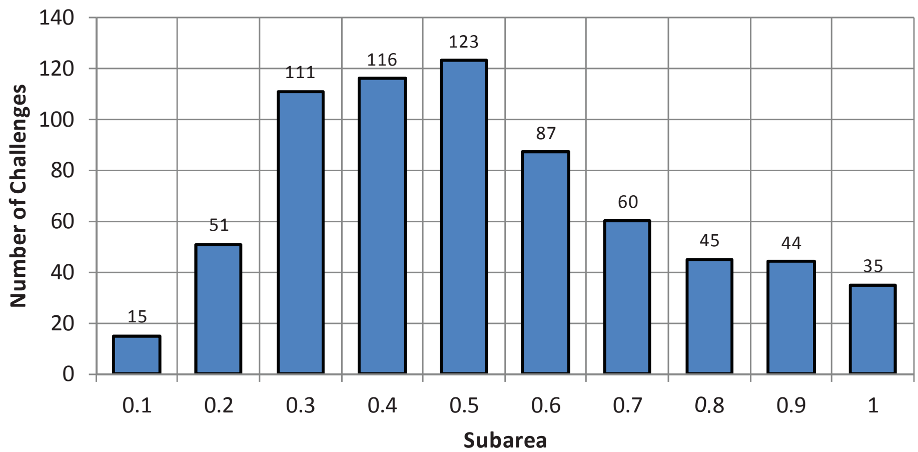


Figure 18. Longitudinal probability distribution—LDVOs only—distances normalized by RDA.

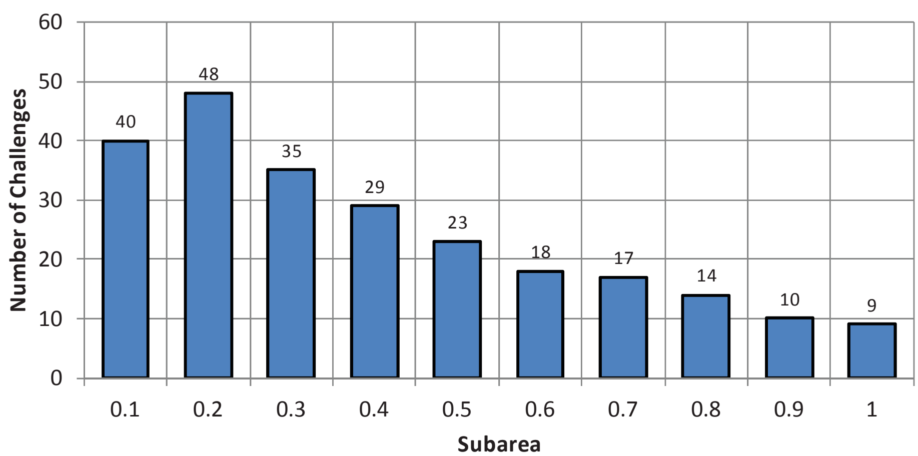


Figure 19. Longitudinal probability distribution—TOVOs only—distances normalized by RDA.

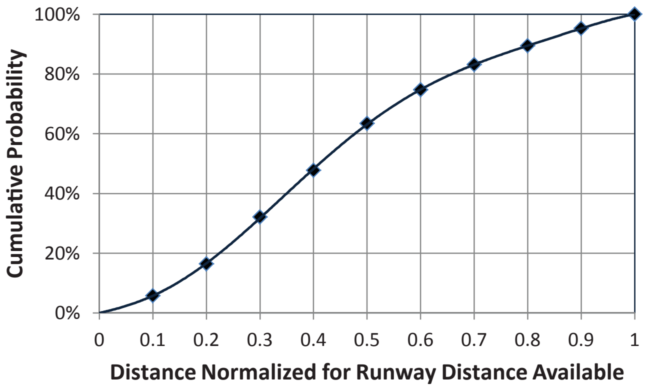


Figure 20. Longitudinal cumulative probability distribution for LDVOs and TOVOs—distances normalized with RDA.

runway distance available were developed. The model integrating both LDVOs and TOVOs is illustrated in Figure 20. A polynomial curve was fit to the cumulative probability points. A high degree polynomial was used to obtain the models representing the probabilities for each subarea with the highest accuracy possible. The models are represented by the following equations. An R^2 of 99.99% was achieved (R^2 is a statistical measure of fit; $R^2 = 100\%$ signifies a perfect fit).

Integrated Model for TOVOs and LDVOs

$$CP = -12.1793D^6 + 36.7712D^5 - 38.3658D^4 + 13.9251D^3 + 0.4265D^2 + 0.4225D (R^2 = 99.9\%)$$

Model for LDVO

$$CP = -20.4465D^6 + 63.2398D^5 - 69.4061D^4 + 29.2622D^3 - 1.8031D^2 + 0.1538D (R^2 = 99.9\%)$$

Model for TOVO

$$CP = 13.1509D^6 - 43.3722D^5 + 54.6310D^4 - 32.0242D^3 + 7.4079D^2 + 1.2068D$$

where:

D is the normalized longitudinal distance from the beginning of the runway and

CP is the cumulative probability that a veer-off will occur within D.

Lateral Probability Distribution

The lateral deviation models were developed using the following form:

$$P\{L > L_1\} = e^{aL^b}$$

where

$P\{L > L_1\}$ is the probability that the lateral deviation L exceeds a given distance L_1 and

a, b are model coefficients.

Mathematical models were developed for each subarea using the lateral deviations generated for each LDVO and TOVO event challenging each subarea. Therefore, ten different models were developed for this normalization alternative with respect to the runway distance available. Table 5 summarizes the model coefficients for each subarea. Figures comparing the model estimates with actual data are presented in Appendix C. The last column in Table 7 shows the models' R^2, which represent the excellent accuracy achieved.

Based on these models, risk contour lines were derived to cover the runway distance available, as shown in Figure 21. It should be noted that the contour lines represent both sides of the runway. Aircraft deviations are referenced to the center point of the aircraft between the main gears. The ISO-risk lines can be used to estimate the probability that an aircraft exceeds the lateral distance in a given subarea. For example, there is a 5% chance that the path of an aircraft veering off the runway and challenging subarea 6 will exceed a lateral deviation of approximately 200 ft.

It should be noted that the risk contour curves presented in Figure 21 are applied to individual subareas. It is not possible to calculate the risk of an accident for a given scenario in which the safety area may have limits and some obstacles may be present. However, it is possible to combine the lateral deviation models with the probability that an aircraft will challenge specific subareas of the runway. Figure 22 combines the results from Figure 21 and the lateral deviation models presented in Table 5, where the probabilities for a given distance are multiplied by the subarea probability.

In this case, the contour lines represent the probabilities that an aircraft will exceed a given lateral distance during a runway excursion.

Table 7. Lateral deviation models for normalization using RDA.

Subarea	*L* Range	*a*	*b*	R^2
1	0–0.1	-0.03399	0.8407	97.4%
2	0.1–0.2	-0.00690	1.1339	99.3%
3	0.2–0.3	-0.01306	1.0032	99.4%
4	0.3–0.4	-0.00644	1.1576	99.5%
5	0.4–0.5	-0.01354	0.9881	99.1%
6	0.5–0.6	-0.00906	1.0482	98.3%
7	0.6–0.7	-0.00909	1.0014	99.0%
8	0.7–0.8	-0.01136	0.9206	99.2%
9	0.8–0.9	-0.01037	0.970348	98.9%
10	0.9–1.0	-0.00361	1.18109	99.1%

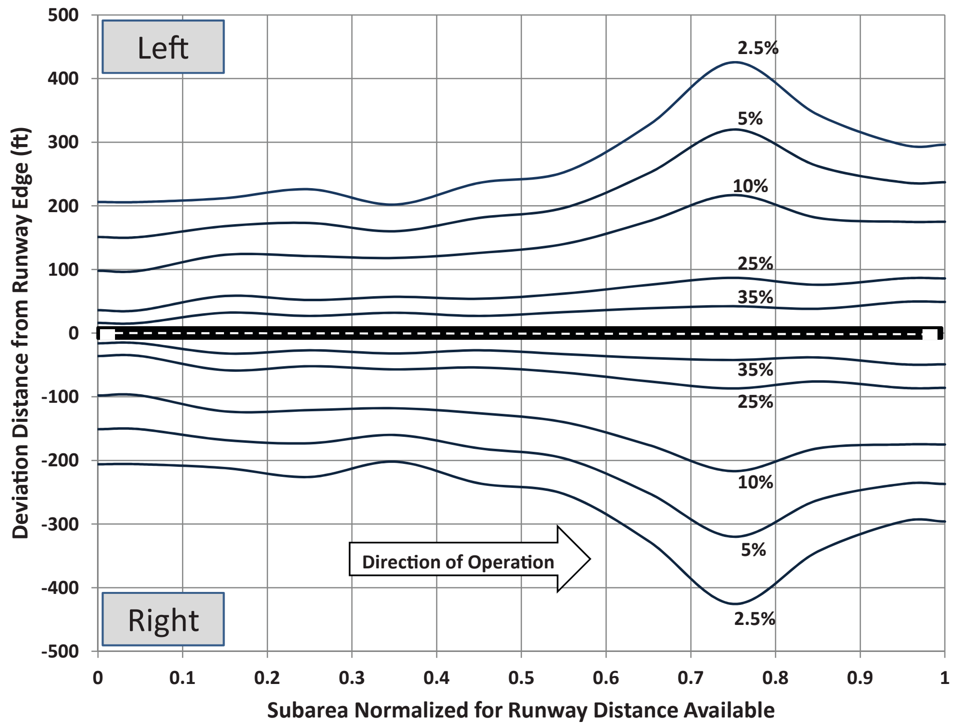


Figure 21. Risk contours—probability of deviations exceeding a given distance L_1 *for each subarea—distances normalized with RDA.*

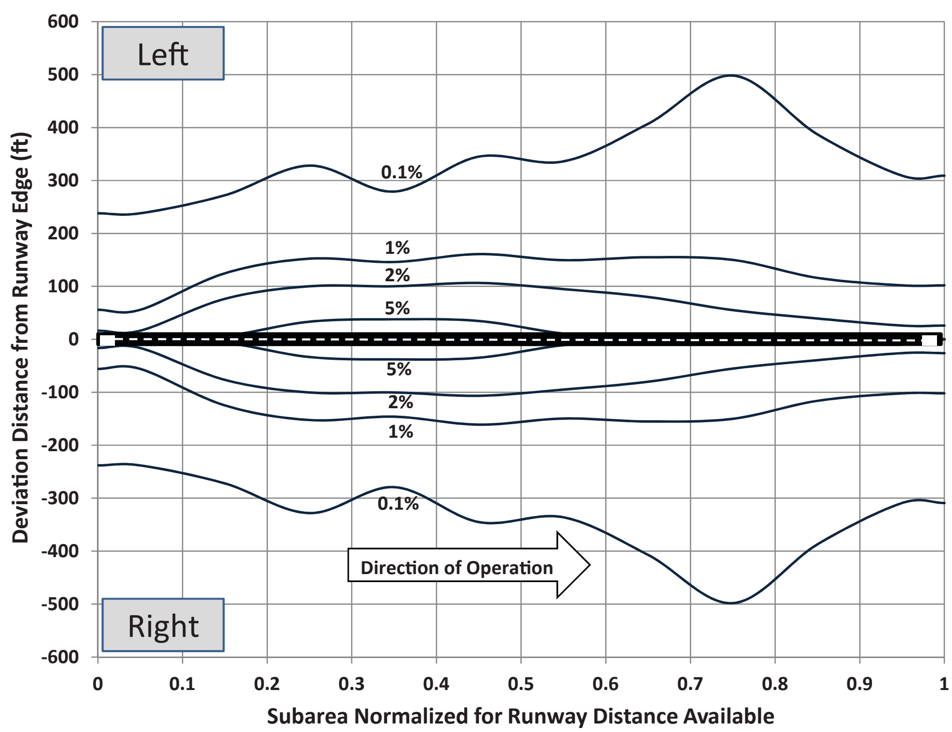


Figure 22. Risk contours—adjusted probability of deviations exceeding a given distance L_1*—distances normalized with RDA.*

Veer-Off Consequences Approach

Using both the lateral deviation models for individual sub-areas in combination with the cumulative probability model for the longitudinal distance, it is possible to evaluate the risk that an aircraft strikes an obstacle during the veer-off. However, the risk of accidents during veer-offs is not always associated with the aircraft collision with an obstacle. For example, in many events the landing gear collapsed during the touchdown resulting in major damage to the aircraft, even before the aircraft departed the runway. In other situations, uneven terrain, sometimes resulting from transitions between paved and unpaved areas, caused the landing gear to collapse or wing/engine to collide with the terrain. Another common occurrence is the collapse of the landing gear during the runway excursion due to high stresses when tires sink in soft terrain. In many cases, minor damage was caused by aircraft striking runway/taxiway lights and signs.

Probability of Accidents

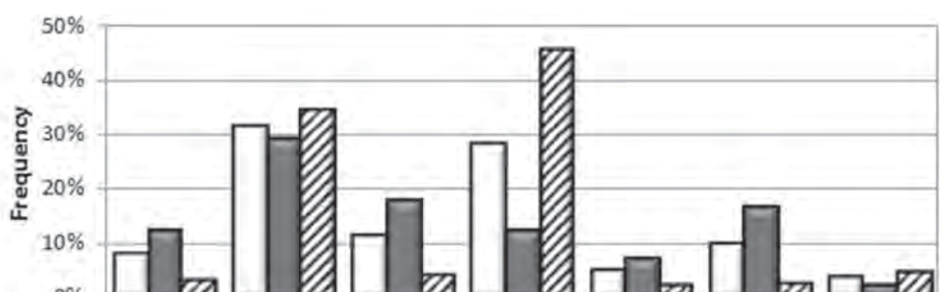
Figure 23 summarizes different causes of damage to aircraft during veer-off events with associated frequencies. The illustration contains three groups involving both accidents and incidents, accidents only, and incidents only. The following categories of aircraft damage cause were identified:

- *Touchdown Hard*—aircraft suffers damage as a result of high stresses or striking the wingtip on the ground. In many cases, damage was a result of the collapse of landing gears.
- *Rough Terrain*—aircraft departed the prepared surface of the safety area, crossed the transitions between paved and unpaved surfaces (e.g., crossing taxiways), unprepared terrain, or areas with varying bearing capacity, in many cases off the RSA.
- *Soft Terrain*—aircraft wheels sinking in soft terrain causing high stresses to landing gear that lead to collapse.
- *Struck Light/Sign*—although frangible, these structures may still cause damage to aircraft during runway excursions and increase severity of veer-offs.
- *Mechanical Collapse of Landing Gear*—this category does not include cases in which gear collapse occurred due to hard touchdown and is only related to the collapse of the gear during normal touchdowns.
- *Struck Obstacles*—aircraft striking obstacles other than runway/taxiway lights and signs. It may include hangars, ditches, other aircraft, etc.
- Other damage causes may include foreign object debris (FOD) ingestion, blown tires, gear-up landings, wildlife strikes, etc.

The frequency observed for each of the seven categories of damage causes are represented in Figure 23.

Based on Figure 23, the main causes of damage to aircraft during veer-offs were rough terrain and the striking of lights and signs. For accidents, the main causes of damage to aircraft were rough terrain, soft terrain, and striking of obstacles. Striking lights and signs were the main cause of damage to aircraft during veer-off incidents.

It is important to note that the damage cause may or may not be the cause of the veer-off. For instance, if the landing gear collapses due to high stresses during touchdown, it may be the cause of the veer-off and the cause of damage. However, if an aircraft strikes an obstacle off the runway, it is normally the result of the veer-off rather than the cause of the event.



	Touchdown Hard	Rough Terrain	Soft Terrain	Struck Light/Sign	Mech Collapse of Gear	Struck Obstacle	Other
Acc/Inc	8.4%	31.8%	11.7%	28.4%	5.3%	10.2%	4.2%
Acc Only	12.7%	29.3%	18.2%	12.7%	7.5%	16.9%	2.8%
Inc Only	3.6%	35.0%	4.6%	45.9%	2.7%	3.0%	5.2%

Figure 23. Damage causes during aircraft veer-offs (Mech = mechanical, Acc = accident, Inc = incident).

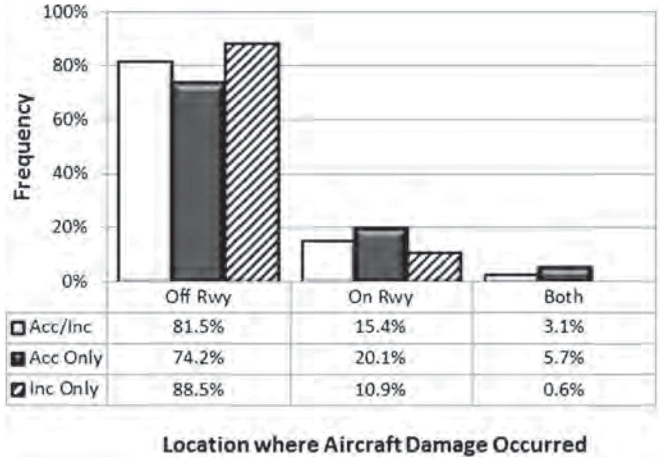


Figure 24. Location at which damage was caused to aircraft (Rwy = runway).

Figure 24 summarizes the data for accidents/incidents for which records contained a veer-off path. This figure indicates aircraft damage frequencies and if the damage occurred on or off the runway. In some cases, aircraft was damaged both on the runway and off.

These results are very important to support the modeling approach for consequences because accidents occurring during veer-offs are not always related to aircraft striking obstacles in the vicinity of the runway. Since the damage cause for many veer-off events is not associated with the presence of obstacles in the safety area or its vicinity, it was necessary to combine the probability of striking an obstacle with the probability of substantial damage to the aircraft from other causes based on evidence from veer-off accidents and incidents. Historically, approximately 25% of reported veer-off events result in substantial damage to aircraft. Out of those 25%, approximately 3% resulted from aircraft colliding with obstacles. Therefore, the probability of an accident from causes not related with obstacles was approximately 22%.

Probability of Aircraft Striking Obstacles

Modeling the probability of an aircraft striking an obstacle will require evaluating the probability that the aircraft path passes within the obstacle area. Each veer-off event has a wreckage path associated with it and Figures 25 and 26 illustrate the average longitudinal distances for each subarea covered by the aircraft path during the runway excursion for LDVOs and TOVOs, respectively.

Based on the results presented in Figure 25 for LDVOs, the *average* distance covered is fairly constant for all the subareas. For TOVOs, the distance is small for subareas near the start of the takeoff and becomes constant for subareas beyond the runway midpoint, as shown in Figure 26. The average distances for each subarea will be used to define an area of influence associated with the position of the obstacle along the runway, as shown in Figure 27.

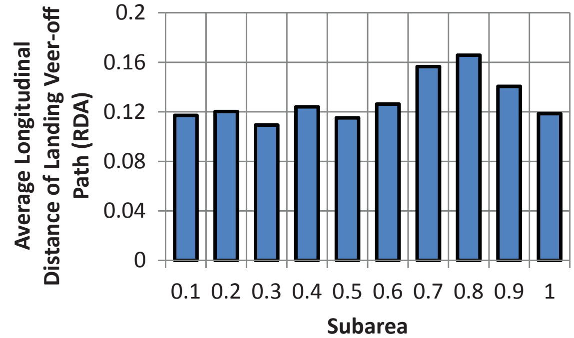


Figure 25. Average longitudinal distance covered during landing veer-off path—fraction of RDA.

Two areas are characterized in the figure. The first area is called *Area of Influence 1* and its length is associated with the average distance X1 covered during veer-offs in the subarea where the obstacle is located, as presented in Figures 25 and 26. X1 depends on the type of operation (landing or takeoff) and the subarea in which the beginning of the obstacle is located. It is assumed that veer-offs initiated in this region will impact the obstacle. The end of this region is located at a distance equivalent to half of the wingspan (WS) of the aircraft considered in the analysis. In this case, it is assumed that the aircraft may collide with the obstacle if located at the farthest point of this region if it deviates enough from the runway edge.

The second region is defined as *Area of Influence 2*. This area has a length X2 that can be calculated with the following formula:

$$X2 = L_{obs} + WS/2 + WS/2 = L_{obs} + WS$$

where

X2 is the length of *Area of Influence 2*,
L_{obs} is the length of the obstacle, and
WS is the wingspan of the aircraft considered.

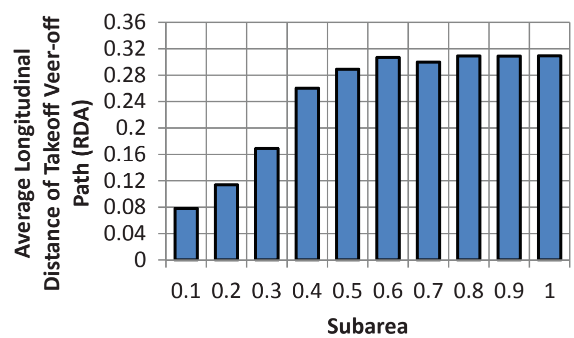


Figure 26. Average longitudinal distance covered during takeoff veer-off path—fraction of RDA.

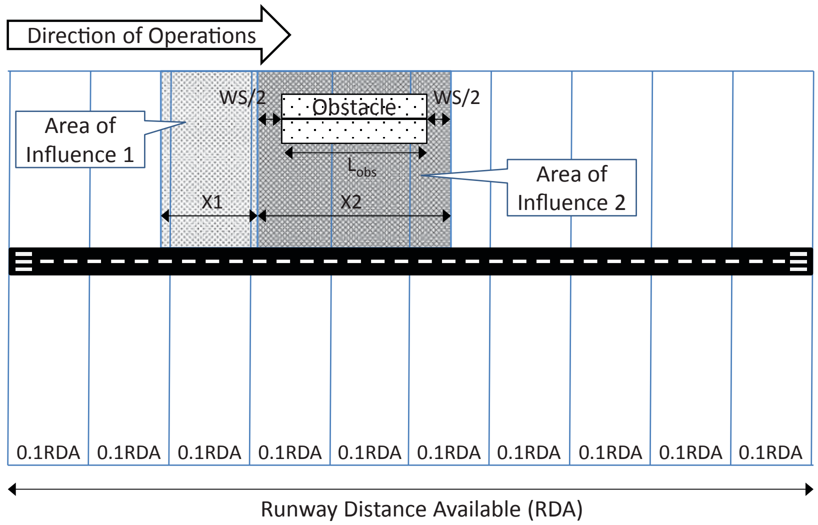


Figure 27. Areas of influence (WS = wingspan, L_{obs} = length of the obstacle, X1 = average distance covered during veer-offs in the subarea where the obstacle is located, X2 = length of Area of Influence 2).

The next step in the modeling approach is illustrated in Figure 28. In this figure (not to scale), the obstacle is located on the left side of the runway at a distance from the runway edge. To use a simple example, the obstacle is parallel to the runway and both the beginning and end of the obstacle are located at the same distance from the runway edge ($L_1 = L_2$) (L_1 is the lateral distance to the beginning of the obstacle measured from the edge of the runway. L_2 is the lateral distance to the end of the obstacle measured from the edge of the runway. The beginning and end of the obstacle are defined based on the direction of operation). For a given aircraft WS, both the length of the obstacle parallel to the runway and the distance from the runway edge are adjusted to include half of the WS (WS/2) as shown in the illustration. The adjustment is to consider the difference between the center of the aircraft, which is the reference for the distances (D – L) used in the probability

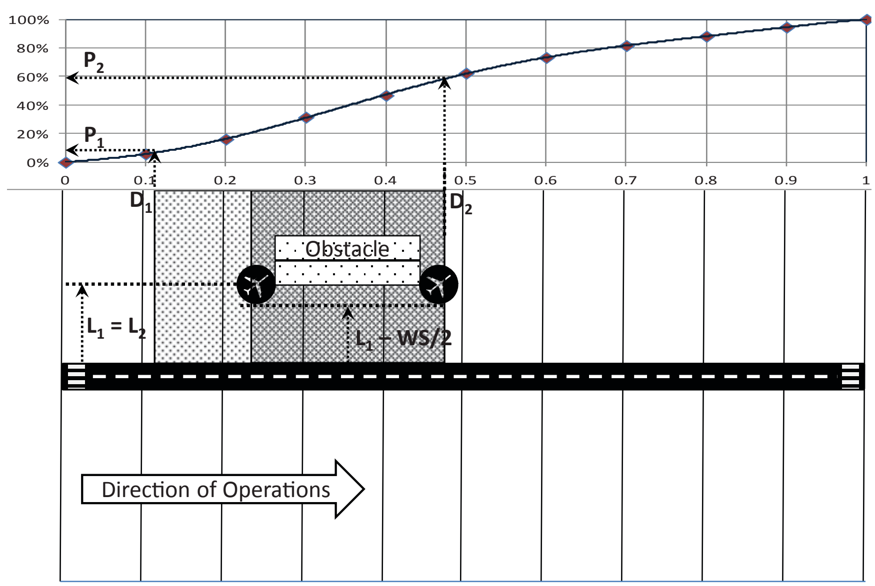


Figure 28. Total area of influence and calculation of probabilities (D_1 is the longitudinal distance from the runway approach end to the beginning of the obstacle. D_2 is the longitudinal distance to the end of the obstacle. Beginning and end of obstacle are defined according to the direction of operation.).

models and the tip of the wing. A collision is assumed when the aircraft wingtip or any part of the aircraft strikes the obstacle.

With D_1, probability (P_1) is calculated from the cumulative probability model developed in this study. Using the same model, probability (P_2) is estimated based on a distance (D_2), as shown in the illustration. The probability that the aircraft will veer off in the longitudinal region of the obstacle (PD) is estimated by $PD = P_2 - P_1$.

Next, the probability that the lateral deviation from the runway edge exceeds $L_1 - WS/2$ (PL) is estimated using the lateral deviation model for the subarea(s) and the total probability that the aircraft may have struck the obstacle is calculated by the product PD*PL.

One or more obstacles may be considered using the approach. In some cases, where the obstacle is at the ground level (e.g., ditches), the center of the aircraft or the width of the main landing gear is considered instead of the wingspan. In addition, the approach may also be applied to obstacles with variable distances to the runway edge, by splitting the obstacle in two or more elements. Theoretically, the lateral deviation models could be used to evaluate an obstacle with limited depth, in case the aircraft veers off the runway and has its path behind the obstacle; however, the approach was conservative and the models incorporated in the analysis software cannot evaluate this scenario; instead, it is assumed that obstacles extend to the limits of the RSA.

The ultimate goal of modeling the consequences is to estimate the probability of accidents resulting from the presence of obstacles. If desired, an adjustment factor can be applied to the probability of veer-offs to estimate the probability of accidents resulting from collision with obstacles. Therefore, the probability of an accident can be calculated using the following equation:

$$P_{acc} = P_{vo} * (P_{cobs} + 0.22)$$

where

- P_{acc} is the probability of an accident in the event of a veer-off,
- P_{vo} is the probability of a veer-off (calculated from the frequency model),
- P_{cobs} is the probability of a collision with an obstacle resulting from the veer-off, and
- 0.22 is a factor used to add the probability of accidents not related to collision with obstacles.

CHAPTER 6

Analysis Software

Overview

Analysis software for aircraft veer-offs developed in this study is named Lateral Runway Safety Area Risk Analysis (LRSARA). It integrates the approach and the models developed into an analysis tool that is user-friendly and incorporates three basic interfaces: (1) an interface for entering data, characterizing the RSA, and managing files; (2) a module that contains the algorithm to check the validity of data, process the information, and perform the calculations to estimate veer-off risk; and (3) an interface to organize results and output in report format.

The software program and the accompanying user guide (presented in Appendix G) are available for download at the Transportation Research Board (TRB) website. The user guide may also be accessed from the Help menu within the program. The software main screen is shown in Figure 29.

Software Capabilities

With LRSARA, airport stakeholders may analyze non-standard RSA widths and the presence of obstacles in the vicinity of the runway lateral RSA. A summary of LRSARA capabilities is presented below:

- Perform full-risk assessment for multiple runways.
- Enter multiple obstacles in each RSA scenario.
- Characterize two different categories of obstacles (ground or high).
- Define and analyze non-standard (non-rectangular) RSA geometry.
- Internally integrate operations and weather data from separate files.
- Automatically convert operations and weather data into parameters used by probability models.
- Include database of aircraft with capability to add new or edit existing aircraft characteristics.
- Automatically compute runway criticality factor for each operation.
- Automatically correct for required distances (landing and takeoff) based on elevation, temperature, wind, and runway surface condition.
- Generate analysis reports from software with summaries of the following parameters:
  - Average risk for each type of incident by runway, by RSA section, and total for the airport.
  - The expected number of years for an accident to occur 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.
- Run a simplified analysis using default or user-defined veer-off probabilities, with no need to enter historical operations and historical weather conditions.

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.) if full analysis is selected.
- Sample of weather data for the airport covering the historical operations sample period (wind, temperature, precipitation, visibility, etc.).
- Characteristics of runways (elevation, direction, declared distances, displaced threshold) if full analysis is selected.
- Characteristics of RSAs (geometry and 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

Figure 29. LRSARA—main program screen.

and data format. Figure 30 shows the program screen and template to input operations data.

The template for drawing the lateral RSA area was also 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 runway edge. To include an obstacle, the user assigns a letter to each cell to define the type of obstacle. Entering "g" represents a ground obstacle (e.g., ditch, rough terrain, depression). If letter "w" is entered, it represents a wing-level obstacle to account for the risk of aircraft wings or fuselage striking the obstacle in the given location. After entering a letter, the color of the cell will change according to the type of obstacle entered to facilitate the visualization of the drawing. Figure 31 shows an example of an RSA defined with the tool.

Output and Interpretation

Two analysis alternatives are available: full and simplified. In full analysis it is necessary to enter historical operations and weather conditions for the airport. The information will feed the frequency models for each historical operation at the airport. If simplified analysis is selected, the probabilities of landing and takeoff veer-offs are fixed and either default values from *ACRP Report 51* will be used, or the user may define the two probabilities.

When the analyses are completed, the user may see the results using the Output option in 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 probability of landing and takeoff veer-off events or view the analysis output for the risk of accidents.

Each worksheet contains the risk estimates for one type of veer-off and individual operation and the total veer-off risk during landings and takeoffs. The results for each individual runway are provided in separate Excel output files. The summary table provides the average risk for each type of accident and expected number of years for a veer-off accident to occur. The accumulated risk distribution is provided in graphical form for the lateral RSA.

The results for the entire airport are provided in one Excel output 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 using the full analysis is shown in Figure 32. The main table contains a summary of average risk levels for each type of veer-off accident and total risk involving both runways analyzed. Risk levels are shown in terms of accident rates per number of operations and expected number of years for one accident to occur. Additional tables are presented showing the average risk for each runway, the percentage of movements with higher risk, and the number of operations challenging the lateral RSA sections associated with each runway. Similar output reports are generated if the analysis involves multiple runways.

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 accidents 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.

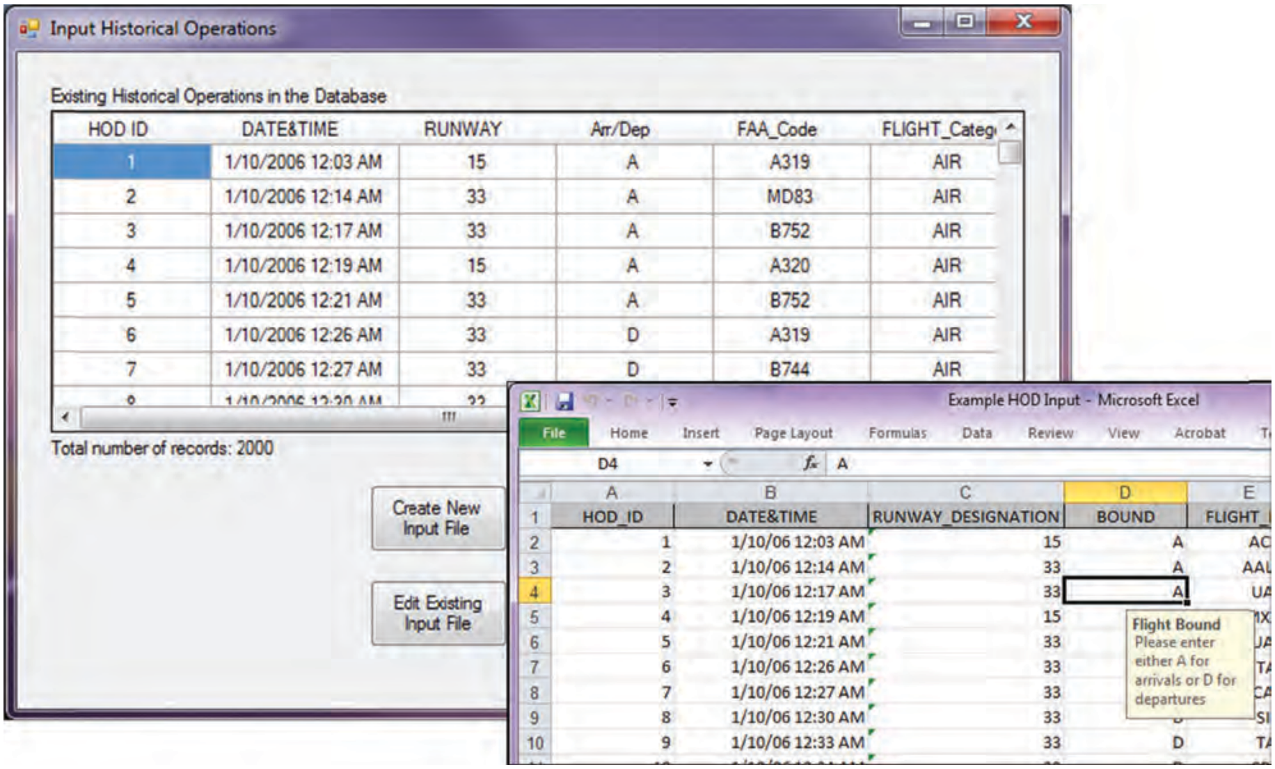


Figure 30. Example of input screen and template.

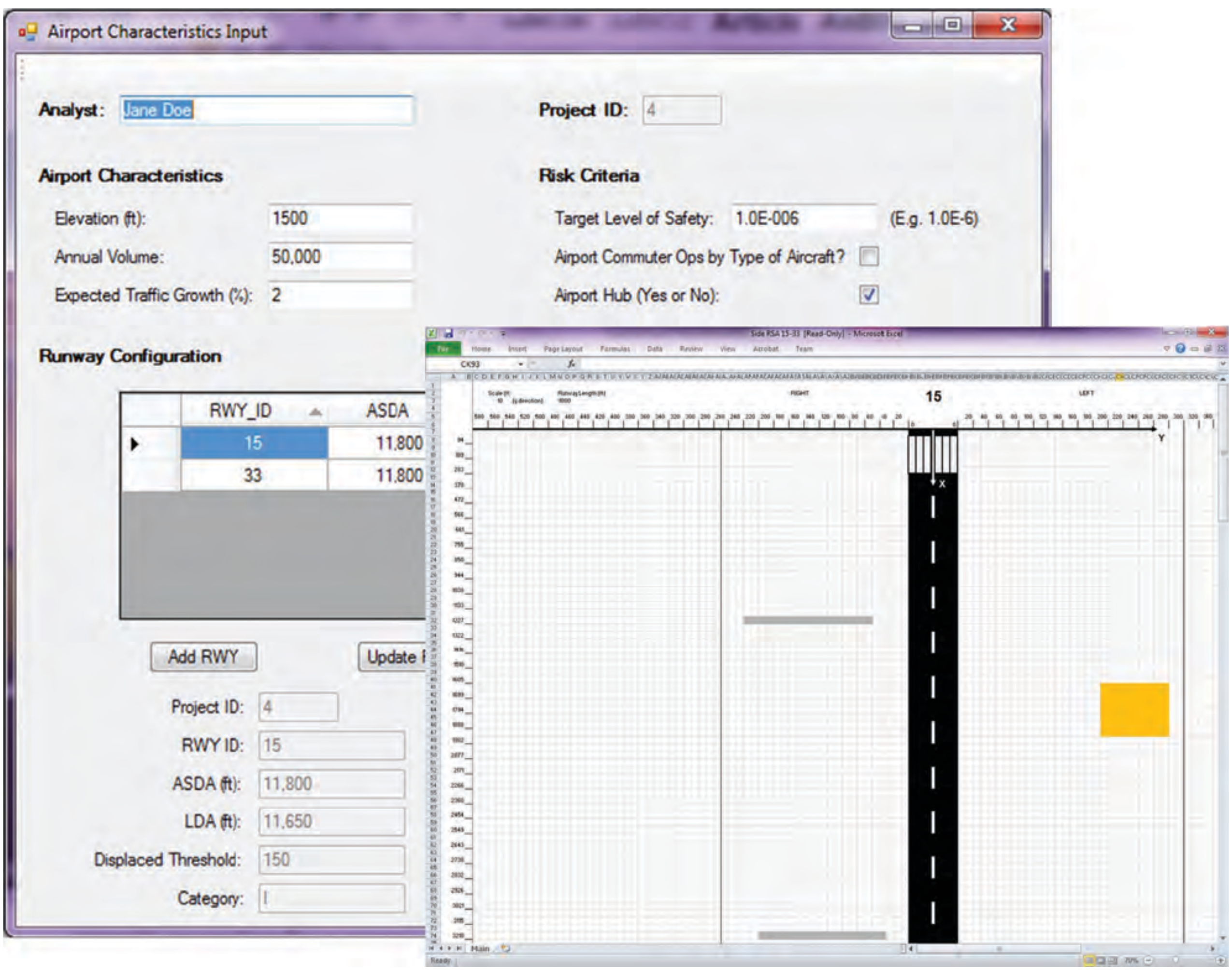


Figure 31. RSA characterization using Microsoft Excel template.

ACRP

Risk of Accident - Summary of Results

Overall Results *Risk Analysis*

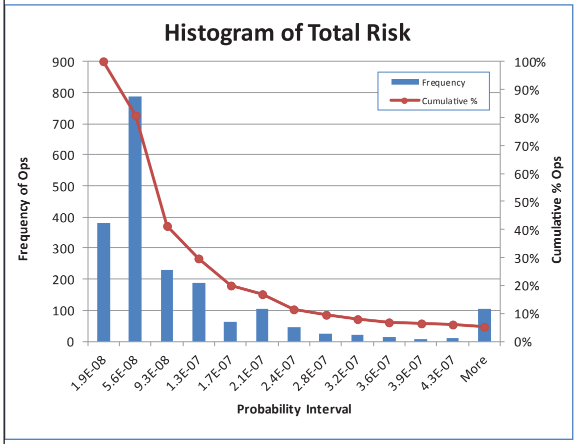
Summary Table

Accident	Average Risk of Accident	Avrg # of Years to Accident	% Ops Above TLS	Avrg # of Years to Accident for TLS
LDVO	2.0E-07	81	5.1	30
TOVO	5.8E-08	>100	0.3	30
Total	**1.2E-07**	**73**	**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: 7/12/2013
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 - The total risk for the airport is per movement (landing and taking off)
3 - Each takeoff and landing will challenge the lateral safety areas for veer-offs
4 - Histogram for the whole airport is for any type of event and includes each movement challenging the LRSA

Summary of Results by Runway

Probability of Event per Operation

Type of Accident	RSA	
	15	33
LDVO	5.78E-07	5.54E-07
TOVO	1.21E-07	1.55E-07

Risk of Accident in Events per Operation

Type of Accident	RSA	
	15	33
LDVO	1.95E-07	2.07E-07
TOVO	5.37E-08	6.21E-08

Average # of Years Between Accidents

Type of Accident	RSA	
	15	33
LDVO	>100	>100
TOVO	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA	
	15	33
LDVO	5.59	4.67
TOVO	0.18	0.38

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA	
	15	33
LDVO	447	471
TOVO	548	520
Total	995	991

Figure 32. Example output summary.

CHAPTER 7

Model Validation

The purpose of model validation was to perform an independent check to compare risk estimated with the models to historical risk rates for a sample of airports. Moreover, probability distributions used to develop the models were compared to the probability distribution generated with an independent sample of veer-off records.

A secondary goal was to validate analysis software by checking its performance, rationality, and consistency in running analyses and outputting estimated risk for given RSA and operation conditions. This chapter describes each test conducted to accomplish these goals.

Validation of Veer-Off Location Models

Mathematical models were developed to characterize the probability distributions for longitudinal and lateral distances associated with veer-off accidents and incidents. To validate these models, an independent sample of data on veer-off accidents and incidents was used to compare the distribution obtained with the models, with the probability distributions derived from the independent validation data. This section presents data used, results, statistical analyses conducted, and conclusions on validation of the runway veer-off location modeling.

Summary of Independent Sample Data

Data on veer-offs were collected prior to the modeling effort. A randomization process was used to select approximately 15% of available data, which were not used in developing the models. This independent sample was kept aside to be used during the validation effort. A summary of data used for validation is as follows:

- Period: 1983 to 2011;
- 91 accident and incident records with information on veer-off path;
- 47 veer-off accidents and 44 veer-off incidents;
- 68 veer-offs during landing and 23 veer-offs during takeoff; and
- 79 records from U.S. databases (NTSB, AIDS, and ASRS), and 12 records from international databases.

A summary of records used for validation of probability distributions is included in Appendix G.

Probability Distribution for Longitudinal Distances

Two models to characterize the probability distribution for longitudinal distances during the veer-offs were developed: one for veer-offs during landings and another model for veer-offs during takeoffs. An integrated model representing both takeoffs and landings was also developed and was used for the comparisons. The main reason in using the integrated model rather than individual models for each type of operation is the size of the independent sample. In the independent sample there are only 23 records of veer-off events during takeoffs. This number of records would be insufficient to conduct the hypothesis test proposed to compare the probability distributions.

Figure 33 presents two probability distributions for longitudinal distance. The distribution obtained during the modeling phase is represented by the white bars and the distribution for the independent sample is represented by the dark gray bars. Except for subarea 0.3, the distributions look very similar. Table 8 contains the number of veer-off occurrences in each subarea of the runway. Each subarea represents 10% of the total distance available for the operation when the veer-off occurred. It is important to note that one veer-off event may challenge more than one subarea; therefore, the number of occurrences in each subarea should not be confused with the number of veer-off events reported.

A Chi-square goodness of fit test was applied to statistically evaluate the similarities of the two distributions shown

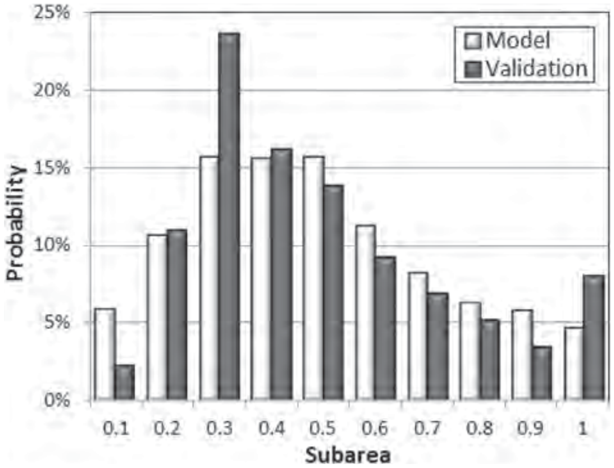


Figure 33. Longitudinal distance probability distributions: model vs. validation sample.

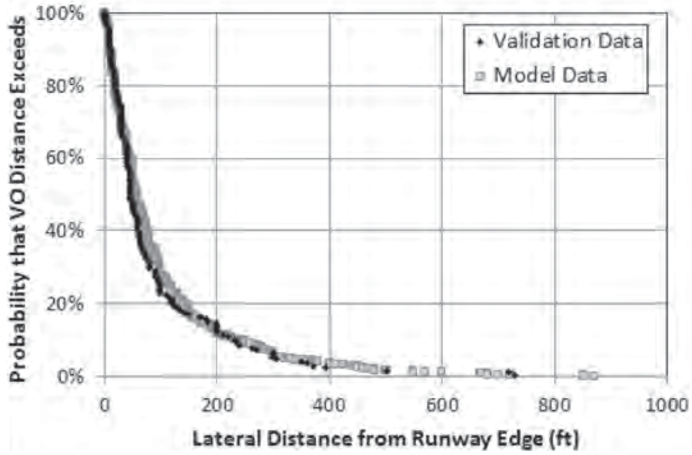


Figure 34. Probability distributions for lateral distances: model vs. validation sample.

in Figure 33. The technique is used to test the hypothesis that two probability distributions match. A p-value of 0.09 was obtained from the analysis, with acceptance of the null hypothesis of no differences, thus indicating that the two distributions may be considered statistically similar.

Probability Distribution for Lateral Distances

Modeling data for all subareas were integrated for the purpose of comparing the modeled probability distribution for lateral distances with the distribution obtained from the independent validation sample. Results are graphically summarized in Figure 34 and based on this plot, an excellent agreement was achieved between the models developed in Task 4 and the probability distribution derived from the validation data. It should be noted that integration of data for all subareas was necessary due to the very small sample sizes.

Table 8. Number of occurrences in each subarea.

Subarea	Model	Validation Sample
0.1	55	4
0.2	99	19
0.3	146	41
0.4	145	28
0.5	146	24
0.6	105	16
0.7	77	12
0.8	59	9
0.9	54	6
1	44	14

Comparison of Estimated Risk with Historical Frequency

The same eight airports used in the *ACRP Report 50* study were also used in this study to compare estimated risk with historical frequency of accidents and incidents for these airports. These airports were initially selected using random stratified sampling to screen airports for generating the sample. Only airports that did not contribute data to create the normal operations data (NOD) used in the modeling process for veer-off frequency were screened. The procedure resulted in a sample of airports with a spectrum of characteristics, from small GA airports to large hubs, and distributed over various regions of the U.S.; the estimated results obtained from analyses are compared to the actual rate of accidents at the selected group of airports. Operational and weather data for the eight airports, presented in Table 9, were collected and processed to make the data compatible with LRSARA software input format.

Lateral RSA conditions and the presence of obstacles were characterized using satellite images (Google Earth). Data for airports were collected and consolidated. Operations data were retrieved from the FAA Operations & Performance Data and Aeronautical Information Management lab. The weather data were obtained from the NOAA database for the meteorological stations serving each airport. A list of veer-off accidents and incidents identified from the sample of eight airports over the past three decades is presented in Appendix F and a summary of results of the analysis is presented in Table 10.

The expected number of years between critical events is based on the average annual volume of operations during 2011 and assuming an average annual growth rate of 2.5%. The estimates were calculated using the average level of risk

Table 9. List of airports for model/software validation.

State	Airport Name	Location ID	City	Hub
FL	Miami International	MIA	Miami	L
AK	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

Note: L = large hub, M = medium hub, s = small hub, N = non-hub, and GA = general aviation.

for the entire airport, as shown in column 5 of Table 10. The last two columns of Table 10 contain the incident type with highest chances of occurrence and the most critical runway.

Validation of Frequency Models

Comparison of the actual rate for each type of veer-off and at each airport individually would not be very helpful because these are rare events and the number of occurrences is relatively low. In addition, given the limited sample size of airports used in the validation, the analysis consisted of comparing the rates for the whole sample of eight airports. Figure 35 shows frequency rates for LDVOs and TOVOs with three different estimates: the historical frequency rate in the United States, the actual frequency 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; in other words, the risk rate for each airport was weighted for its associated annual volume of operations.

The actual rate represents the total number of veer-offs from 1981 to 2011 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 figure also presents the total probability for veer-off events compared for the three scenarios evaluated.

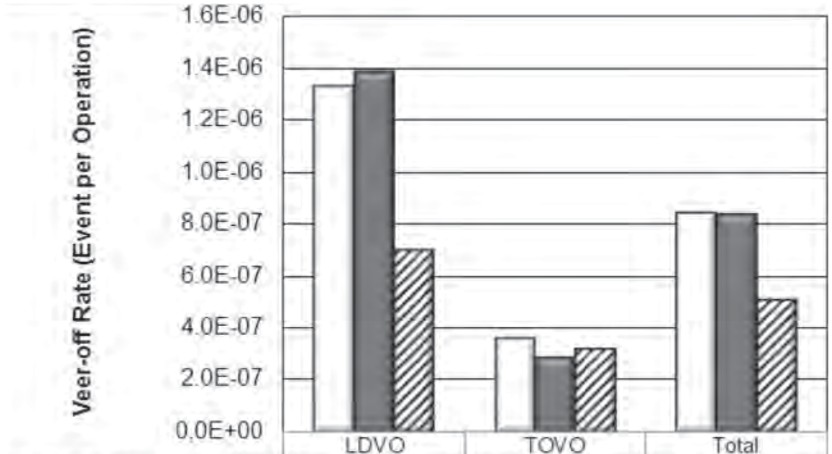
The results presented in Figure 35 demonstrate good agreement between actual accident rates for the sample of airports and the historical rate for all the airports in the United States. The results support that the sample of airports is representative of conditions for the population of airports in the United States. It can also be noted that the estimated probability for LDVOs is almost half of the U.S. historical rate and almost half the actual rate of LDVOs for the sample airports. A similar trend was observed for LDVO events in the *ACRP Report 50* study, which used the same group of eight airports. Despite the difference observed, the research team assumes that the difference may be attributed to the small sample size of eight airports used for the comparison of such rare events. The actual frequency rate of TOVOs for the eight airports agreed with the estimated frequency rates for this sample and with the U.S. historical rate of TOVOs. It is important to note that frequency rates involve both accidents and incidents, with no distinction of the level of severity.

Validation of Accident Risk Models

The second part of the validation effort consisted of the comparison of actual accident risk rates with those estimated

Table 10. Summary of analysis results for sample of airports.

Airport	State	Annual NOD in 2011	No. of Runways	Average Airport Risk	Average # of Years to Critical Veer-Off	Most Critical Runway	Airport's Most Critical Type of Incident
ANC	AK	270K	3	1.7E-07	18	07R	LDVO
CRW	WV	70K	1	4.4E-07	24	05	LDVO
DVT	AZ	190K	2	1.7E-07	23	07L	TOVO
FXE	FL	33K	2	2.4E-07	58	13	LDVO
MIA	FL	380K	4	8.4E-08	23	30	LDVO
FSD	SD	54K	2	2.3E-07	44	21	LDVO
GEG	WA	67K	2	3.2E-07	32	25	TOVO
STL	MO	191K	4	1.2E-07	31	30R	LDVO



	LDVO	TOVO	Total
US Historical	1.32E-06	3.64E-07	8.44E-07
Actual for Sample Airports	1.38E-06	2.91E-07	8.36E-07
Estimated for Sample	7.00E-07	3.26E-07	5.12E-07

Figure 35. Actual and estimated frequency of veer-offs for sample of airports.

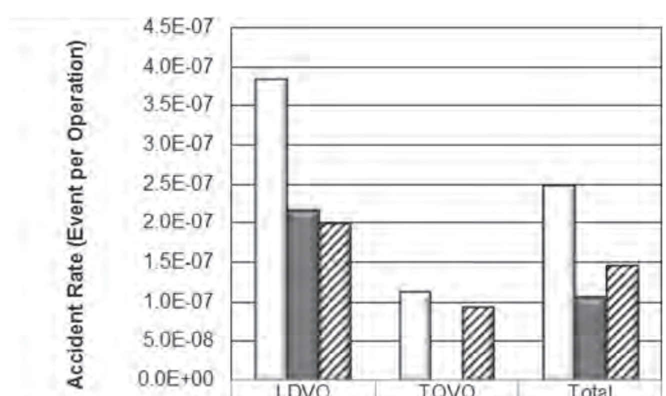
for the sample of eight airports. The estimated risk of veer-off accidents is associated with the likelihood of an accident, rather than a simple incident. According to NTSB, accident is defined as an occurrence associated with the operation of an aircraft where, as a result of the operation, any person receives fatal or serious injury or any aircraft receives substantial damage. This is also the definition used in this study to characterize an aircraft accident.

Data presented in Appendix F contain the accidents that took place at the eight sample airports from 1981 to 2011. The table includes three LDVO accidents that took place at FXE airport (two events) and STL airport (one event). The ratio between the actual number of LDVO accidents in that period divided by the volume of landings at the airports provides the actual risk of LDVOs for the airport sample. There were no TOVO accidents for the 8 airports during the analysis period; therefore, the historical rate of takeoff veer-offs for the airport sample is nil.

Similar to the validation of the frequency models, the comparison is made for LDVO and TOVO accidents, as well as for the total accident rate. Again, three types of rates were calculated for each type of accident: the estimated rate for the sample of eight airports, the actual (historical) rate for the sample of airports, and the historical rate in the U.S. The results are shown in Figure 36 in both graphical and tabular form.

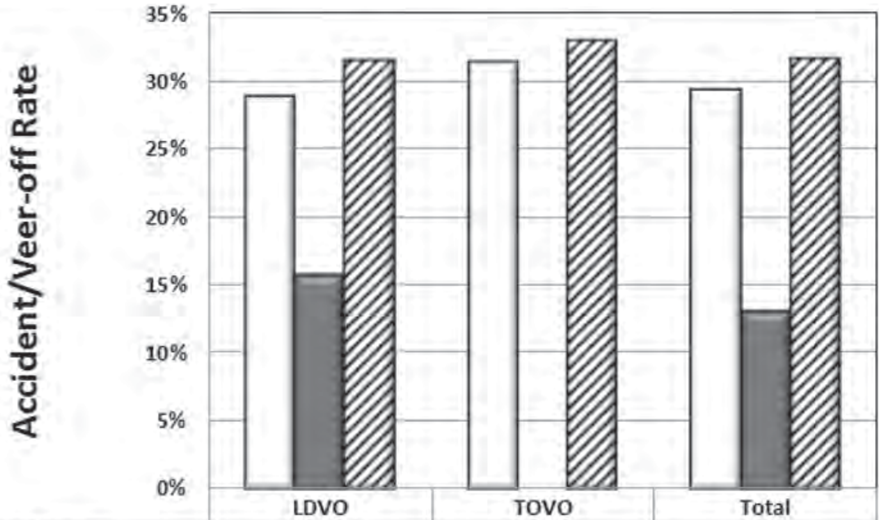
The rates for LDVO accidents are in good agreement between actual and estimated risk for the sample of airports. It may be noted that the historic risk of runway veer-off accidents is relatively higher for U.S. airports. However the estimated and actual rates are quite similar, thus indicating that the models are reflecting airport conditions for the sample of eight airports. On the other hand, the sample of airports did not include any TOVO events so the historical rate for the sample of airports is nil; however, the estimated rate of TOVOs is in good agreement with the U.S. historical rate. The number of accidents during the analysis period was 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.

Another type of analysis compared the proportion of accidents to the total number of incidents and accidents. In other words, the analysis obtained the ratio between the number of veer-off accidents and the total number of veer-offs (incidents



	LDVO	TOVO	Total
U.S. Historical	3.83E-07	1.14E-07	2.48E-07
Actual for Sample	2.18E-07	0.00E+00	1.09E-07
Estimated for Sample	2.00E-07	9.47E-08	1.47E-07

Figure 36. Actual and estimated risk of veer-off accidents for sample of airports.



	LDVO	TOVO	Total
Historical US Airports	28.9%	31.4%	29.4%
Actual for Sample 8 Airports	15.8%	0.0%	13.0%
Estimated for Sample 8 Airports	31.5%	33.0%	31.7%

Figure 37. Actual and estimated accident to incident ratios for runway veer-offs.

and accidents). This is an important parameter since it may be used to validate the consequence approach developed in this study. Similar to previous analyses, three types of ratios were calculated for LDVOs and TOVOs: the historical ratio in the U.S., the actual ratio for the sample, and the estimated ratio for the sample of eight airports. Figure 37 illustrates the findings; as shown, the estimated ratios are in good agreement with the actual historical ratios for the entire U.S. However, variations exist when comparing the actual ratio for the sample of airports because there were only three veer-off accidents at the eight airports during the 30 year period of analysis and none of them were a TOVO.

CHAPTER 8

Conclusions and Guidance

The risk of fatal aircraft accidents in the vicinity of runways is relatively large compared to those occurring in other areas of the airport. The RSA is intended to mitigate the consequences of aircraft veering off, overrunning, or undershooting a runway; RSA design standards have proven to provide good protection for these types of events.

The demand to operate larger aircraft coupled with higher traffic volumes has often resulted in airport operators being unable to meet airfield standards that were created three or four decades ago based upon engineering judgment. In many cases, adhering to these standards would be cost prohibitive due to physical, economic, and/or environmental restrictions. However, even more compelling is that adhering to the existing standards may not improve the level of safety. This has created the need to reassess the level of safety provided by these standards through the use of risk-based methodologies.

One of the current challenges with airfield design is to develop a tool to evaluate the level of safety at airports that cannot comply with current standards for RSA. ACRP Reports 3, 50 and 51 were intended to fill some of those gaps; however, a methodology to evaluate risk in certain subareas of the RSA was not available to the industry. This study attempts to fill such need with the development of models and analysis tools to allow assessing risk when RSA standards cannot be met.

Major Achievements

Updated Veer-off Accident and Incident Database

The number of aircraft veer-off events identified during this study can be helpful for additional research in this field. The comprehensive database includes 1,144 recorded events in an organized structure to facilitate its use.

The database includes veer-off events involving aircraft over 6,000 lbs of MTOW. In addition to basic information on location and date, data about the airport, the operation, and the consequences were collected when available. The veer-off pathway was characterized for approximately 50% of the records, and each report was reviewed in an attempt to identify the causes of aircraft damage to support the consequence model.

Validated Location Models to Estimate Likelihood of Aircraft Challenging Runway Safety Subareas

The objective of the model validation effort was to check if the risk estimates provided by the new models compare to historical veer-off accident rates and that probability distributions generated would be similar to those provided by an independent sample of veer-off reports.

Results obtained demonstrate excellent agreement between probability distributions given by the location models and that of the independent sample of 91 veer-off events. Also, there was good agreement between historical accident and incident rates for U.S. airports compared to the rate for a sample of eight airports, and the rate estimated from LRSARA analyses for each airport. Some differences were identified; however, these may be attributed to the small sample size and large variations expected when modeling rare events.

Finally, the validation effort has helped identify bugs in the LRSARA software and allowed them to be resolved. Several enhancements were made to the program, resulting in increased protection for inconsistent input data and improved accuracy of modeling runway veer-off risk.

The models integrated to the approach were based on evidence of worldwide veer-off accidents and incidents collected from 1982 to 2011. The models utilize a transformation to the longitudinal veer-off distance that is based on the RDA for the operation. Two other alternatives were attempted; however, more accurate results were obtained by using the selected alternative.

The resulting models provide a way to estimate the probability of veer-offs. The models also provide a way to assess risk when obstacles are present or proposed in the vicinity of the runway.

Approach Incorporating Veer-Off Location Models to Estimate Risk

In addition to developing the mathematical models for veer-off risk, an approach integrating the models in a step-by-step process was necessary to serve as the basis for the computer algorithm developed for the analysis.

The approach concept is similar to that used in previous ACRP studies and the framework is based on a three-part model: event probability, location probability, and veer-off consequences. The event probability (frequency) models are those presented in *ACRP Reports 50* and *51*. The location probability and veer-off consequences models were developed in this study. The risk-based approach introduced in this report is rational and robust, and it can be used to quantify the risk of veer-off accidents and evaluate how obstacles in the vicinity of the runway may impact the risk.

Software Tool to Analyze Lateral RSA

The standalone analysis software was named Lateral Runway Safety Area Risk Analysis (LRSARA) and combines Microsoft Access databases and Microsoft Excel spreadsheets to store and output results generated during the analysis. This concept provides user-friendly interfaces for inputting data, running the analysis, and outputting results.

There are two sources of information required for this analysis: general data and analysis-specific data. General data are requirements that apply to all analyses, such as model parameters and aircraft characteristics. Analysis-specific data are information specific to the airport and the lateral RSA to be evaluated.

The software records user input data into a project-specific database where the information can be later assessed along with the results of the analysis. Updates to general data, as well as uploads of analysis-specific data, are made through a specific software interface. There is no need for user interaction with the databases; however, the databases are also available as regular Microsoft Access files.

Outputs of the analysis results are reported in Excel spreadsheets. These spreadsheets are generated based on a predefined template. One spreadsheet for each runway in a given airport is created. The spreadsheet contains the summary probabilities of veer-off incidents and accidents. The probabilities are illustrated with graphs of accumulated risk and probability histograms. The templates for databases and spreadsheets are compatible with MS Office version 2010 and newer.

Model Limitations

The main challenge to develop the models and analysis tool presented in this report was the availability of reliable information to develop the mathematical probability models. Only approximately 10% of the accident and incident reports for events identified as veer-offs had comprehensive information about the pathway during the aircraft veer-offs, and 50% of reports contained no information that could be used to infer the veer-off path.

To overcome these limitations, it was necessary to use the report narrative and obtain information from additional sources to make inferences to characterize the veer-off pathway. These inferences can certainly have some negative impact on characterizing the exact track during the veer-off and to a lesser degree on the accuracy of the location models developed in this study.

Although some accuracy may have been lost due to the assumptions made, the information presented in this report will assist the industry in understanding the mechanisms and the relationship between risk, available safety areas, and the presence of obstacles associated with aircraft veer-off accidents and incidents. The approach will certainly improve the knowledge of the relationship between airfield design standards and the risk level involved when standards cannot be met.

Guidance

Expand the Approach to Lighter Aircraft

The prevalence of and risks associated with runway excursions have not been addressed for aircraft weighing less than 6,000 lb, in part because no effort has been made to compile a database of those excursions. Little research effort has been spent to evaluate how design standards and non-compliance issues may impact risk of runway excursions at airports.

Most aircraft with MTOW lower than 6,000 lb are operated under 14 CFR Part 91 rules, which represent close to 90% of civil aircraft registered in the United States. Many communities benefit from general aviation flights, which generate over $150 billion in economic activity (AOPA). Many of the airports used by lighter GA aircraft are not certificated and have no towers that could report incidents.

A research study using approaches similar to those presented in ACRP Reports 3, 50 and 51 would greatly benefit general aviation airports to reduce risks of runway excursions and improve aviation safety in the United States.

Improve Veer-Off Reporting

The FAA has recently adopted a Safety Management Systems (SMS) approach to aviation safety. In this approach, one needs to identify risks and then take measures to mitigate those risks. FAA Order 8000.369A furthers safety management by moving towards a more process-oriented system safety approach with an emphasis on risk management and safety assurance.

Comprehensive information required to identify the stopping location and veer-off path of the runway veer-offs is seldom explicitly available in accident and incident reports, except for major accidents for which a full investigation report was developed.

This study identified some gaps in veer-off reporting in existing aviation databases. These gaps are related to information required to develop risk models for veer-off events and the suggestions provided are intended to enhance data collection to improve accuracy of risk models.

The main suggestion is to report information to characterize the veer-off path. It can be a drawing or a picture showing the veer-off path, or a narrative describing the incident. A template was created and is presented in Appendix A. It helps the reporter identify key information that may be provided in narrative format. The gaps in information made available in veer-off events reported were identified for the three main aviation accident and incident databases available in the U.S. Filling those gaps may be beneficial to improve accuracy of existing models.

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Abbreviations & Acronyms

AAIB	UK Air Accidents Investigation Branch
AAIBS	Air Accident Investigation Bureau of Singapore
AAIU	Ireland Air Accident Investigation Unit
ADG	Airplane Design Group
AIDS	FAA Accident/Incident Data System
AOPA	Aircraft Owners and Pilots Association
ASDA	Accelerate-Stop Distance Available
ASRS	FAA/NASA Aviation Safety Reporting System
ATC	Air Traffic Control
ATSB	Australian Transport Safety Bureau
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CIAIAC	Comisión de Investigación de Accidentes e Incidentes de Aviación Civil
DSB	Dutch Safety Board
FAR	Federal Aviation Regulation
FOD	Foreign Object Debris
GA	General Aviation
ICAO	International Civil Aviation Organization
ISO	International Organization for Standardization
kn	Knot
LDA	Landing Distance Available
LDVO	Landing Veer-Off
LRSARA	Lateral Runway Safety Area Risk Assessment 1.0 (software tool)
MTOW	Maximum Takeoff Weight
NASA	National Aeronautics and Space Administration
NASB	Netherlands Aviation Safety Board
NAVAID	Navigational Aid
NOAA	National Oceanic and Atmospheric Administration
NOD	Normal Operations Data
NTSC	Indonesia National Transportation Safety Committee
RDA	Runway Distance Available
RDR	Runway Distance Required
OD	Origin/Destination
ROFA	Runway Object Free Area
RSA	Runway Safety Area

SACAA	South African Civil Aviation Authority
SM	Statute Miles
TAIC	New Zealand Transport Accident Investigation Commission
TLS	Target Level of Safety
TOVO	Takeoff Veer-off
TSBC	Transportation Safety Board of Canada
VOR	VHF Omnidirectional Range

Glossary

The terms as used in this report are defined as follows:

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

Aircraft Accident: occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage (source: NTSB).

Aircraft Incident: an occurrence, other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations (source: NTSB).

Beginning of the Runway: for takeoffs, this is the point on the runway where takeoffs may start. For landings, this area starts at the landing threshold. The beginning of the runway for takeoffs and landings normally coincide with each other except when the threshold is displaced or when a takeoff takes place at a taxiway intersection.

Consequence: the direct effect of an event, incident, or accident. In this study, 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.

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 1x10-7).

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

METAR: aviation routine weather report.

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 *ACRP Report 50* to represent the relationship between the runway distance available for that operation (landing or takeoff), and the runway distance required by a given aircraft and specific operational conditions. Runway criticality is represented mathematically by the ratio between the runway distance available and the runway distance required. A lower ratio means a lower safety margin and greater operation criticality (note: this definition is a correction to that presented in *ACRP Report 50*).

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.

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.

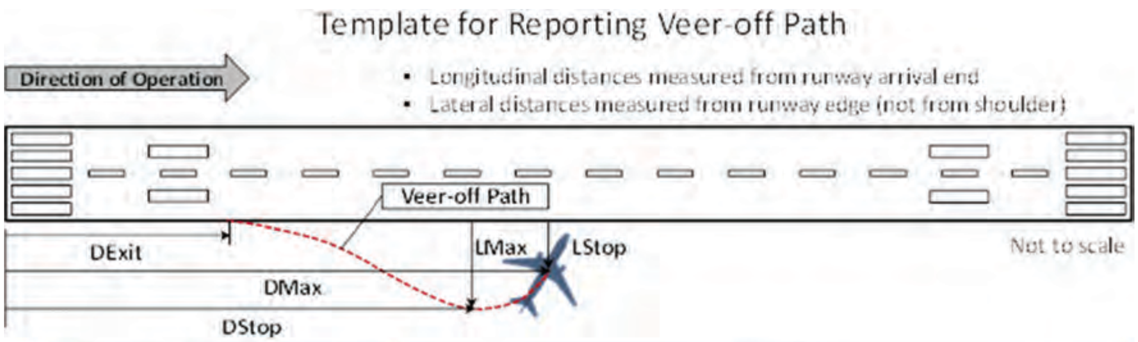
Substantial Damage: damage or failure that adversely affects the structural strength, performance, or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected component.

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.

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

APPENDIX A

Template for Veer-Off Reporting



Parameter	Example
Aircraft Model (Amod)	B728, A311
Airport Code (Acode)	IATA Code (e.g. GYK)
Date and Time (D&T)	04/15/2007 @ 15:23 Local
Runway Used (RWY)	RWY 23
Type of Operation (TOp)	Landing or Takeoff
Runway Surface Condition (RSC)	Dry, Damp, Wet, Water Patches, Flooded, Snow, Ice, Slush covered
DBR	Distance for beginning of roll (e.g. touchdown distance for landing)
LBR	Lateral distance, if touchdown occurred off the runway
DExit	Longitudinal distance where aircraft departed the runway during the roll
Dmax	Longitudinal distance to maximum lateral distance of veer-off
LMax	Maximum lateral veer-off distance
DStop	Longitudinal distance where aircraft stopped after the veer-off
LStop	Lateral distance where aircraft stopped after veer-off
Runway Side (RSide)	Runway side where veer-off occurred, right or left

Typical Lateral Runway Excursion Paths

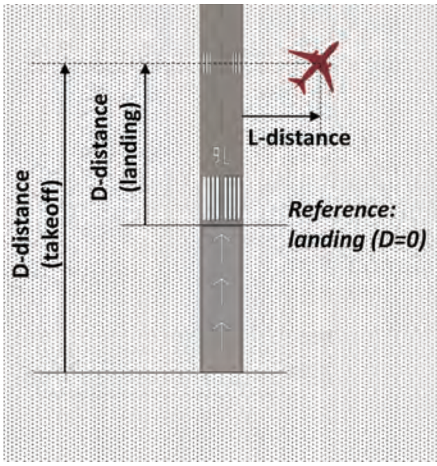


Figure A1. Location references.

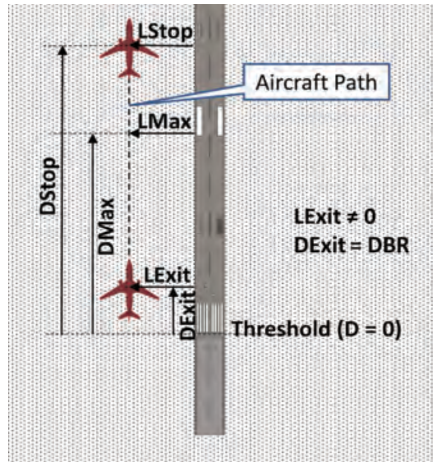


Figure A2. Touchdown off the Runway.

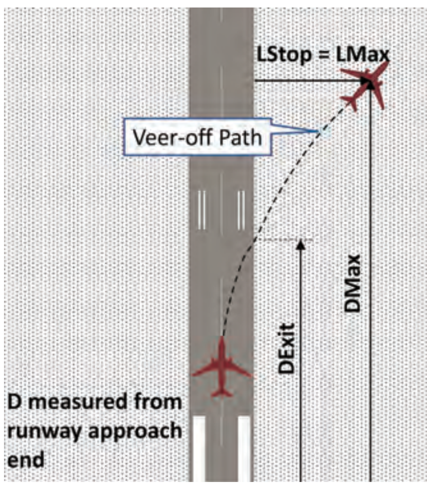


Figure A3. Typical veer-off Path.

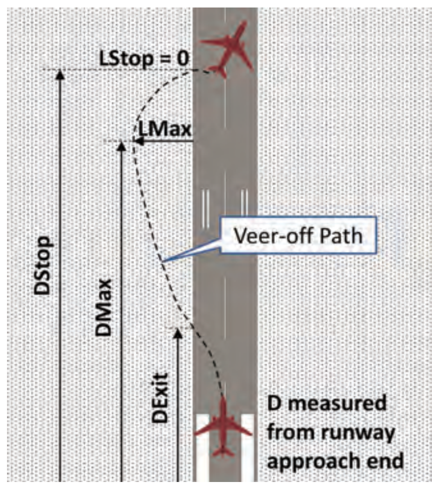


Figure A4. Veer-off with aircraft back to runway.

APPENDIX B

Summary of Accidents and Incidents for Modeling

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
1	01-Oct-98	US	DENVER	CO	AIDS	Landing	Incident
2	15-Nov-03	US	UNKNOWN	US	ASRS	Takeoff	Incident
3	01-Feb-02	US	LYNCHBURG	VA	ASRS	Landing	Incident
4	27-Oct-06	US	LOUISVILLE	KY	AIDS	Landing	Incident
5	03-Aug-95	US	PORTLAND	OR	NTSB	Landing	Accident
6	25-Jul-11	UK	SOUTH YORKSHIRE		AAIB	Landing	Incident
7	19-Jan-08	US	DILLINGHAM	AK	AIDS	Landing	Incident
8	26-Jan-78	US	FLINT	MI	AIDS	Landing	Incident
9	24-Jul-09	US	DAYTON	OH	NTSB	Landing	Accident
10	01-Mar-83	US	HOUSTON	TX	AIDS	Landing	Incident
11	01-May-09	US	NA	NA	ASRS	Takeoff	Incident
12	15-Jul-06	US	UNKNOWN	US	ASRS	Landing	Incident
13	23-Oct-95	US	SAN JUAN	PR	AIDS	Landing	Incident
14	27-Jul-85	US	MANAHAWKIN	NJ	NTSB	Landing	Accident
15	16-Sep-95	US	CHARLESTON	SC	AIDS	Landing	Incident
16	28-May-03	US	BISMARCK	ND	AIDS	Takeoff	Incident
17	02-Jul-96	US	RAMONA	CA	NTSB	Landing	Accident
18	18-Aug-03	US	ST AUGUSTINE	FL	MITRE	Takeoff	Accident
19	23-May-80	US	LUMBERTON	NC	AIDS	Takeoff	Incident
20	13-Aug-94	US	SANTA FE	NM	AIDS	Landing	Incident
21	01-Nov-09	US	NA	NA	ASRS	Landing	Incident
22	14-May-97	US	ARCATA	CA	AIDS	Landing	Incident
23	14-Feb-08	US	GREENSBORO	NC	AIDS	Takeoff	Incident
24	07-Nov-97	US	PORTLAND	OR	NTSB	Takeoff	Accident
25	19-Dec-98	US	CO SPRINGS	CO	AIDS	Takeoff	Incident
26	01-Jun-93	US	GRAND RAPIDS	MI	ASRS	Takeoff	Incident
27	24-Sep-99	US	CHICAGO	IL	AIDS	Takeoff	Incident
28	04-Mar-07	US	FAYETTEVILLE	AR	AIDS	Landing	Incident
29	15-Sep-03	US	UNKNOWN	MS	ASRS	Landing	Incident
30	06-Oct-05	US	HAYDEN	CO	AIDS	Landing	Incident
31	10-Apr-91	US	RICHMOND	VA	AIDS	Landing	Incident
32	20-Dec-08	US	DENVER	CO	NTSB	Takeoff	Accident
33	20-Feb-90	US	CHICAGO	IL	AIDS	Landing	Incident
34	01-Sep-10	US	PICKENS	SC	ASRS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
35	03-Jan-94	US	CLEVELAND	OH	MITRE	Landing	Accident
36	15-Jun-00	US	UNKNOWN	AL	ASRS	Landing	Incident
37	28-Aug-01	US	CHICAGO	IL	MITRE	Takeoff	Accident
38	01-Nov-93	US	MINNEAPOLIS	MN	ASRS	Landing	Incident
39	01-Jun-04	US	LANCASTER	PA	ASRS	Takeoff	Incident
40	21-May-99	US	SOUTH BEND	IN	AIDS	Landing	Incident
41	22-Dec-09	US	MOAB	UT	NTSB	Takeoff	Accident
42	05-Dec-85	US	LAFAYETTE	IN	AIDS	Landing	Incident
43	21-Sep-02	US	CHICAGO	IL	AIDS	Takeoff	Incident
44	01-Dec-92	US	KANSAS CITY	MO	ASRS	Landing	Incident
45	17-Dec-00	US	FARMINGDALE	NY	AIDS	Landing	Accident
46	21-Nov-04	US	DENVER	CO	AIDS	Landing	Incident
47	15-Sep-05	US	UNKNOWN	TX	ASRS	Takeoff	Incident
48	01-May-03	US	DETROIT	MI	ASRS	Landing	Incident
49	20-Dec-96	US	DENVER	CO	AIDS	Landing	Incident
50	15-Sep-04	US	UNKNOWN	KS	ASRS	Landing	Incident
51	01-Mar-00	US	NORFOLK	VA	ASRS	Landing	Incident
52	11-Jan-83	US	MADISON	GA	NTSB	Takeoff	Accident
53	03-Feb-82	US	DETROIT	MI	AIDS	Takeoff	Incident
54	12-Apr-92	US	ALBANY	NY	AIDS	Landing	Incident
55	20-Feb-06	US	CASPER	WY	NTSB	Takeoff	Incident
56	17-Mar-89	US	CHICAGO	IL	AIDS	Landing	Incident
57	21-Aug-86	US	INDIAN HEAD	MD	NTSB	Landing	Accident
58	28-Aug-01	US	WEST CHICAGO	IL	NTSB	Takeoff	Accident
59	23-Aug-07	US	WESTHAMPTON	NY	NTSB	Landing	Accident
60	20-Jan-05	CANADA	CALGARY	ALBERTA	CANADA TSB	Landing	Incident
61	01-May-96	US	DENVER	CO	AIDS	Landing	Incident
62	08-Feb-88	US	SPRINGFIELD	IL	AIDS	Takeoff	Incident
63	18-Mar-98	US	DENVER	CO	AIDS	Landing	Incident
64	01-Jan-10	US	NA	NA	ASRS	Landing	Incident
65	28-Mar-02	US	JACKSON	WY	AIDS	Landing	Incident
66	01-Jan-10	US	DALLAS	TX	ASRS	Landing	Incident
67	15-Feb-00	US	ESCANABA	MI	NTSB	Landing	Accident
68	29-Jan-04	US	HUNTSVILLE	AL	AIDS	Landing	Incident
69	01-Apr-09	US	NA	NA	ASRS	Landing	Incident
70	30-Jan-98	US	MISSOULA	MT	AIDS	Takeoff	Incident
71	08-Dec-02	US	NEW ORLEANS	LA	AIDS	Takeoff	Incident
72	17-Dec-98	US	TRAVERSE CITY	MI	NTSB	Landing	Accident
73	03-Jan-09	US	TELLURIDE	CO	NTSB	Landing	Accident
74	24-Dec-83	US	BIG PINEY	WY	NTSB	Landing	Accident
75	01-Nov-95	US	LEWISTON	ID	ASRS	Landing	Incident
76	19-Jan-10	US	SIOUX CITY	IA	NTSB	Landing	Accident
77	18-Aug-95	US	COLUMBUS	OH	AIDS	Landing	Incident
78	01-Jun-09	US	NA	NA	ASRS	Landing	Incident
79	09-Apr-08	US	OKLAHOMA CITY	OK	AIDS	Landing	Incident
80	01-Nov-88	US	OCRACOKE	NC	ASRS	Takeoff	Incident
81	08-Feb-85	US	SPOKANE	WA	NTSB	Landing	Accident
82	29-Sep-00	US	SHOW LOW	AZ	AIDS	Landing	Incident
83	29-Mar-09	US	SALT LAKE CITY	UT	NTSB	Landing	Accident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
84	08-May-00	US	NANTUCKET	MA	AIDS	Landing	Incident
85	01-Jun-98	US	LYNCHBURG	VA	ASRS	Landing	Incident
86	05-Mar-97	US	CLEVELAND	OH	NTSB	Landing	Accident
87	01-Jan-01	US	GARDEN CITY	KS	ASRS	Landing	Incident
88	08-Mar-03	US	KINSTON	NC	MITRE	Landing	Accident
89	17-Jul-95	US	ALLENTOWN	PA	AIDS	Landing	Incident
90	14-Mar-97	US	CONCORD	NH	AIDS	Takeoff	Incident
91	01-Apr-11	US	NA	NA	ASRS	Landing	Incident
92	06-Mar-89	US	JOHNSTOWN	PA	NTSB	Landing	Accident
93	09-Feb-07	S. AFRICA	PRETORIA	NA	SACAA	Landing	Accident
94	10-Jan-96	US	HYANNIS	MA	AIDS	Takeoff	Incident
95	01-Sep-10	US	NA	NA	ASRS	Takeoff	Incident
96	28-Jan-05	US	KANSAS CITY	MO	AIDS	Landing	Incident
97	04-Sep-98	US	SPRINGDALE	AR	AIDS	Landing	Incident
98	11-Nov-06	US	INDIANAPOLIS	IN	AIDS	Landing	Incident
99	10-Mar-06	US	DALLAS	TX	AIDS	Landing	Incident
100	01-Feb-08	US	MORRISTOWN	NJ	AIDS	Landing	Incident
101	21-Feb-05	CANADA	BROMONT	QUEBEC	CANADA TSB	Landing	Accident
102	13-Oct-82	US	ATLANTA	GA	AIDS	Landing	Incident
103	08-Mar-08	US	MILWAUKEE	WI	AIDS	Landing	Incident
104	24-Feb-07	US	DALLAS	TX	NTSB	Landing	Incident
105	12-Jan-09	US	CHICAGO	IL	AIDS	Landing	Incident
106	05-Feb-86	US	PHILADELPHIA	PA	AIDS	Takeoff	Incident
107	24-Jul-95	US	BINGHAMTON	NY	AIDS	Landing	Incident
108	14-Jan-99	US	YOUNGSTOWN	OH	NTSB	Landing	Accident
109	30-Jan-06	US	LAS VEGAS	NV	CANADA TSB	Takeoff	Incident
110	07-Feb-86	US	BRIGHAM CITY	UT	AIDS	Takeoff	Incident
111	01-Jul-96	US	DETROIT	MI	ASRS	Landing	Incident
112	08-Jan-98	US	CHICAGO	IL	AIDS	Landing	Incident
113	13-Dec-94	US	CHICAGO	IL	AIDS	Landing	Incident
114	01-Feb-11	US	NA	NA	ASRS	Takeoff	Incident
115	01-Jun-89	US	FRESNO	CA	ASRS	Landing	Incident
116	01-Nov-09	US	NA	NA	ASRS	Landing	Incident
117	17-Aug-90	US	NANTUCKET	MA	AIDS	Takeoff	Incident
118	07-Jul-94	US	LAS VEGAS	NV	AIDS	Landing	Incident
119	01-Mar-01	US	DENVER	CO	ASRS	Landing	Incident
120	26-Apr-91	US	TETERBORO	NJ	AIDS	Takeoff	Incident
121	26-Dec-87	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
122	26-May-08	US	EVERETT	WA	AIDS	Takeoff	Incident
123	13-Jan-09	US	KODIAK	AK	AIDS	Landing	Incident
124	05-Aug-98	US	BEND	OR	AIDS	Landing	Incident
125	11-Nov-07	US	KANSAS CITY	MO	AIDS	Takeoff	Incident
126	07-Mar-95	US	TUPELO	MS	AIDS	Landing	Incident
127	26-May-11	US	SELLERSBURG	IN	AIDS	Takeoff	Incident
128	03-Aug-93	US	NORFOLK	VA	NTSB	Landing	Accident
129	18-May-06	US	FAIRBANKS	AK	AIDS	Landing	Incident
130	05-Feb-05	US	MURRIETA	CA	NTSB	Landing	Accident
131	20-Jun-04	US	MT. VERNON	IL	NTSB	Landing	Accident
132	05-Jan-01	US	ATLANTA	GA	ASRS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
133	22-Feb-98	US	LAWTON	OK	MITRE	Landing	Incident
134	01-May-91	US	DENVER	CO	ASRS	Landing	Incident
135	19-Jan-10	US	SIOUX CITY	IA	NTSB	Landing	Accident
136	01-Jul-86	US	WEST CHICAGO	IL	AIDS	Landing	Incident
137	08-Jun-94	US	BECKLEY	WV	AIDS	Landing	Incident
138	15-Jan-82	US	ATLANTA	GA	AIDS	Landing	Incident
139	27-Mar-09	US	RIVERSIDE	CA	AIDS	Landing	Incident
140	25-Jan-97	US	HAYDEN	CO	AIDS	Takeoff	Incident
141	13-Dec-84	US	CORTEZ	CO	NTSB	Takeoff	Accident
142	27-Jul-06	US	LOUISVILLE	KY	AIDS	Takeoff	Incident
143	22-Feb-97	US	AUSTIN	TX	AIDS	Takeoff	Incident
144	15-Mar-00	US	SAN ANTONIO	TX	NTSB	Landing	Accident
145	20-Oct-01	US	COLUMBUS	NE	NTSB	Takeoff	Accident
146	15-Sep-00	US	UNKNOWN	US	ASRS	Landing	Incident
147	12-Feb-06	US	NEW YORK	NY	AIDS	Landing	Incident
148	15-May-08	US	UNKNOWN	US	ASRS	Takeoff	Incident
149	01-Dec-93	US	PHILADELPHIA	PA	ASRS	Takeoff	Incident
150	31-Mar-04	BAHAMAS	WALKER'S CAY	BAHAMAS	NTSB	Landing	Accident
151	26-Sep-00	US	CHARLOTTE	NC	MITRE	Landing	Accident
152	11-Apr-07	US	WHEELING	IL	NTSB	Takeoff	Accident
153	28-Oct-99	US	ANGEL FIRE	NM	NTSB	Landing	Accident
154	25-Nov-97	US	BILLINGS	MT	NTSB	Landing	Accident
155	29-Nov-86	PR	SAN JUAN	PR	NTSB	Takeoff	Accident
156	24-Jan-04	SINGAPORE	CHANGI		SING. AAI	Landing	Incident
157	18-Dec-10	UK	ORKNEY ISLANDS,	SCOTLAND	AAIB	Landing	Incident
158	24-Feb-94	US	TETERBORO	NJ	AIDS	Landing	Incident
159	01-Dec-90	US	NEWARK	NJ	ASRS	Takeoff	Incident
160	25-Oct-84	US	SUGAR LAND	TX	AIDS	Takeoff	Incident
161	29-Sep-02	US	HAWTHORNE	CA	NTSB	Takeoff	Accident
162	22-Dec-06	US	MOSINEE	WI	NTSB	Landing	Accident
163	01-May-92	US	WAYNE	NE	ASRS	Landing	Incident
164	20-Apr-96	US	ALBUQUERQUE	NM	AIDS	Landing	Incident
165	08-Apr-82	US	TETERBORO	NJ	AIDS	Landing	Incident
166	13-Aug-06	UK	MIDDLESEX		AAIB	Landing	Accident
167	07-Feb-05	US	COLUMBUS	OH	AIDS	Landing	Incident
168	30-Jun-98	UK	STANSTED	ESSEX	AAIB	Takeoff	Incident
169	31-Aug-04	CANADA	MONCTON	NB	CANADA TSB	Landing	Incident
170	14-Jan-04	US	SAINT LOUIS	MO	AIDS	Landing	Incident
171	31-Oct-91	US	WICHITA	KS	AIDS	Takeoff	Incident
172	15-Jul-11	UK	SURREY		AAIB	Landing	Incident
173	01-Jan-91	US	INDIANAPOLIS	IN	ASRS	Landing	Incident
174	13-Mar-02	US	SALT LAKE CITY	UT	AIDS	Landing	Incident
175	06-Aug-00	US	WEST MILFORD	NJ	NTSB	Landing	Accident
176	09-Jul-88	US	LEXINGTON	MO	NTSB	Landing	Accident
177	04-Dec-04	US	MC ALLEN	TX	MITRE	Landing	Accident
178	01-Nov-98	US	ATLANTA	GA	NTSB	Landing	Accident
179	27-Apr-06	AUSTRALIA	MABUIAG ISLAND		ATSB	Landing	Incident
180	14-Oct-88	US	ANCHORAGE	AK	AIDS	Landing	Incident
181	01-Dec-90	US	LOVINGTON	NM	ASRS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
182	15-Jun-05	US	CHARLOTTE AMALIE	VI	AIDS	Landing	Incident
183	22-Dec-00	US	HOLLAND	MI	AIDS	Landing	Incident
184	04-Sep-78	US	ANGIER	NC	AIDS	Landing	Incident
185	22-Nov-02	US	FORT LAUDERDALE	FL	AIDS	Landing	Accident
186	29-Jan-79	US	INDEPENDENCE	KS	AIDS	Landing	Incident
187	04-Jan-00	US	JACKSON	WY	NTSB	Landing	Accident
188	06-Nov-86	US	BEDFORD	MA	AIDS	Landing	Incident
189	03-Jan-94	US	ORLANDO	FL	ASRS	Takeoff	Incident
190	01-Mar-92	US	BLUEFIELD	WV	ASRS	Takeoff	Incident
191	01-Dec-91	US	ERIE	PA	ASRS	Landing	Incident
192	06-Sep-93	US	OAK GROVE	LA	NTSB	Landing	Accident
193	25-Jan-94	US	LEXINGTON	KY	AIDS	Landing	Incident
194	28-Nov-97	UK	EAST MIDLANDS		AAIB	Takeoff	Incident
195	26-Mar-05	US	EL PASO	TX	AIDS	Landing	Incident
196	04-Dec-90	US	SUMMERVILLE,	WV	NTSB	Landing	Accident
197	31-Jan-85	US	DENVER	CO	AIDS	Landing	Incident
198	08-Nov-98	US	AMARILLO	TX	AIDS	Landing	Incident
199	05-Jul-96	US	MOULTONBORO	NH	AIDS	Landing	Incident
200	22-Mar-83	US	ULYSSES	KS	AIDS	Landing	Incident
201	04-Apr-79	US	VANDALIA	OH	AIDS	Landing	Incident
202	21-Feb-93	US	BELLINGHAM	WA	AIDS	Landing	Incident
203	04-Jan-05	US	CLEVELAND	OH	MITRE	Landing	Accident
204	23-Mar-05	US	BRIGHAM CITY	UT	AIDS	Landing	Incident
205	01-Oct-80	UK	SAINT PETER	JERSEY	AAIB	Landing	Accident
206	31-Jul-88	US	SAINT LOUIS	MO	AIDS	Landing	Incident
207	19-Jul-91	US	ALBUQUERQUE	NM	NTSB	Takeoff	Accident
208	15-Mar-02	US	UNKNOWN	IL	ASRS	Takeoff	Incident
209	23-Nov-81	US	SAINT PAUL	MN	AIDS	Landing	Incident
210	21-Aug-05	US	READINGTON	NJ	NTSB	Landing	Accident
211	15-Jan-08	US	KENOSHA	WI	AIDS	Landing	Incident
212	15-Jul-03	US	UNKNOWN	OH	ASRS	Takeoff	Incident
213	01-Dec-09	US	NA	NA	ASRS	Landing	Incident
214	20-Oct-94	US	DYERSBURG	TN	AIDS	Landing	Incident
215	05-Sep-82	UK	STANSTED	UTTLESFORD	AAIB	Landing	Incident
216	01-Sep-95	US	DENVER	CO	AIDS	Takeoff	Incident
217	05-Dec-80	US	ISLIP	NY	AIDS	Landing	Incident
218	01-Mar-09	US	NA	NA	ASRS	Landing	Incident
219	01-Dec-89	US	SOUTH BEND	IN	ASRS	Landing	Incident
220	01-Dec-00	US	ATLANTA	GA	ASRS	Landing	Incident
221	14-Dec-87	US	CHICAGO	IL	AIDS	Landing	Incident
222	08-Feb-09	FRANCE	PARIS		BEA	Landing	Incident
223	24-Mar-87	US	DALLAS	TX	NTSB	Takeoff	Accident
224	31-Jan-85	US	HUNTINGTON	WV	NTSB	Takeoff	Accident
225	15-Apr-07	US	UNKNOWN	US	ASRS	Landing	Incident
226	17-Nov-95	US	BRENHAM	TX	AIDS	Landing	Incident
227	20-Mar-97	US	HAILEY	ID	MITRE	Landing	Accident
228	01-Sep-03	US	RICHMOND	VA	ASRS	Landing	Incident
229	09-Aug-05	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
230	03-Sep-88	US	SOUTH SAINT PAUL	MN	AIDS	Takeoff	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
231	01-Dec-91	US	SAN DIEGO	CA	ASRS	Takeoff	Incident
232	19-Mar-04	US	UTICA	NY	MITRE	Landing	Accident
233	28-Aug-93	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
234	04-Jan-05	US	CLEVELAND	OH	NTSB	Landing	Accident
235	05-Oct-90	US	MINNEAPOLIS	MN	NTSB	Landing	Accident
236	15-Feb-03	US	MARIETTA	GA	AIDS	Landing	Incident
237	18-May-82	US	GILLETTE	WY	NTSB	Landing	Incident
238	10-Jan-92	US	COEUR D'ALENE	ID	AIDS	Landing	Incident
239	05-Feb-08	US	ANKENY	IA	NTSB	Takeoff	Accident
240	07-Apr-01	US	ANCHORAGE	AK	AIDS	Takeoff	Incident
241	29-Oct-88	US	ASPEN	CO	NTSB	Takeoff	Accident
242	01-May-97	US	ONTARIO	CA	AIDS	Takeoff	Incident
243	18-Mar-98	US	SHOW LOW	AZ	NTSB	Takeoff	Accident
244	09-Aug-01	US	SANDERSVILLE	GA	NTSB	Landing	Accident
245	15-May-00	US	UNKNOWN	UT	ASRS	Takeoff	Incident
246	04-Dec-03	US	SAN DIEGO	CA	NTSB	Landing	Accident
247	15-May-06	US	UNKNOWN	IL	ASRS	Landing	Incident
248	22-May-07	US	KOKOMO	IN	NTSB	Landing	Accident
249	01-Jan-91	US	SIBLEY	IA	ASRS	Takeoff	Incident
250	08-Nov-83	US	FRANKLIN	PA	NTSB	Landing	Accident
251	27-Dec-96	US	MENOMINEE	MI	NTSB	Landing	Accident
252	10-Jun-93	US	WONDER LAKE	IL	NTSB	Landing	Accident
253	13-Aug-97	US	SEATTLE	WA	MITRE	Landing	Accident
254	08-Nov-95	US	SAGINAW	MI	AIDS	Landing	Incident
255	16-Feb-09	US	SOLDOTNA	AK	NTSB	Landing	Accident
256	29-Nov-94	US	SPOKANE	WA	AIDS	Takeoff	Incident
257	17-Jan-11	UK	ALDERNEY	CHANNEL ISLDS	AAIB	Landing	Incident
258	12-Sep-05	NETHERLANDS	ROTTERDAM		NETH. TSB	Landing	Incident
259	02-Mar-93	US	CHESTERFIELD	MO	NTSB	Landing	Accident
260	01-Jan-92	US	DAYTON	OH	ASRS	Landing	Incident
261	25-Oct-85	US	MONTEREY	CA	AIDS	Landing	Incident
262	17-Aug-06	US	GRAIN VALLEY	MO	NTSB	Landing	Accident
263	20-Dec-95	US	JAMAICA	NY	NTSB	Takeoff	Accident
264	29-Jan-85	US	DOBBINS AFB	GA	NTSB	Landing	Accident
265	24-Sep-84	US	TITUSVILLE	PA	NTSB	Landing	Accident
266	28-Feb-09	SINGAPORE	SINGAPORE		SING. AAI	Landing	Incident
267	18-Jun-08	S. AFRICA	JOHANNESBURG	GAUTENG	SACAA	Landing	Accident
268	06-Jan-99	US	PLYMOUTH	IN	NTSB	Landing	Accident
269	09-Mar-01	US	DENVER	CO	AIDS	Landing	Incident
270	04-Apr-07	US	KNOXVILLE	TN	AIDS	Landing	Incident
271	13-Jan-88	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
272	19-Apr-00	US	HYANNIS	MA	AIDS	Landing	Incident
273	19-Jul-91	US	BOONE	NC	AIDS	Landing	Incident
274	01-Aug-93	US	LOUISVILLE	KY	ASRS	Landing	Incident
275	10-Dec-90	US	INDIANAPOLIS	IN	AIDS	Landing	Incident
276	20-Feb-01	US	MANASSAS	VA	AIDS	Landing	Incident
277	24-May-08	US	NA	FL	AIDS	Landing	Incident
278	18-May-00	US	BARBADOS		NTSB	Landing	Incident
279	06-Feb-04	US	KANSAS CITY	MO	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
280	01-Apr-98	US	LAS VEGAS	NV	AIDS	Landing	Incident
281	17-Mar-81	US	TUCSON	AZ	AIDS	Landing	Incident
282	27-Jul-96	US	SAINT PAUL	MN	AIDS	Landing	Incident
283	12-Apr-08	US	POTSDAM	NY	NTSB	Landing	Accident
284	01-Sep-91	US	AURORA	IL	ASRS	Landing	Incident
285	04-Dec-91	US	WHEELING	IL	NTSB	Landing	Accident
286	22-Jan-99	US	PONTIAC	MI	AIDS	Landing	Incident
287	02-Oct-80	US	CLEVELAND	OH	AIDS	Landing	Incident
288	15-Feb-00	US	UNKNOWN	VA	ASRS	Landing	Incident
289	03-Jan-97	UK	LIVERPOOL		AAIB	Landing	Accident
290	01-Jan-96	US	ATLANTA	GA	ASRS	Landing	Incident
291	15-Mar-88	US	TETERBORO	NJ	AIDS	Landing	Incident
292	24-Sep-90	US	TWIN FALLS	ID	NTSB	Takeoff	Accident
293	20-Feb-85	US	HIBBING	MN	NTSB	Landing	Accident
294	06-Sep-85	US	COLUMBIA	SC	NTSB	Landing	Accident
295	05-Sep-78	US	LAFAYETTE	IN	AIDS	Landing	Incident
296	11-Nov-95	US	ROMEO	MI	NTSB	Landing	Accident
297	15-Dec-09	US	UNKNOWN	US	ASRS	Landing	Incident
298	14-Feb-97	US	AMES	IA	AIDS	Landing	Incident
299	03-Sep-04	US	HOUSTON	TX	AIDS	Landing	Incident
300	30-Jul-07	US	MADISON	WI	AIDS	Landing	Incident
301	29-Aug-88	US	BAKERSFIELD	CA	AIDS	Landing	Incident
302	05-Apr-83	US	HUTCHINSON	KS	NTSB	Landing	Accident
303	12-Oct-90	US	BURLINGTON	VT	AIDS	Landing	Incident
304	18-May-99	US	GEORGETOWN	SC	AIDS	Landing	Incident
305	21-Sep-04	US	LORDSBERG	NM	NTSB	Takeoff	Accident
306	21-Sep-88	US	VAN NUYS	CA	AIDS	Landing	Incident
307	01-Sep-00	CANADA	OTTAWA	ON	ASRS	Landing	Incident
308	03-Jan-83	US	SACRAMENTO	CA	AIDS	Landing	Incident
309	20-Oct-03	US	KEY WEST	FL	AIDS	Landing	Incident
310	21-Sep-04	CANADA	LA RONGE	SASKATCHEWAN	CANADA TSB	Landing	Accident
311	26-Sep-94	US	FORT LAUDERDALE	FL	MITRE	Landing	Incident
312	10-Dec-98	US	MONROE	MI	AIDS	Landing	Incident
313	24-Apr-08	US	STERLING	CO	NTSB	Landing	Accident
314	22-Jan-88	US	STARKVILLE	MS	AIDS	Landing	Incident
315	03-Feb-08	US	JACKSON	WY	AIDS	Landing	Incident
316	14-Jun-04	US	PITTSBURGH	PA	AIDS	Landing	Incident
317	13-Aug-06	US	PAWTUCKET	RI	NTSB	Landing	Accident
318	01-Feb-03	US	CHICAGO/WAUKEGAN	IL	ASRS	Landing	Incident
319	17-May-95	US	SHREVEPORT	LA	AIDS	Landing	Incident
320	29-Apr-79	US	FAIRBANKS	AK	AIDS	Landing	Incident
321	18-Sep-87	US	RENO	NV	AIDS	Landing	Incident
322	15-Dec-04	US	UNKNOWN	NJ	ASRS	Landing	Incident
323	15-Aug-06	US	UNKNOWN	US	ASRS	Takeoff	Incident
324	15-Aug-02	US	UNKNOWN	VA	ASRS	Landing	Incident
325	06-Feb-02	US	CAMDEN	AR	NTSB	Landing	Accident
326	08-Jun-82	US	GILLETTE	WY	NTSB	Landing	Incident
327	07-Sep-08	US	SAN ANTONIO	TX	AIDS	Landing	Incident
328	24-Oct-97	US	PORTLAND	ME	AIDS	Takeoff	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
329	08-Jan-97	US	EL PASO	TX	AIDS	Landing	Incident
330	03-Feb-88	US	WHEELING	IL	NTSB	Landing	Accident
331	01-May-01	US	CHICAGO	IL	ASRS	Landing	Incident
332	04-Jun-01	US	LAS VEGAS	NV	MITRE	Landing	Accident
333	21-Dec-83	US	DETROIT	MI	NTSB	Landing	Accident
334	10-Mar-98	US	CLEVELAND	OH	AIDS	Landing	Incident
335	28-May-05	US	DENVER	CO	AIDS	Landing	Incident
336	03-Oct-08	US	LEWISTON	ID	AIDS	Landing	Incident
337	01-Sep-98	US	ATLANTA	GA	ASRS	Landing	Incident
338	01-Sep-10	US	NA	NA	ASRS	Takeoff	Incident
339	15-Dec-03	US	BANGOR	ME	AIDS	Landing	Incident
340	27-Mar-83	US	WHEELING	IL	AIDS	Landing	Incident
341	08-Jan-07	US	DENVER	CO	AIDS	Landing	Accident
342	15-Dec-08	US	UNKNOWN	US	ASRS	Landing	Incident
343	01-Aug-91	US	HOUSTON	TX	ASRS	Takeoff	Incident
344	01-Feb-06	US	YAKUTAT	AK	AIDS	Landing	Incident
345	10-Jan-95	US	CAHOKIA	IL	AIDS	Landing	Incident
346	29-Sep-84	US	HOUSTON	TX	NTSB	Landing	Incident
347	05-Dec-84	US	MINNEAPOLIS	MN	AIDS	Landing	Incident
348	10-Dec-96	US	CHICAGO	IL	AIDS	Takeoff	Incident
349	22-Sep-87	US	SELLERSBURG,	IN	NTSB	Takeoff	Accident
350	01-Nov-89	US	WASHINGTON	DC	ASRS	Takeoff	Incident
351	28-Sep-85	US	BROOMFIELD	CO	AIDS	Landing	Incident
352	10-Jan-00	US	EVERETT	WA	NTSB	Takeoff	Accident
353	10-May-02	US	MERIDIAN	MS	AIDS	Landing	Accident
354	15-Jul-09	US	UNKNOWN	WI	ASRS	Landing	Incident
355	06-Apr-90	US	ORLANDO	FL	AIDS	Takeoff	Incident
356	20-Jul-02	US	ARDMORE	OK	AIDS	Takeoff	Incident
357	06-Sep-81	US	DENVER	CO	AIDS	Landing	Incident
358	22-Oct-00	US	BETHEL	AK	MITRE	Landing	Accident
359	18-Aug-03	US	ST. AUGUSTINE	FL	NTSB	Takeoff	Accident
360	15-Jan-06	US	UNKNOWN	US	ASRS	Landing	Incident
361	08-Aug-90	US	AMES	IA	AIDS	Landing	Incident
362	02-Mar-03	US	RENO	NV	AIDS	Landing	Incident
363	09-Aug-03	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
364	02-Oct-89	US	SEDONA	AZ	NTSB	Landing	Accident
365	19-Feb-88	US	LANSING	MI	AIDS	Landing	Incident
366	04-Mar-97	US	ABILENE	TX	MITRE	Landing	Incident
367	01-Jan-92	US	OLATHE	KS	ASRS	Landing	Incident
368	16-Jun-04	US	BEND	OR	NTSB	Takeoff	Accident
369	31-Jan-96	US	MORRISTOWN	NJ	AIDS	Landing	Incident
370	24-Mar-01	US	PITTSBURGH	PA	AIDS	Landing	Incident
371	03-Apr-10	US	PRINCETON	KY	NTSB	Landing	Accident
372	17-Dec-98	US	LOS ANGELES	CA	MITRE	Landing	Accident
373	10-Jan-99	US	ST. JOSEPH	MO	NTSB	Landing	Accident
374	06-Aug-89	US	WATERVILLE	ME	NTSB	Landing	Accident
375	15-Mar-04	US	MANHATTAN	KS	NTSB	Landing	Accident
376	16-Mar-87	US	OKLAHOMA CITY	OK	AIDS	Landing	Incident
377	19-Jun-02	US	PRINEVILLE	OR	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
378	13-Feb-99	US	STATE COLLEGE	PA	ASRS	Landing	Incident
379	25-Oct-99	US	CORONA	CA	NTSB	Takeoff	Accident
380	16-Mar-83	US	HOUSTON	TX	NTSB	Takeoff	Accident
381	11-Mar-84	US	COLUMBUS,	OH	NTSB	Takeoff	Accident
382	15-Sep-11	US	UNKNOWN	FO	ASRS	Landing	Incident
383	01-May-93	US	WINDSOR LOCKS	CT	ASRS	Landing	Incident
384	15-May-09	US	UNKNOWN	FO	ASRS	Takeoff	Incident
385	03-Jun-95	US	SUSANVILLE	CA	AIDS	Landing	Incident
386	19-Jan-92	US	GAYLORD,	MI	NTSB	Takeoff	Accident
387	15-Apr-04	US	UNKNOWN	US	ASRS	Landing	Incident
388	14-Feb-12	US	YELLOW PINE	ID	AIDS	Landing	Incident
389	01-Dec-88	US	INDIANAPOLIS	IN	ASRS	Takeoff	Incident
390	01-Feb-88	US	PITTSBURG	PA	ASRS	Landing	Incident
391	03-Mar-03	US	TRACY	CA	NTSB	Takeoff	Accident
392	01-May-97	US	ARCATA/EUREKA	CA	ASRS	Landing	Incident
393	22-Sep-83	US	POMONA	NJ	NTSB	Landing	Accident
394	14-Mar-05	US	ATLANTA	GA	AIDS	Takeoff	Incident
395	01-Feb-03	US	WASHINGTON	DC	ASRS	Landing	Incident
396	15-May-01	US	UNKNOWN	IL	ASRS	Landing	Incident
397	01-Sep-96	US	DENVER	CO	ASRS	Landing	Incident
398	17-Jul-11	IRELAND	SHANNON	CO. CLARE	AAIU	Landing	Accident
399	15-Nov-02	US	UNKNOWN	AZ	ASRS	Takeoff	Incident
400	01-Nov-01	US	NA	NA	ASRS	Landing	Incident
401	30-Oct-06	FRANCE	ROUEN		BEA	Landing	Incident
402	11-Jan-84	US	OLD TOWN	ME	AIDS	Takeoff	Incident
403	08-Aug-02	US	LOUISVILLE	KY	ASRS	Landing	Incident
404	09-Jan-01	US	WINDSOR LOCKS	CT	AIDS	Landing	Incident
405	15-Jan-03	US	UNKNOWN	US	ASRS	Landing	Incident
406	15-Nov-01	US	UNKNOWN	US	ASRS	Landing	Incident
407	14-Jul-07	AUSTRALIA	SYDNEY		ATSB	Takeoff	Incident
408	10-Feb-05	US	INDIANAPOLIS	IN	NTSB	Landing	Accident
409	17-Nov-05	US	JAMESTOWN	NY	AIDS	Landing	Incident
410	01-Dec-93	US	MAMMOTH LAKES	CA	ASRS	Landing	Incident
411	20-Dec-85	US	CLEVELAND	OH	AIDS	Landing	Incident
412	14-Jul-07	AUSTRALIA	SYDNEY		ATSB	Takeoff	Incident
413	04-Dec-03	US	LITTLE ROCK	AR	AIDS	Landing	Incident
414	17-Dec-95	US	PHILADELPHIA	PA	AIDS	Takeoff	Incident
415	10-Jan-12	AUSTRALIA	HORN ISLAND	QUEENSLAND	ATSB	Landing	Incident
416	28-May-03	US	DETROIT	MI	AIDS	Landing	Incident
417	11-Mar-05	US	MILWAUKEE	WI	MITRE	Landing	Accident
418	06-May-83	US	LINCOLN	NE	AIDS	Landing	Incident
419	17-Dec-98	US	TRAVERSE CITY	MI	MITRE	Landing	Accident
420	15-Oct-99	US	UNKNOWN	FL	ASRS	Landing	Incident
421	27-Feb-98	UK	LEEDS		AAIB	Takeoff	Incident
422	16-Apr-07	US	WILMINGTON	DE	AIDS	Landing	Incident
423	08-Apr-11	US	EDEN PRAIRIE	MN	NTSB	Landing	Accident
424	05-Mar-85	US	UTICA	NY	NTSB	Landing	Accident
425	02-May-06	US	CHICAGO	IL	AIDS	Landing	Incident
426	24-Feb-88	US	MORGANTON,	NC	NTSB	Takeoff	Accident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
427	23-Jan-05	S. AFRICA	DURBAN		SACAA	Landing	Accident
428	16-Jan-80	US	CLARKSBURG	WV	AIDS	Landing	Incident
429	14-Jan-99	US	YOUNGSTOWN	OH	NTSB	Landing	Accident
430	16-Jan-97	US	TERRE HAUTE	IN	AIDS	Landing	Incident
431	05-May-00	US	CAHOKIA	IL	AIDS	Landing	Incident
432	13-Jan-91	US	PALMYRA	PA	AIDS	Landing	Incident
433	24-May-03	US	AMARILLO	TX	MITRE	Landing	Accident
434	18-Nov-80	US	NEW CASTLE	DE	AIDS	Landing	Incident
435	24-Sep-97	US	SALT LAKE CITY	UT	NTSB	Landing	Incident
436	05-Feb-91	US	COCHRAN	GA	NTSB	Landing	Incident
437	18-Dec-02	US	SOLDOTNA	AK	NTSB	Landing	Accident
438	11-Jul-09	US	ANGEL FIRE	NM	NTSB	Takeoff	Accident
439	27-Nov-98	US	AUSTIN	TX	MITRE	Landing	Accident
440	30-Jun-84	US	EL PASO	TX	NTSB	Landing	Accident
441	01-Apr-95	US	LEXINGTON	KY	ASRS	Landing	Incident
442	17-Nov-01	US	GREENWOOD	IN	NTSB	Landing	Accident
443	09-Jul-02	US	MESA	AZ	NTSB	Landing	Accident
444	23-Mar-11	US	SELLERSBURG	IN	NTSB	Landing	Accident
445	22-Sep-03	US	GULFPORT	MS	AIDS	Landing	Incident
446	09-Jan-04	US	GARDEN CITY	KS	ASRS	Landing	Incident
447	29-Jul-93	US	LAKE CITY	FL	NTSB	Landing	Accident
448	22-Jan-99	US	HYANNIS	MA	MITRE	Landing	Accident
449	24-Feb-99	US	NA	NA	AIDS	Landing	Incident
450	29-Aug-04	US	LAKEVILLE	MN	NTSB	Landing	Accident
451	15-Feb-10	US	UNKNOWN	US	ASRS	Landing	Incident
452	16-Sep-88	US	HAYS	KS	NTSB	Takeoff	Accident
453	21-Jul-97	US	ELKO	NV	MITRE	Landing	Accident
454	15-May-03	US	UNKNOWN	US	ASRS	Takeoff	Incident
455	24-Jan-97	US	WASHINGTON	IN	AIDS	Landing	Incident
456	16-Apr-03	US	YUMA	AZ	AIDS	Landing	Incident
457	07-Aug-07	US	ANKENY	IA	AIDS	Landing	Incident
458	16-Mar-03	US	CEDAR CITY	UT	NTSB	Takeoff	Incident
459	06-Feb-83	US	SAINT PAUL ISLAND	AK	AIDS	Landing	Incident
460	16-Feb-83	US	MANCHESTER	NH	AIDS	Landing	Incident
461	19-Jun-98	US	FISHERS ISLAND	NY	AIDS	Landing	Incident
462	10-Nov-02	US	GOODYEAR	AZ	AIDS	Takeoff	Incident
463	01-Oct-90	US	BURLINGTON	VT	ASRS	Landing	Incident
464	27-Feb-87	US	KALAMAZOO	MI	AIDS	Landing	Incident
465	19-Jul-94	US	TAFT	CA	NTSB	Takeoff	Accident
466	16-Jun-04	US	INDIANAPOLIS	IN	AIDS	Landing	Incident
467	01-Mar-08	US	SAINT LOUIS	MO	AIDS	Landing	Incident
468	19-Nov-00	US	GRAND RAPIDS	MI	AIDS	Landing	Incident
469	03-Jan-99	US	MUSKEGON	MI	AIDS	Landing	Incident
470	29-Nov-86	US	SAN JUAN	PR	NTSB	Takeoff	Incident
471	22-Sep-08	US	CHICAGO	IL	NTSB	Landing	Incident
472	11-Jul-89	US	ROCHESTER	NY	AIDS	Takeoff	Incident
473	17-Feb-07	US	INDIANAPOLIS	IN	AIDS	Landing	Accident
474	01-Mar-92	US	DENVER	CO	ASRS	Landing	Incident
475	01-Jun-92	US	LANSING	MI	ASRS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
476	18-Dec-03	US	MEMPHIS	TN	MITRE	Landing	Accident
477	31-Oct-81	US	JACKSON	MS	AIDS	Landing	Incident
478	22-Dec-83	US	ROCK SPRINGS	WY	NTSB	Landing	Accident
479	26-Apr-01	US	SAINT GEORGE	UT	AIDS	Landing	Incident
480	27-Mar-97	US	SAN CARLOS	CA	MITRE	Landing	Accident
481	02-Mar-89	US	RIFLE	CO	AIDS	Landing	Incident
482	22-Oct-95	US	ALBUQUERQUE	NM	NTSB	Landing	Accident
483	15-Nov-94	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
484	09-Mar-02	US	CHICAGO	IL	AIDS	Takeoff	Incident
485	11-Oct-99	US	OPA LOCKA	FL	MITRE	Landing	Accident
486	24-Dec-84	US	FLINT	MI	NTSB	Landing	Accident
487	01-Mar-95	US	SALT LAKE CITY	UT	ASRS	Landing	Incident
488	01-Dec-09	US	NA	NA	ASRS	Landing	Accident
489	18-Sep-78	US	WALLA WALLA	WA	AIDS	Landing	Incident
490	01-Dec-04	CANADA	SAINT-GEORGES	QUEBEC	CANADA TSB	Landing	Accident
491	28-Jan-00	US	NEWARK	NJ	AIDS	Landing	Incident
492	15-Jan-08	FRANCE	PARIS		BEA	Landing	Incident
493	01-Jan-99	US	LEWISTOWN	MT	ASRS	Takeoff	Incident
494	02-Feb-02	US	SANTA ANA	CA	NTSB	Landing	Accident
495	01-Dec-97	US	BURBANK	CA	ASRS	Takeoff	Incident
496	29-Jul-98	US	MOSES LAKE	WA	NTSB	Takeoff	Incident
497	21-Feb-02	S. AFRICA	WONDERBOOM		SACAA	Landing	Incident
498	13-Feb-08	US	CEDAR CITY	UT	AIDS	Landing	Incident
499	22-Jul-01	US	FORT PIERCE	FL	AIDS	Landing	Incident
500	16-Feb-09	US	SOLDOTNA	AK	NTSB	Landing	Accident
501	27-Dec-87	US	DENVER	CO	NTSB	Landing	Incident
502	12-Feb-08	AUSTRALIA	THANGOOL	QUEENSLAND	ATSB	Landing	Incident
503	14-Apr-93	US	DALLAS	TX	NTSB	Landing	Accident
504	13-Feb-01	US	SALINA	KS	AIDS	Landing	Incident
505	27-Jul-94	US	SIOUX FALLS	SD	AIDS	Landing	Incident
506	23-Apr-07	US	BATON ROUGE	LA	AIDS	Landing	Incident
507	09-Dec-10	UK	SOUTH YORKSHIRE		AAIB	Landing	Incident
508	01-May-91	US	OXFORD	CT	NTSB	Landing	Accident
509	01-Jul-89	US	SOUTH BEND	IN	ASRS	Landing	Incident
510	01-Jun-93	US	CHICAGO	IL	ASRS	Landing	Incident
511	02-Feb-97	US	GRAND FORKS	ND	AIDS	Landing	Incident
512	01-Feb-99	US	MONTROSE	CO	ASRS	Takeoff	Incident
513	15-Feb-00	US	UNKNOWN	GA	ASRS	Landing	Incident
514	25-Dec-00	US	ADDISON	TX	NTSB	Landing	Accident
515	14-May-00	US	MONROE	NC	NTSB	Landing	Accident
516	15-Dec-96	US	HONOLULU	HI	NTSB	Landing	Accident
517	17-Feb-03	US	RICHMOND	VA	AIDS	Takeoff	Incident
518	09-Nov-93	US	INDIANAPOLIS	IN	AIDS	Landing	Incident
519	30-Jan-08	US	PALM BEACH	FL	AIDS	Landing	Incident
520	17-Jun-04	US	LANCASTER	PA	AIDS	Takeoff	Incident
521	02-Mar-02	US	ANCHORAGE	AK	ASRS	Landing	Incident
522	23-Nov-83	US	WHEELING	IL	AIDS	Landing	Incident
523	15-Jun-92	BAHAMAS	MARSH HARBOUR	FO	ASRS	Landing	Incident
524	17-Mar-83	US	BROOMFIELD	CO	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
525	05-Feb-99	US	GAYLORD	MI	NTSB	Landing	Accident
526	17-Oct-94	US	GRAND CANYON	AZ	MITRE	Landing	Incident
527	16-Feb-03	US	CAHOKIA	IL	NTSB	Landing	Accident
528	11-Feb-81	US	INDIANAPOLIS	IN	AIDS	Landing	Incident
529	22-May-07	UK	EXETER		AAIB	Takeoff	Accident
530	11-Apr-92	US	SOUTH LAKE TAHOE	CA	AIDS	Landing	Incident
531	02-Mar-10	US	DEKALB	IL	NTSB	Landing	Accident
532	20-Jul-84	US	MCALLEN,	TX	NTSB	Takeoff	Accident
533	01-Jun-90	US	LEXINGTON	KY	ASRS	Landing	Incident
534	18-May-89	US	MARION	IL	NTSB	Landing	Accident
535	29-Nov-04	US	EAGLE	CO	MITRE	Landing	Accident
536	01-May-87	US	JACKSONVILLE	FL	AIDS	Landing	Incident
537	01-Feb-88	US	NEWBURGH	NY	ASRS	Landing	Incident
538	09-Jan-91	US	PHILADELPHIA	PA	AIDS	Landing	Incident
539	15-Nov-07	US	UNKNOWN	US	ASRS	Landing	Incident
540	10-Feb-94	US	CHICAGO	IL	AIDS	Landing	Incident
541	15-Jan-10	US	UNKNOWN	US	ASRS	Landing	Incident
542	26-Apr-05	US	LAWRENCEVILLE	GA	NTSB	Landing	Accident
543	15-Aug-06	US	UNKNOWN	TX	ASRS	Takeoff	Incident
544	03-Mar-89	US	ROCKFORD	IL	AIDS	Landing	Incident
545	14-Jan-99	US	YOUNGSTOWN/WARREN	OH	MITRE	Landing	Accident
546	07-Jan-91	US	KANSAS CITY	MO	NTSB	Takeoff	Incident
547	15-Dec-99	US	UNKNOWN	VA	ASRS	Landing	Incident
548	10-Jun-01	US	MIAMI	FL	AIDS	Landing	Incident
549	01-Jun-06	US	BIRMINGHAM	AL	ASRS	Landing	Incident
550	30-Jan-91	US	CLEVELAND	OH	AIDS	Landing	Incident
551	11-Sep-05	US	LAS VEGAS	NV	AIDS	Landing	Incident
552	16-May-86	US	LARAMIE	WY	NTSB	Landing	Accident
553	01-Mar-83	US	CORPUS CHRISTI	TX	AIDS	Landing	Incident
554	16-Nov-01	US	ALTUS	OK	NTSB	Landing	Accident
555	20-Aug-08	US	BALTIMORE,	MD	NTSB	Takeoff	Accident
556	01-Apr-11	US	NA	NA	ASRS	Takeoff	Incident
557	15-Apr-01	US	UNKNOWN	US	ASRS	Landing	Incident
558	03-Jan-95	US	PORTLAND	OR	ASRS	Landing	Incident
559	01-Jan-92	US	GAYLORD	MI	ASRS	Takeoff	Incident
560	20-Sep-06	UK	BEDFORDSHIRE		AAIB	Landing	Incident
561	03-Jul-84	US	DENVER	CO	NTSB	Landing	Incident
562	10-Jul-01	UK	CLYST HONITON		AAIB	Landing	Incident
563	31-Jul-97	US	NEWARK	NJ	MITRE	Landing	Accident
564	06-Mar-00	US	ADRIAN	MI	AIDS	Landing	Incident
565	20-Nov-86	US	WHITE PLAINS	NY	AIDS	Landing	Incident
566	01-Mar-11	US	NA	NA	ASRS	Landing	Incident
567	13-Jun-08	US	ATLANTA	GA	AIDS	Landing	Incident
568	12-Aug-98	US	KNEELAND	CA	AIDS	Landing	Incident
569	15-Jan-01	US	TWO HARBORS	MN	AIDS	Landing	Incident
570	10-Aug-05	US	SPEARFISH	SD	AIDS	Landing	Incident
571	02-May-00	US	SAINT PAUL	MN	AIDS	Landing	Incident
572	06-Sep-99	US	ADA	OK	NTSB	Landing	Accident
573	16-Jul-98	CANADA	OTTAWA	ONTARIO	CANADA TSB	Landing	Accident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
574	05-Nov-04	US	HOUSTON	TX	AIDS	Landing	Incident
575	14-Dec-00	US	ATLANTA	GA	AIDS	Landing	Incident
576	02-May-95	US	SHREVEPORT	LA	AIDS	Landing	Incident
577	16-Dec-81	US	DES MOINES	IA	AIDS	Takeoff	Incident
578	19-Apr-08	US	CARLSBAD	CA	NTSB	Landing	Accident
579	28-Sep-98	US	PUEBLO	CO	MITRE	Landing	Accident
580	01-Feb-91	US	EAU CLAIRE	WI	ASRS	Takeoff	Incident
581	03-Jan-94	US	RICHMOND HEIGHTS	OH	NTSB	Landing	Accident
582	01-Dec-11	US	PALM BEACH	FL	ASRS	Landing	Incident
583	26-Feb-98	US	BIRMINGHAM	AL	NTSB	Landing	Accident
584	01-Jan-03	US	CHICAGO	IL	ASRS	Takeoff	Incident
585	15-Jun-09	US	UNKNOWN	US	ASRS	Landing	Incident
586	24-Mar-93	US	SOLDIERS GROVE	WI	AIDS	Landing	Incident
587	27-Apr-09	US	NANTUCKET	MA	AIDS	Landing	Incident
588	01-Dec-99	US	AMARILLO	TX	ASRS	Landing	Incident
589	09-Mar-09	US	BELMAR	NJ	NTSB	Landing	Accident
590	20-Dec-04	US	CEDAR RAPIDS	IA	MITRE	Landing	Accident
591	01-Nov-03	US	RAWLINS	WY	NTSB	Landing	Accident
592	07-Dec-85	US	DETROIT	MI	AIDS	Landing	Incident
593	06-Jul-94	US	POINT LOOKOUT	MO	AIDS	Landing	Incident
594	09-Oct-96	US	PITTSBURGH	PA	AIDS	Landing	Incident
595	02-Jan-96	US	ATLANTA	GA	ASRS	Landing	Incident
596	08-Jul-05	US	ISLESBORO	ME	AIDS	Landing	Incident
597	15-Jan-05	US	UNKNOWN	CA	ASRS	Takeoff	Incident
598	15-Apr-04	US	UNKNOWN	IN	ASRS	Takeoff	Incident
599	10-Mar-97	US	BOISE	ID	AIDS	Landing	Incident
600	09-Dec-87	US	VAN NUYS	CA	AIDS	Landing	Incident
601	12-Aug-06	US	AMARILLO	TX	AIDS	Takeoff	Incident
602	01-Nov-95	US	HELENA	MT	ASRS	Takeoff	Incident
603	27-Jan-92	US	LOUISVILLE	KY	AIDS	Landing	Incident
604	01-Jan-99	US	PONTIAC	MI	ASRS	Landing	Incident
605	06-Nov-85	US	SYLACAUGA,	AL	NTSB	Takeoff	Accident
606	29-Dec-79	US	VAN NUYS	CA	AIDS	Landing	Incident
607	21-Jan-06	US	CALDWELL	ID	AIDS	Takeoff	Incident
608	14-Jul-96	US	MARSHALL,	MI	NTSB	Takeoff	Accident
609	03-Feb-00	US	PERU	IN	AIDS	Takeoff	Accident
610	15-Jul-05	US	EAGLE	CO	MITRE	Landing	Accident
611	15-Feb-00	US	UNKNOWN	CA	ASRS	Landing	Incident
612	18-Jan-02	US	BAKER CITY	OR	NTSB	Landing	Accident
613	21-May-82	US	DAYTON	OH	NTSB	Landing	Incident
614	26-Oct-91	US	CHEVAK	AK	NTSB	Takeoff	Accident
615	15-Jan-00	US	UNKNOWN	OH	ASRS	Landing	Incident
616	10-Nov-00	US	DICKINSON	ND	AIDS	Landing	Incident
617	26-Dec-92	US	WELLINGTON	KS	AIDS	Landing	Incident
618	01-Mar-78	US	LAWRENCE	KS	AIDS	Takeoff	Incident
619	01-May-00	US	WASHINGTON	DC	ASRS	Takeoff	Incident
620	21-May-99	US	MIDLAND	TX	AIDS	Landing	Incident
621	13-Feb-99	US	STATE COLLEGE	PA	AIDS	Landing	Incident
622	17-Sep-11	US	HILLSBORO	TX	NTSB	Landing	Accident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
623	11-Nov-91	US	ROCHESTER	NY	AIDS	Landing	Incident
624	11-Nov-83	US	CLEVELAND	OH	AIDS	Landing	Incident
625	14-Sep-99	SPAIN	GIRONA		SPAIN TSB	Landing	Accident
626	18-Jun-92	US	COALINGA	CA	NTSB	Landing	Accident
627	01-May-01	US	LEWISBURG	TN	ASRS	Landing	Incident
628	20-Dec-98	US	DENVER	CO	AIDS	Landing	Incident
629	27-Apr-83	US	IRVINE	KY	NTSB	Landing	Accident
630	11-Nov-85	US	BIRMINGHAM	AL	NTSB	Landing	Accident
631	17-Aug-98	US	NOME	AK	AIDS	Landing	Incident
632	05-Jan-06	US	SAULT STE MARIE	MI	NTSB	Landing	Accident
633	13-Dec-85	US	LEXINGTON	KY	NTSB	Landing	Accident
634	18-Oct-87	US	NANTUCKET	MA	NTSB	Landing	Accident
635	03-Mar-91	US	COLUMBUS	OH	AIDS	Landing	Incident
636	16-Jul-00	US	DENVER	CO	AIDS	Landing	Incident
637	10-Dec-89	US	DENVER	CO	AIDS	Landing	Incident
638	25-Feb-04	CANADA	EDMONTON	ALBERTA	CANADA TSB	Landing	Incident
639	16-Aug-99	US	FORT LAUDERDALE	FL	MITRE	Landing	Accident
640	15-Oct-03	US	UNKNOWN	NJ	ASRS	Landing	Incident
641	15-Feb-04	US	CHICAGO	IL	AIDS	Landing	Incident
642	23-May-08	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
643	22-Mar-11	US	ABERDEEN	SD	NTSB	Takeoff	Accident
644	01-Apr-04	US	NA	NA	ASFRS	Landing	Incident
645	30-Mar-85	US	FORT LAUDERDALE	FL	NTSB	Landing	Incident
646	01-Nov-99	US	LAWRENCE	KS	ASRS	Landing	Incident
647	19-Dec-95	US	SAINT LOUIS	MO	AIDS	Landing	Incident
648	01-Dec-91	US	TYLER	TX	ASRS	Takeoff	Incident
649	18-Mar-87	US	ATLANTA	GA	AIDS	Landing	Incident
650	04-Jun-04	US	FAIRBANKS	AK	AIDS	Takeoff	Incident
651	04-Feb-10	US	COLUMBIA	MO	NTSB	Landing	Accident
652	01-Dec-89	US	DENVER	CO	ASRS	Landing	Incident
653	17-Jul-94	US	PLYMOUTH	FL	AIDS	Landing	Incident
654	09-Dec-04	US	ATLANTA	GA	AIDS	Landing	Incident
655	15-Jul-07	US	UNKNOWN	CA	ASRS	Landing	Incident
656	02-Oct-97	US	LAKE ELMO	MN	NTSB	Takeoff	Accident
657	14-Apr-83	US	ELKHART	IN	AIDS	Landing	Incident
658	22-Jan-99	US	COLUMBUS	OH	MITRE	Landing	Accident
659	11-Dec-97	US	CHICAGO	IL	AIDS	Landing	Incident
660	31-Jan-11	US	DAYTON	OH	NTSB	Landing	Accident
661	22-Nov-01	US	PITTSBURGH	PA	NTSB	Takeoff	Accident
662	24-Jun-92	US	MAYAGUEZ	PR	NTSB	Landing	Incident
663	21-Nov-95	US	REXBURG	ID	AIDS	Landing	Incident
664	13-Apr-07	US	TETERBORO	NJ	AIDS	Landing	Incident
665	24-Dec-87	US	ASPEN	CO	AIDS	Landing	Incident
666	01-Mar-88	US	CHAMPAIGN/URBANA	IL	ASRS	Landing	Incident
667	08-Oct-87	US	ALBUQUERQUE	NM	NTSB	Landing	Accident
668	25-Feb-00	US	ATLANTA	GA	AIDS	Landing	Incident
669	05-Feb-97	US	NEW YORK	NY	AIDS	Landing	Accident
670	03-Apr-98	US	WEST PALM BEACH	FL	MITRE	Landing	Accident
671	21-Sep-04	US	GARDEN CITY	KS	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
672	05-Jan-02	US	SACRAMENTO	CA	AIDS	Landing	Incident
673	01-Jul-92	US	LEXINGTON	KY	ASRS	Landing	Incident
674	01-Jun-08	US	GUYMON	OK	NTSB	Landing	Accident
675	01-Dec-96	US	SALT LAKE CITY	UT	ASRS	Takeoff	Incident
676	13-Nov-97	US	WHEELING	WV	NTSB	Landing	Accident
677	21-Aug-11	US	DILLINGHAM	AK	NTSB	Landing	Accident
678	06-Jan-80	US	CHICAGO	IL	AIDS	Landing	Incident
679	15-Apr-88	US	SEATTLE	WA	NTSB	Landing	Accident
680	14-Jul-82	US	SANTA FE	NM	AIDS	Takeoff	Incident
681	06-Jun-10	AUSTRALIA	MOUNT GAMBIER		ATSB	Landing	Incident
682	28-Jul-06	US	MEMPHIS	TN	NTSB	Landing	Accident
683	15-Mar-01	US	UNKNOWN	PA	ASRS	Landing	Incident
684	01-Dec-93	US	ONEIDA	NY	ASRS	Landing	Incident
685	30-Jul-83	US	REVENSWOOD	WV	NTSB	Landing	Accident
686	31-Mar-89	US	WINDSOR LOCKS	CT	AIDS	Landing	Incident
687	27-Dec-89	US	MERCED	CA	AIDS	Landing	Incident
688	21-Sep-02	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
689	11-Mar-80	US	ISLIP	NY	AIDS	Landing	Incident
690	12-Mar-02	US	ALBUQUERQUE	NM	MITRE	Landing	Accident
691	04-Mar-04	US	SPRINGDALE	AR	MITRE	Landing	Accident
692	04-Feb-10	US	AMARILLO	TX	NTSB	Landing	Accident
693	25-Jan-05	US	MONTROSE	CO	AIDS	Landing	Incident
694	23-Sep-05	US	DALLAS	TX	AIDS	Landing	Incident
695	06-Jun-06	US	FORT LAUDERDALE	FL	AIDS	Takeoff	Incident
696	23-Jan-97	US	LEBANON	MO	AIDS	Landing	Incident
697	05-Jul-86	US	PROVO	UT	NTSB	Landing	Accident
698	19-Apr-01	US	DENVER	CO	AIDS	Landing	Incident
699	01-Jan-03	US	NA	NA	ASRS	Landing	Incident
700	24-Apr-92	US	CLEVELAND	OH	AIDS	Landing	Incident
701	18-Jul-83	US	EL PASO	TX	AIDS	Landing	Incident
702	11-Feb-83	US	TALLADEGA	AL	NTSB	Takeoff	Accident
703	21-Jan-88	US	DALLAS	TX	AIDS	Landing	Incident
704	03-Jan-97	US	WATERTOWN	SD	AIDS	Landing	Incident
705	29-Jul-05	US	MOUNT PLEASANT	SC	AIDS	Takeoff	Incident
706	30-Dec-96	US	ORLANDO	FL	MITRE	Takeoff	Incident
707	06-Apr-96	US	BIRMINGHAM	AL	AIDS	Landing	Incident
708	01-May-86	US	MARQUETTE	MI	NTSB	Landing	Accident
709	27-Dec-98	US	WEISER	ID	AIDS	Landing	Incident
710	05-Sep-91	US	CHICAGO	IL	AIDS	Landing	Incident
711	13-Dec-91	US	ROSEAU,	MN	NTSB	Landing	Accident
712	10-Oct-96	US	BELLVILLE	TX	NTSB	Landing	Accident
713	07-Sep-02	SPAIN	MADRID		SPAIN TSB	Landing	Incident
714	13-Jul-09	US	YAKUTAT	AK	NTSB	Landing	Accident
715	09-Dec-11	US	PAMPA	TX	NTSB	Landing	Accident
716	14-Nov-85	US	BLOOMINGTON	IL	AIDS	Landing	Incident
717	20-Apr-98	US	TAMPA	FL	NTSB	Landing	Accident
718	17-Jan-08	US	BIGFORK	MN	AIDS	Landing	Incident
719	08-Jun-99	US	FORT LAUDERDALE	FL	NTSB	Takeoff	Accident
720	08-Dec-04	US	TWIN FALLS	ID	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
721	13-Jan-81	US	SAVOY	IL	AIDS	Landing	Incident
722	15-Dec-07	US	UNKNOWN	US	ASRS	Landing	Incident
723	17-Nov-07	US	VINEYARD HAVEN	MA	AIDS	Landing	Incident
724	13-Dec-04	US	CLEVELAND	OH	AIDS	Landing	Incident
725	22-Mar-86	US	MELBOURNE	FL	AIDS	Takeoff	Incident
726	01-Oct-99	US	LOUISVILLE	KY	AIDS	Takeoff	Incident
727	24-Sep-97	US	LAKE CHARLES	LA	AIDS	Landing	Incident
728	30-Oct-86	US	SAINT LOUIS	MO	AIDS	Landing	Accident
729	26-Dec-05	CANADA	WINNIPEG	MANITOBA	CANADA TSB	Landing	Incident
730	25-Mar-03	US	COLUMBUS	OH	AIDS	Landing	Incident
731	07-Sep-95	US	ALBUQUERQUE	NM	NTSB	Landing	Accident
732	01-Mar-97	US	ABILENE	TX	ASRS	Landing	Incident
733	15-Aug-79	US	CAMPBELLTON	TX	AIDS	Landing	Incident
734	27-Apr-96	US	LYNCHBURG	VA	NTSB	Landing	Accident
735	05-May-95	US	RAPID CITY	SD	AIDS	Landing	Incident
736	01-Jan-92	US	LOUISVILLE	KY	ASRS	Landing	Incident
737	07-Feb-03	US	MOUNTAIN VILLAGE	AK	AIDS	Landing	Incident
738	01-Mar-89	US	CHEYENNE	WY	ASRS	Landing	Incident
739	20-Feb-03	US	PIERRE	SD	AIDS	Landing	Incident
740	08-Nov-05	US	EUREKA	CA	AIDS	Takeoff	Incident
741	25-Oct-01	US	ST. LOUIS	MO	NTSB	Landing	Accident
742	22-Jan-87	US	WASHINGTON	DC	AIDS	Takeoff	Incident
743	28-Aug-94	US	PONTIAC	MI	AIDS	Landing	Incident
744	01-Sep-03	US	DENVER	CO	ASRS	Landing	Incident
745	15-Mar-02	US	UNKNOWN	WY	ASRS	Landing	Incident
746	12-Jun-01	US	KOTZEBUE	AK	AIDS	Landing	Incident
747	04-Apr-00	US	MIAMI	FL	MITRE	Landing	Incident
748	01-Mar-01	US	PITTSBURG	PA	ASRS	Landing	Incident
749	01-Mar-89	US	PITTSBURG	PA	ASRS	Landing	Incident
750	29-Jan-06	US	LAS VEGAS	NV	AIDS	Takeoff	Incident
751	19-Dec-84	US	SPRINGDALE	AR	AIDS	Landing	Incident
752	10-Jan-02	US	FORT COLLINS	CO	AIDS	Landing	Incident
753	25-Nov-07	US	MINNEAPOLIS	MN	AIDS	Landing	Incident
754	24-Feb-83	US	ANCHORAGE	AK	AIDS	Landing	Incident
755	17-Sep-96	US	MIAMI	FL	AIDS	Takeoff	Incident
756	13-Dec-05	US	KOTZEBUE	AK	AIDS	Landing	Incident
757	30-Apr-70	ITALY	ROME		ATSB	Takeoff	Incident
758	11-May-04	US	ROSEAU	MN	AIDS	Landing	Incident
759	28-Feb-03	US	OAKLAND	CA	AIDS	Landing	Incident
760	15-Jun-00	US	UNKNOWN	IA	ASRS	Landing	Incident
761	07-Jan-88	US	OAKLAND	CA	AIDS	Landing	Incident
762	01-Aug-95	US	PORTLAND	OR	ASRS	Landing	Incident
763	29-Oct-04	US	DUBUQUE	IA	AIDS	Landing	Incident
764	11-Jul-09	US	ANGEL FIRE	NM	NTSB	Takeoff	Accident
765	31-May-05	US	TETERBORO	NJ	MITRE	Landing	Accident
766	31-Jan-05	US	EVERETT	WA	AIDS	Landing	Incident
767	01-Feb-09	US	NA	NA	ASRS	Landing	Incident
768	13-Jun-90	US	BRIGHAM CITY	UT	NTSB	Landing	Accident
769	26-Apr-05	US	LAWRENCEVILLE	GA	MITRE	Landing	Accident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
770	26-Feb-98	US	BIRMINGHAM	AL	MITRE	Landing	Accident
771	21-Jul-04	US	RIFLE	CO	NTSB	Takeoff	Accident
772	24-Jan-96	US	DETROIT	MI	MITRE	Landing	Accident
773	01-Feb-93	US	FT LAUDERDALE	FL	ASRS	Landing	Incident
774	15-Feb-11	US	UNKNOWN	US	ASRS	Takeoff	Incident
775	25-Jan-78	US	OWENSBORO	KY	AIDS	Landing	Incident
776	09-Dec-81	US	SAN DIEGO	CA	AIDS	Takeoff	Incident
777	01-Jan-10	US	NA	NA	ASRS	Landing	Incident
778	25-Feb-87	US	DURANGO	CO	NTSB	Landing	Incident
779	27-Mar-97	US	SAN CARLOS	CA	NTSB	Landing	Accident
780	01-Aug-88	US	KNOXVILLE	TN	ASRS	Landing	Incident
781	14-Apr-94	US	LINCOLN	NE	AIDS	Landing	Incident
782	15-Apr-11	US	UNKNOWN	US	ASRS	Takeoff	Incident
783	03-Sep-03	US	RICHMOND	VA	AIDS	Landing	Incident
784	13-Dec-85	US	OPA LOCKA	FL	NTSB	Takeoff	Accident
785	20-Feb-07	US	CORDOVA	AK	NTSB	Landing	Accident
786	01-Jan-10	US	NA	NA	ASRS	Landing	Incident
787	01-Dec-89	US	KALAMAZOO	MI	ASRS	Takeoff	Incident
788	18-Nov-80	US	ROCHESTER	NY	AIDS	Takeoff	Incident
789	31-Jan-10	CUBA	VARADERO	CUBA	CANADA TSB	Landing	Incident
790	16-Oct-00	US	SAINT LOUIS	MO	AIDS	Landing	Incident
791	29-Aug-83	US	FLORALA	AL	NTSB	Takeoff	Accident
792	13-Mar-80	US	HAGERSTOWN	MD	AIDS	Landing	Incident
793	06-Jan-99	US	PLYMOUTH	IN	NTSB	Landing	Accident
794	12-Nov-99	US	FREMONT	OH	AIDS	Landing	Incident
795	01-Jun-92	US	BOSTON	MA	ASRS	Landing	Incident
796	12-Jan-07	US	DENVER	CO	AIDS	Landing	Incident
797	15-Feb-99	US	UNKNOWN	PA	ASRS	Landing	Incident
798	03-Apr-85	US	GRAND RAPIDS	MI	NTSB	Landing	Accident
799	16-Apr-02	S. AFRICA	PILANESBERG		SACAA	Landing	Accident
800	29-Dec-97	US	NEWBURGH	NY	AIDS	Landing	Incident
801	19-Jan-05	US	MUNCIE	IN	NTSB	Landing	Accident
802	12-Sep-98	US	HOT SPRINGS	AR	AIDS	Landing	Incident
803	13-Jan-07	US	LARAMIE	WY	AIDS	Landing	Incident
804	27-Jul-07	US	WALLKILL	NY	NTSB	Landing	Accident
805	03-Oct-04	US	MIDLAND	TX	NTSB	Takeoff	Accident
806	21-Jan-01	US	JAMAICA	NY	NTSB	Landing	Incident
807	01-Oct-94	US	KALISPELL	MT	ASRS	Landing	Incident
808	15-Mar-01	US	UNKNOWN	CO	ASRS	Landing	Incident
809	05-Jun-00	US	CEDAR RAPIDS	IA	AIDS	Landing	Incident
810	01-Apr-11	US	NA	NA	ASRS	Landing	Incident
811	26-Jul-10	US	SUGAR LAND	TX	AIDS	Landing	Incident
812	21-Mar-91	US	BURBANK,	CA	NTSB	Takeoff	Accident
813	02-Feb-88	US	DURANGO	CO	NTSB	Landing	Accident
814	28-Aug-85	US	NEWARK,	NJ	NTSB	Takeoff	Accident
815	30-Jan-90	US	COEUR D'ALENE	ID	NTSB	Landing	Accident
816	21-Jan-83	US	NAPLES	FL	NTSB	Landing	Accident
817	09-Jan-87	US	BLOOMINGTON	IL	AIDS	Landing	Incident
818	01-Dec-98	US	MCGRATH	AK	ASRS	Takeoff	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
819	13-Jun-90	PR	MAYAGUEZ	PR	NTSB	Landing	Accident
820	22-Dec-93	US	MORRISVILLE	VT	AIDS	Landing	Incident
821	12-Jan-84	US	PLYMOUTH	MA	AIDS	Takeoff	Incident
822	17-Dec-83	US	HARBOR SPRINGS	MI	NTSB	Takeoff	Accident
823	06-Mar-97	US	PROVIDENCE	RI	AIDS	Takeoff	Incident
824	11-Oct-99	US	OPA LOCKA	FL	NTSB	Landing	Accident
825	15-Jun-02	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
826	16-Sep-98	MEXICO	GUADALAJARA	MEXICO	NTSB	Landing	Accident
827	06-Aug-06	US	SALINA	KS	AIDS	Landing	Incident
828	30-Jun-94	US	GAMBELL	AK	AIDS	Landing	Incident
829	15-Jul-01	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
830	31-Mar-92	US	GARDEN CITY	KS	AIDS	Landing	Incident
831	13-Mar-06	US	HOUSTON	TX	AIDS	Landing	Incident
832	02-Mar-98	US	JOHNSTOWN	PA	AIDS	Takeoff	Incident
833	13-Feb-85	US	SANTA MARIA	CA	NTSB	Landing	Accident
834	16-May-08	US	CALDWELL	NJ	NTSB	Landing	Accident
835	18-Nov-99	US	LAWRENCE	KS	AIDS	Landing	Incident
836	15-May-01	US	UNKNOWN	GA	ASRS	Landing	Incident
837	19-Sep-08	US	VAN NUYS	CA	AIDS	Landing	Incident
838	04-Mar-04	US	DENVER	CO	AIDS	Landing	Incident
839	06-Jun-96	US	SAN LUIS OBISPO	CA	MITRE	Takeoff	Accident
840	19-May-97	US	NEW ORLEANS	LA	AIDS	Landing	Incident
841	27-Dec-97	US	DENVER	CO	AIDS	Landing	Incident
842	01-Apr-88	US	PHILADELPHIA	PA	ASRS	Takeoff	Incident
843	01-Jul-88	US	LORAIN/ELYRIA	OH	ASRS	Takeoff	Incident
844	16-Feb-03	US	CAHOKIA/ST LOUIS	IL	MITRE	Landing	Accident
845	01-Apr-91	US	HOUSTON	TX	ASRS	Takeoff	Incident
846	15-Jul-01	US	UNKNOWN	FL	ASRS	Landing	Incident
847	01-Feb-89	US	PADUCAH	KY	ASRS	Landing	Incident
848	20-Aug-08	US	CHICAGO	IL	AIDS	Takeoff	Accident
849	23-Nov-98	US	LONG BEACH	CA	AIDS	Takeoff	Incident
850	15-Aug-87	US	RAVENNA	OH	NTSB	Landing	Accident
851	27-Jan-96	US	PENDLETON	OR	AIDS	Takeoff	Incident
852	02-Oct-81	US	LEXINGTON	KY	AIDS	Landing	Incident
853	20-Sep-94	US	PORTSMOUTH	NH	AIDS	Takeoff	Incident
854	01-Mar-89	US	CHICAGO/WAUKEGAN	IL	ASRS	Landing	Incident
855	15-Jan-07	US	UNKNOWN	US	ASRS	Landing	Incident
856	22-Jan-98	US	SELMER	TN	NTSB	Landing	Accident
857	17-Feb-99	BAHAMAS	NASSAU	BAHAMAS	NTSB	Landing	Accident
858	24-Jan-97	US	CHICAGO	IL	AIDS	Landing	Incident
859	10-Jan-92	US	BATON ROUGE	LA	AIDS	Takeoff	Incident
860	26-Jan-95	US	LEXINGTON	KY	AIDS	Landing	Incident
861	27-Nov-99	US	BOISE	ID	MITRE	Landing	Accident
862	01-Feb-10	US	NA	NA	ASRS	Landing	Incident
863	19-Jan-08	US	NEW YORK	NY	AIDS	Takeoff	Incident
864	22-Sep-00	US	MISSOULA	MT	NTSB	Landing	Accident
865	27-Oct-95	US	GRT BARRINGTON	MA	NTSB	Landing	Accident
866	24-Dec-04	CANADA	KUUJJUAQ	QUEBEC	CANADA TSB	Landing	Accident
867	01-Nov-94	US	FORT LAUDERDALE	FL	MITRE	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
868	27-Oct-94	US	WASHINGTON	PA	AIDS	Landing	Incident
869	13-Sep-98	US	LAS VEGAS	NV	AIDS	Landing	Incident
870	01-Sep-11	CANADA	OTTAWA	ONTARIO	ASRS	Landing	Incident
871	25-Jan-96	US	LOUISVILLE	KY	AIDS	Takeoff	Incident
872	18-Nov-90	US	ATLANTA	GA	AIDS	Landing	Incident
873	16-May-96	US	HOUSTON	TX	MITRE	Landing	Accident
874	03-Jan-94	US	TYLER	TX	ASRS	Takeoff	Incident
875	24-Oct-01	CANADA	PEACE RIVER,	ALBERTA	CANADA TSB	Landing	Incident
876	27-Mar-02	CANADA	SAINT JOHN	N. BRUNSWICK	CANADA TSB	Landing	Incident
877	16-Apr-02	CANADA	WINNIPEG	MANITOBA	CANADA TSB	Landing	Accident
878	01-Jan-90	US	IRONWOOD	MI	ASRS	Takeoff	Incident
879	03-Feb-02	IRELAND	DUBLIN		AAIU	Landing	Incident
880	24-Dec-97	NETHERLAND	AMSTERDAM		NETH. TSB	Landing	Accident
881	02-Apr-03	NETHERLAND	AMSTERDAM		NETH. TSB	Takeoff	Incident
882	07-Feb-01	SPAIN	BALBOA		SPAIN TSB	Landing	Accident
883	17-Jan-07	UK	SOUTHAMPTON		AAIB	Landing	Incident
884	29-Nov-01	US	FLAGSTAFF	AZ	NTSB	Landing	Accident
885	30-Oct-96	US	CHICAGO	IL	MITRE	Takeoff	Accident
886	21-Dec-99	GUATEMALA	GUATEMALA		BEA	Landing	Accident
887	19-Nov-99	FRANCE	PARIS		BEA	Takeoff	Accident
888	02-May-00	FRANCE	LYON-SATOLAS		BEA	Landing	Accident
889	05-Nov-00	FRANCE	PARIS		BEA	Landing	Accident
890	10-Jan-78	US	WHITE PLAINS	NY	AIDS	Landing	Incident
891	30-Jun-95	US	SAGINAW	MI	AIDS	Landing	Incident
892	21-Jan-07	US	CRAIG	CO	NTSB	Landing	Accident
893	17-Mar-02	US	LARAMIE	WY	AIDS	Landing	Incident
894	18-Mar-99	US	LINCOLN	NE	AIDS	Landing	Incident
895	18-May-91	US	ENGLEWOOD	CO	NTSB	Takeoff	Accident
896	02-Apr-00	US	YAP	FM	AIDS	Landing	Incident
897	16-Mar-01	US	CEDAR RAPIDS	IA	AIDS	Landing	Incident
898	15-Apr-91	US	HOUSTON	TX	AIDS	Takeoff	Incident
899	11-Jul-83	US	MORRISTOWN	NJ	AIDS	Takeoff	Incident
900	01-Mar-93	US	TETERBORO	NJ	ASRS	Landing	Incident
901	15-Feb-06	US	UNKNOWN	NY	ASRS	Landing	Incident
902	01-Jul-98	US	ANCHORAGE	AK	ASRS	Landing	Incident
903	02-Apr-96	US	BECKLEY	WV	AIDS	Landing	Incident
904	01-Sep-88	US	SARANAC LAKE	NY	ASRS	Landing	Incident
905	04-Mar-02	US	CHICAGO	IL	AIDS	Landing	Incident
906	29-Dec-87	US	TELLURIDE	CO	NTSB	Landing	Accident
907	15-Mar-11	US	UNKNOWN	US	ASRS	Landing	Incident
908	01-Jan-84	US	COOLIDGE,	AZ	NTSB	Takeoff	Accident
909	10-Jan-98	US	SAN FRANCISCO	CA	AIDS	Takeoff	Incident
910	24-Aug-00	US	MILWAUKEE	WI	AIDS	Landing	Incident
911	14-Feb-07	US	TETERBORO	NJ	AIDS	Landing	Incident
912	20-Mar-96	US	PORTLAND	TN	AIDS	Landing	Incident
913	01-Jan-10	US	NA	NA	ASRS	Landing	Incident
914	22-Sep-90	US	POMPANO BEACH	FL	NTSB	Landing	Accident
915	01-Mar-96	US	CHARLOTTESVILLE	VA	ASRS	Landing	Incident
916	28-Feb-79	US	MORRISTOWN	TN	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
917	07-Jul-05	US	MEDINA	OH	NTSB	Landing	Accident
918	20-Apr-92	US	CHICAGO	IL	AIDS	Landing	Incident
919	15-Apr-06	US	UNKNOWN	CA	ASRS	Takeoff	Incident
920	02-Jan-99	US	SPRINGFIELD	MO	AIDS	Landing	Incident
921	30-Sep-07	US	HOUSTON	TX	AIDS	Landing	Incident
922	22-Mar-11	US	ABERDEEN	SD	NTSB	Takeoff	Accident
923	04-Mar-02	CANADA	GOOSE BAY	NFD & LABRDR	CANADA TSB	Landing	Accident
924	24-Apr-10	US	DENTON	TX	AIDS	Landing	Incident
925	11-Sep-07	BAHAMAS	NASSAU	BAHAMAS	AIDS	Landing	Incident
926	17-Apr-03	US	FORT LAUDERDALE	FL	AIDS	Landing	Incident
927	24-May-09	UK	ELSTREE	HERTFORDSHIRE	AAIB	Landing	Incident
928	17-Apr-11	UK	MONTSERRAT	MONTSERRAT	AAIB	Landing	Incident
929	22-May-11	UK	MONTSERRAT	MONTSERRAT	AAIB	Landing	Incident
930	26-Feb-87	US	ENGLEWOOD	CO	NTSB	Takeoff	Accident
931	20-Feb-82	US	HUNTINGTON	IN	NTSB	Takeoff	Accident
932	07-Jan-83	US	HOUSTON	TX	NTSB	Landing	Accident
933	15-May-00	US	MONUMENT VALLEY	UT	ASRS	Takeoff	Incident
934	15-Mar-98	US	ASPEN	CO	ASRS	Landing	Incident
935	15-Jan-04	CANADA	DRYDEN	ONTARIO	CANADA TSB	Landing	Incident
936	30-Mar-09	N. ZEALAND	NEW PLYMOUTH		TAIC	Landing	Incident
937	10-Feb-11	IRELAND	CORK		AAIU	Landing	Accident
938	15-May-00	US	UNKNOWN	UT	ASRS	Takeoff	Incident
939	18-Mar-01	US	MONUMENT VALLEY	UT	AIDS	Landing	Incident
940	07-Oct-88	US	DURANGO	CO	AIDS	Landing	Incident
941	28-May-88	US	RENO	NV	NTSB	Landing	Accident
942	06-Jan-03	US	CHICAGO	IL	AIDS	Landing	Incident
943	08-Jan-99	US	COLUMBUS	OH	AIDS	Landing	Incident
944	01-Nov-88	US	NASHVILLE	TN	ASRS	Takeoff	Incident
945	26-Sep-03	CANADA	TORONTO	ONTARIO	CANADA TSB	Landing	Incident
946	08-Jun-05	US	DULLES	VA	MITRE	Landing	Incident
947	11-Dec-96	US	GRAND FORKS	ND	AIDS	Landing	Incident
948	15-Jun-00	US	UNKNOWN	FO	ASRS	Landing	Incident
949	03-Mar-95	US	SALT LAKE CITY	UT	AIDS	Landing	Incident
950	01-Sep-11	US	NA	NA	ASRS	Landing	Incident
951	23-Oct-87	US	AVALON	CA	NTSB	Landing	Accident
952	15-May-94	US	COEUR D'ALENE	ID	AIDS	Landing	Incident
953	27-Feb-10	US	GROVE CITY	PA	NTSB	Landing	Accident
954	14-Dec-04	US	CLEVELAND	OH	AIDS	Landing	Incident
955	10-Aug-04	US	GRAND CANYON	AZ	AIDS	Landing	Incident
956	08-Aug-99	US	CHICAGO	IL	AIDS	Takeoff	Incident
957	01-Oct-91	US	MANCHESTER	NH	ASRS	Landing	Incident
958	01-Mar-93	US	BOSTON	MA	ASRS	Landing	Incident
959	03-Jul-08	US	DESTIN	FL	AIDS	Landing	Incident
960	15-Feb-10	US	UNKNOWN	US	ASRS	Takeoff	Incident
961	15-Sep-02	US	ITHACA	NY	NTSB	Landing	Accident
962	16-Jan-08	US	HEREFORD	TX	NTSB	Landing	Accident
963	26-Sep-04	US	BROOMFIELD	CO	NTSB	Landing	Accident
964	19-Oct-89	US	CHICAGO	IL	AIDS	Landing	Incident
965	03-Aug-96	US	WEST PALM BEACH	FL	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
966	01-Mar-92	US	CAMDEN	AR	ASRS	Takeoff	Incident
967	26-Jun-87	US	DOYLESTOWN	PA	NTSB	Landing	Accident
968	03-Mar-04	US	SAINT PAUL ISLAND	AK	AIDS	Landing	Incident
969	01-Feb-11	US	NA	NA	ASRS	Landing	Accident
970	15-Jul-08	US	PORTLAND	OR	AIDS	Landing	Incident
971	25-Jun-92	US	BOSTON	MA	NTSB	Landing	Accident
972	12-Jun-06	US	KAUNAKAKAI	HI	AIDS	Landing	Incident
973	01-Jan-02	US	OGDEN	UT	ASRS	Takeoff	Incident
974	11-Jan-04	US	ALLENDALE	SC	NTSB	Takeoff	Accident
975	10-Dec-98	US	CHARLOTTE AMALIE	VI	MITRE	Landing	Accident
976	15-Feb-91	US	LOUISVILLE	KY	AIDS	Landing	Incident
977	06-May-91	US	WICHITA	KS	NTSB	Landing	Accident
978	01-Jan-97	US	HAYDEN	CO	ASRS	Takeoff	Incident
979	01-Apr-94	US	NEW ORLEANS	LA	ASRS	Landing	Incident
980	01-Jul-11	US	NA	NA	ASRS	Landing	Incident
981	10-May-96	US	DALLAS	TX	NTSB	Landing	Incident
982	15-Jun-04	US	UNKNOWN	PA	ASRS	Takeoff	Incident
983	01-Apr-01	US	NA	NA	ASRS	Landing	Incident
984	26-Oct-80	US	FLUSHING	NY	AIDS	Landing	Incident
985	02-Sep-94	US	CHICAGO	IL	AIDS	Landing	Incident
986	29-Sep-02	US	HAWTHORNE	CA	NTSB	Takeoff	Accident
987	13-Sep-03	US	KNEELAND	CA	NTSB	Landing	Accident
988	15-Dec-08	US	UNKNOWN	US	ASRS	Landing	Incident
989	01-Feb-91	US	JAMESTOWN	NY	ASRS	Landing	Incident
990	30-Mar-85	US	ASPEN	CO	NTSB	Landing	Accident
991	27-Jul-86	US	FARMINGDALE	NY	NTSB	Takeoff	Accident
992	15-Sep-03	US	RICHMOND	VA	ASRS	Landing	Incident
993	01-Sep-03	US	GULFPORT	MS	ASRS	Landing	Incident
994	02-Feb-79	US	GRAND RAPIDS	MI	AIDS	Landing	Incident
995	02-Aug-92	US	SAINT PETERSBURG	FL	AIDS	Landing	Incident
996	12-Dec-84	US	YPSILANTI	MI	AIDS	Landing	Incident
997	15-Feb-07	US	UNKNOWN	US	ASRS	Landing	Incident
998	17-Nov-87	US	PORT ANGELES	WA	NTSB	Landing	Incident
999	16-Feb-00	US	PALM SPRINGS	CA	AIDS	Landing	Incident
1000	06-Jun-90	US	ALTON	IL	AIDS	Landing	Incident
1001	21-Feb-86	US	DALLAS	TX	AIDS	Landing	Incident
1002	21-Oct-87	US	SALT LAKE CITY	UT	NTSB	Landing	Accident
1003	07-Jun-95	US	OMAHA	NE	AIDS	Landing	Incident
1004	31-Jul-83	US	VALLEY	NE	NTSB	Landing	Accident
1005	07-Nov-99	SPAIN	BARCELONA		SPAIN TSB	Landing	Accident
1006	01-Feb-10	US	NA	NA	ASRS	Takeoff	Incident
1007	29-Jun-96	US	GRAND CANYON	AZ	NTSB	Landing	Accident
1008	17-Sep-94	US	PARKERSBURG	WV	AIDS	Landing	Incident
1009	01-Jan-01	US	NA	NA	ASRS	Landing	Incident
1010	31-Mar-94	US	ORLANDO	FL	AIDS	Takeoff	Incident
1011	10-Mar-01	US	BAR HARBOR	ME	AIDS	Takeoff	Incident
1012	09-Feb-10	US	PORTLAND, OR	OR	NTSB	Takeoff	Accident
1013	14-Sep-95	US	ATLANTA	GA	AIDS	Landing	Incident
1014	30-Aug-93	US	HARTFORD	CT	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
1015	13-Dec-02	US	MANASSAS	VA	MITRE	Takeoff	Accident
1016	20-Jan-06	UK	GLASGOW		AAIB	Takeoff	Incident
1017	15-Dec-00	US	ATLANTA	GA	ASRS	Landing	Incident
1018	28-Feb-96	US	GRAND CANYON	AZ	MITRE	Landing	Accident
1019	02-Feb-85	US	SHREVEPORT	LA	NTSB	Landing	Accident
1020	01-Nov-93	US	HOUSTON	TX	ASRS	Landing	Incident
1021	01-Dec-93	US	PHILADELPHIA	PA	ASRS	Landing	Incident
1022	07-Feb-79	US	ELKO	NV	AIDS	Landing	Incident
1023	06-Oct-84	US	CINCINNATI	OH	NTSB	Landing	Accident
1024	01-Jan-10	US	NA	NA	ASRS	Landing	Incident
1025	01-Sep-08	US	ATHENS	GA	ASRS	Landing	Incident
1026	16-Jun-82	US	SCOTTSBLUFF	NE	AIDS	Landing	Incident
1027	25-Jul-02	US	COLUMBIA	SC	AIDS	Landing	Incident
1028	23-Jun-81	US	PHILADELPHIA	PA	AIDS	Takeoff	Incident
1029	10-Jan-97	US	BANGOR	ME	NTSB	Takeoff	Accident
1030	24-Feb-88	US	MORGANTON	NC	NTSB	Takeoff	Accident
1031	24-Feb-82	US	CHICAGO	IL	NTSB	Landing	Incident
1032	02-Jan-82	US	PAROWAN	UT	AIDS	Landing	Incident
1033	28-Dec-00	US	ERIE	PA	AIDS	Takeoff	Incident
1034	28-Jan-94	US	WASHINGTON	DC	MITRE	Takeoff	Incident
1035	15-Oct-81	US	SAINT LOUIS	MO	AIDS	Landing	Incident
1036	26-Feb-94	US	KIVALINA	AK	NTSB	Landing	Accident
1037	27-Dec-05	US	MARQUETTE	MI	AIDS	Landing	Incident
1038	06-Jan-89	US	WASHINGTON	DC	AIDS	Takeoff	Incident
1039	16-Aug-89	US	DALLAS	TX	AIDS	Takeoff	Incident
1040	28-Jan-00	US	FAYETTEVILLE	AR	MITRE	Landing	Accident
1041	19-Dec-88	US	ELKHART	KS	NTSB	Landing	Accident
1042	01-May-01	US	NEW YORK	NY	ASRS	Landing	Incident
1043	03-Oct-08	US	LEWISTON	ID	AIDS	Landing	Incident
1044	27-Nov-08	US	IRONWOOD	MI	AIDS	Landing	Incident
1045	15-Nov-01	US	PASCO	WA	NTSB	Landing	Accident
1046	01-Dec-90	US	GRAND CANYON	AZ	ASRS	Takeoff	Incident
1047	02-Jan-97	US	LAKELAND	FL	NTSB	Takeoff	Accident
1048	01-Dec-09	US	NA	NA	ASRS	Landing	Incident
1049	20-Jan-98	US	SARANAC LAKE	NY	NTSB	Landing	Accident
1050	22-Oct-88	US	HOUSTON	TX	AIDS	Takeoff	Incident
1051	18-Apr-97	US	RANGELEY	ME	AIDS	Landing	Incident
1052	19-Jan-09	UK	ISLE OF MAN	ISLE OF MAN	AAIB	Landing	Incident
1053	25-Feb-06	US	TRENTON	NJ	AIDS	Landing	Incident
1054	10-Mar-98	US	DETROIT	MI	AIDS	Takeoff	Incident
1055	14-Sep-94	US	ROCHESTER	NY	AIDS	Takeoff	Incident
1056	23-Sep-99	US	SANTA MONICA	CA	NTSB	Landing	Accident
1057	25-Aug-01	US	KANSAS CITY	MO	MITRE	Landing	Accident
1058	03-Dec-05	US	ANN ARBOR	MI	AIDS	Landing	Incident
1059	14-Dec-06	US	SARASOTA	FL	AIDS	Landing	Incident
1060	12-Jan-09	US	CORONA	CA	NTSB	Takeoff	Accident
1061	15-Feb-03	US	UNKNOWN	VA	ASRS	Landing	Incident
1062	30-Mar-82	US	CHICAGO	IL	NTSB	Takeoff	Incident
1063	19-Dec-84	US	SALT LAKE CITY	UT	AIDS	Landing	Incident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
1064	09-May-04	US	SAN JUAN	PR	NTSB	Landing	Accident
1065	15-Feb-03	US	UNKNOWN	IL	ASRS	Landing	Incident
1066	01-Mar-02	US	LARAMIE	WY	ASRS	Landing	Incident
1067	31-Mar-04	US	OMAHA	NE	NTSB	Takeoff	Accident
1068	03-Aug-95	US	PORTLAND	OR	MITRE	Landing	Incident
1069	10-Apr-95	US	DALLAS	TX	AIDS	Landing	Incident
1070	01-Dec-09	US	NA	NA	ASRS	Landing	Incident
1071	02-Feb-96	US	MEMPHIS	TN	AIDS	Landing	Incident
1072	19-Jan-97	US	ASPEN	CO	AIDS	Takeoff	Incident
1073	22-Dec-10	US	SAINT MICHAEL	AK	NTSB	Landing	Accident
1074	07-Jul-84	US	GUALALA	CA	NTSB	Landing	Accident
1075	01-Dec-05	US	SIOUX FALLS	SD	AIDS	Landing	Incident
1076	03-Mar-01	US	FORT LAUDERDALE	FL	MITRE	Landing	Accident
1077	24-Jan-90	US	OLATHE	KS	AIDS	Landing	Incident
1078	13-Dec-00	US	PENSACOLA	FL	MITRE	Landing	Accident
1079	15-Feb-08	US	PHOENIX	AZ	ASRS	Landing	Incident
1080	15-Oct-04	US	UNKNOWN	US	ASRS	Landing	Incident
1081	16-Sep-06	US	MODESTO	CA	AIDS	Landing	Incident
1082	28-Sep-02	US	MINERAL WELLS	TX	NTSB	Landing	Accident
1083	13-Jul-09	US	YAKUTAT	AK	NTSB	Landing	Accident
1084	06-Jan-82	US	ATLANTA	GA	AIDS	Landing	Incident
1085	01-Apr-11	US	NA	NA	ASRS	Takeoff	Incident
1086	22-Dec-09	US	MOAB	UT	NTSB	Takeoff	Accident
1087	20-Mar-06	US	MINNEAPOLIS	MN	AIDS	Landing	Incident
1088	17-Dec-81	US	VAN NUYS	CA	AIDS	Landing	Incident
1089	02-Feb-82	US	PORT CLINTON	OH	AIDS	Landing	Incident
1090	16-Jan-93	US	JOHN DAY	OR	NTSB	Landing	Accident
1091	28-Aug-02	US	PHOENIX	AZ	NTSB	Landing	Accident
1092	23-Nov-94	US	AKRON	OH	AIDS	Landing	Incident
1093	01-May-98	US	FORT LAUDERDALE	FL	AIDS	Takeoff	Incident
1094	01-Dec-93	US	FT LAUDERDALE	FL	ASRS	Landing	Incident
1095	23-Apr-99	AUSTRALIA	FITIUTA	AUSTRALIA	ATSB	Landing	Accident
1096	07-Aug-93	US	SPRUCE CREEK	FL	AIDS	Landing	Incident
1097	21-Feb-79	US	DETROIT	MI	AIDS	Takeoff	Incident
1098	11-Jun-91	US	SEATTLE	WA	AIDS	Landing	Incident
1099	14-May-99	US	HICKORY	NC	MITRE	Landing	Accident
1100	15-May-00	US	UNKNOWN	NM	ASRS	Landing	Incident
1101	01-Mar-88	US	NASHVILLE	TN	ASRS	Takeoff	Incident
1102	01-Feb-88	US	TETERBORO	NJ	ASRS	Takeoff	Incident
1103	18-Aug-84	US	CEDAR CITY	UT	AIDS	Landing	Incident
1104	17-Jan-04	US	RAPID CITY	SD	NTSB	Landing	Incident
1105	27-Jan-97	US	SPRINGFIELD	MO	NTSB	Landing	Accident
1106	21-May-00	US	NANTUCKET	MA	AIDS	Takeoff	Incident
1107	15-Nov-07	US	UNKNOWN	US	ASRS	Landing	Incident
1108	01-Jul-92	US	DAYTON	OH	ASRS	Landing	Incident
1109	01-Nov-98	US	ATLANTA	GA	MITRE	Landing	Accident
1110	30-Jan-91	US	JOHNSTOWN	PA	NTSB	Landing	Accident
1111	25-Mar-85	US	FORT MYERS	FL	NTSB	Landing	Accident
1112	11-Feb-87	US	ONEONTA	NY	NTSB	Landing	Accident

Rec #	Event Date	Country	City	State	Source	Type of Veer-Off	Severity
1113	25-Oct-94	US	SHREVEPORT	LA	AIDS	Landing	Incident
1114	16-Mar-00	US	FORT LAUDERDALE	FL	NTSB	Takeoff	Accident
1115	11-Sep-98	US	HOUSTON	TX	NTSB	Landing	Accident
1116	04-Feb-88	US	NEWBURGH	NY	AIDS	Landing	Incident
1117	11-Jun-04	US	DALLAS	TX	NTSB	Landing	Incident
1118	08-Jul-84	US	PONTIAC	MI	AIDS	Landing	Incident
1119	01-Jan-88	US	CORTEZ	CO	ASRS	Landing	Incident
1120	31-Jan-94	US	ANDERSON	IN	NTSB	Takeoff	Accident
1121	01-Jun-92	US	BOSTON	MA	ASRS	Landing	Incident
1122	26-Jan-96	US	ATLANTA	GA	AIDS	Landing	Incident
1123	21-Jan-04	US	PUEBLO	CO	MITRE	Landing	Accident
1124	30-Sep-96	US	ASPEN	CO	MITRE	Landing	Accident
1125	15-May-04	US	PONTIAC	MI	AIDS	Landing	Incident
1126	01-Jan-91	US	LAKE CHARLES	LA	ASRS	Landing	Incident
1127	30-Oct-96	US	WHEELING	IL	NTSB	Takeoff	Accident
1128	06-Feb-04	US	RICHMOND	VA	AIDS	Landing	Incident
1129	01-Mar-11	US	NA	NA	ASRS	Landing	Incident
1130	07-Jun-00	US	BIRMINGHAM	AL	AIDS	Landing	Incident
1131	01-Aug-02	US	MANASSAS	VA	ASRS	Landing	Incident
1132	29-Aug-09	FRANCE	LYON		BEA	Takeoff	Incident
1133	22-Feb-84	US	CORDOVA	AK	NTSB	Landing	Incident
1134	15-Jan-06	US	UNKNOWN	FO	ASRS	Landing	Incident
1135	09-Oct-07	US	CHICAGO	IL	NTSB	Landing	Incident
1136	29-Oct-00	IRELAND	CORK		AAIU	Landing	Incident
1137	31-Jul-00	US	LAS VEGAS	NV	AIDS	Takeoff	Incident
1138	22-Feb-97	US	ALMA	MI	AIDS	Landing	Incident
1139	01-Jul-05	US	AMARILLO	TX	MITRE	Landing	Accident
1140	15-Sep-02	US	UNKNOWN	IL	ASRS	Takeoff	Incident
1141	04-Jan-88	US	BELMAR	NJ	AIDS	Landing	Incident
1142	31-Aug-94	US	FORT SMITH	AR	AIDS	Landing	Incident
1143	01-Jun-83	US	NORTH LAS VEGAS	NV	NTSB	Landing	Accident
1144	22-Sep-00	US	MISSOULA	MT	NTSB	Landing	Accident

APPENDIX C

Lateral Deviation Models for Normalization Alternative 1—Runway Distance Available

The figures presented in this Appendix illustrate the lateral deviation models developed when normalizing the longitudinal veer-off distances with the runway distance available (RDA)

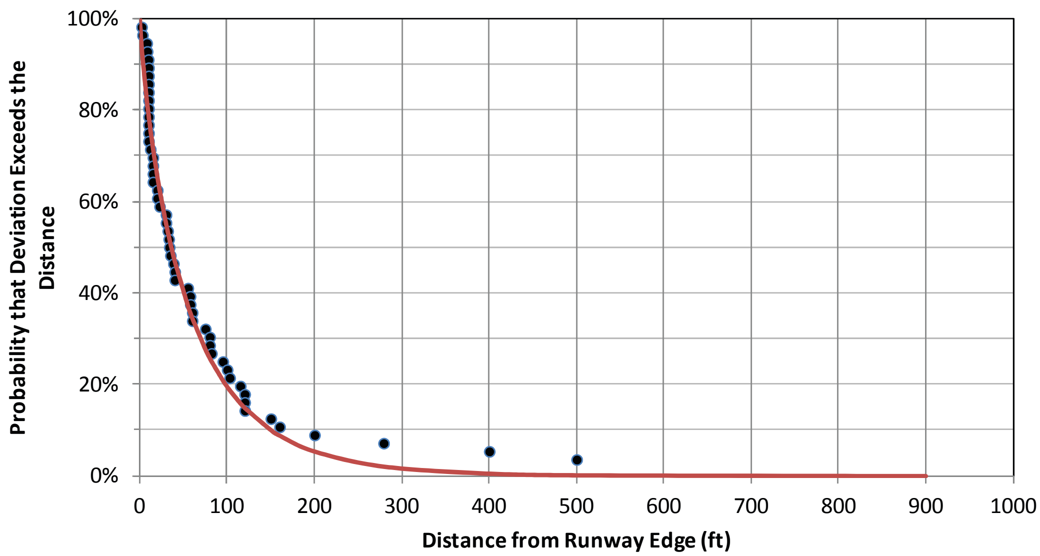


Figure C1. Lateral probability distribution: – Subarea 1—distances normalized by RDA.

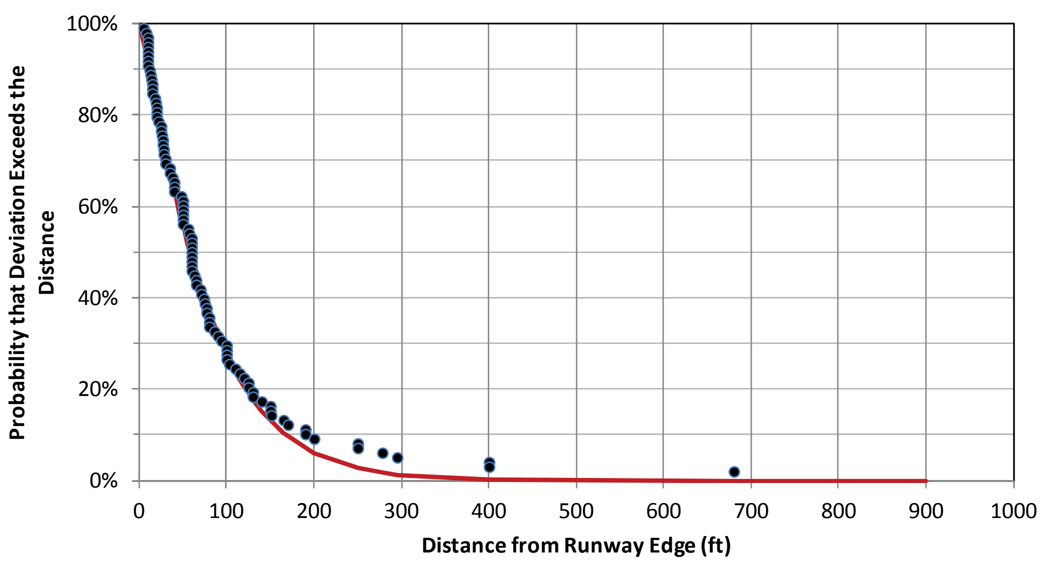


Figure C2. Lateral probability distribution: – Subarea 2—distances normalized by RDA.

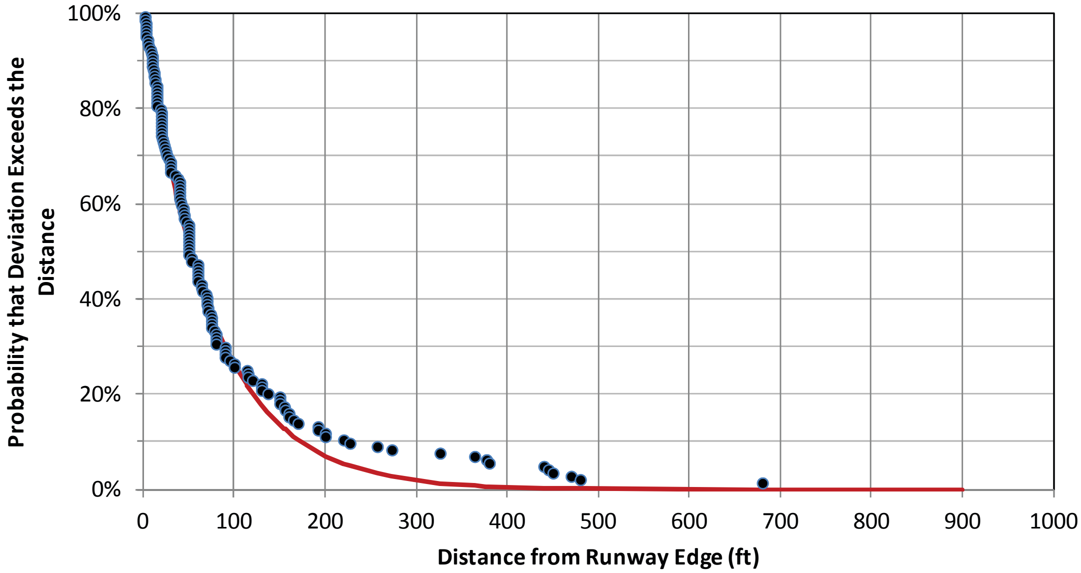


Figure C3. Lateral probability distribution: Subarea 3—distances normalized by RDA.

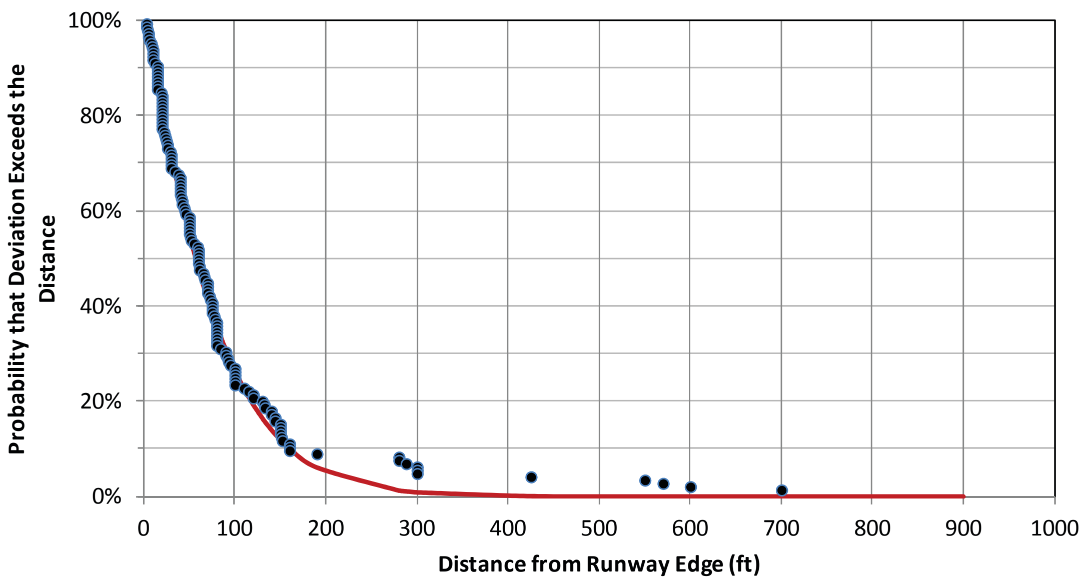


Figure C4. Lateral probability distribution: Subarea 4—distances normalized by RDA.

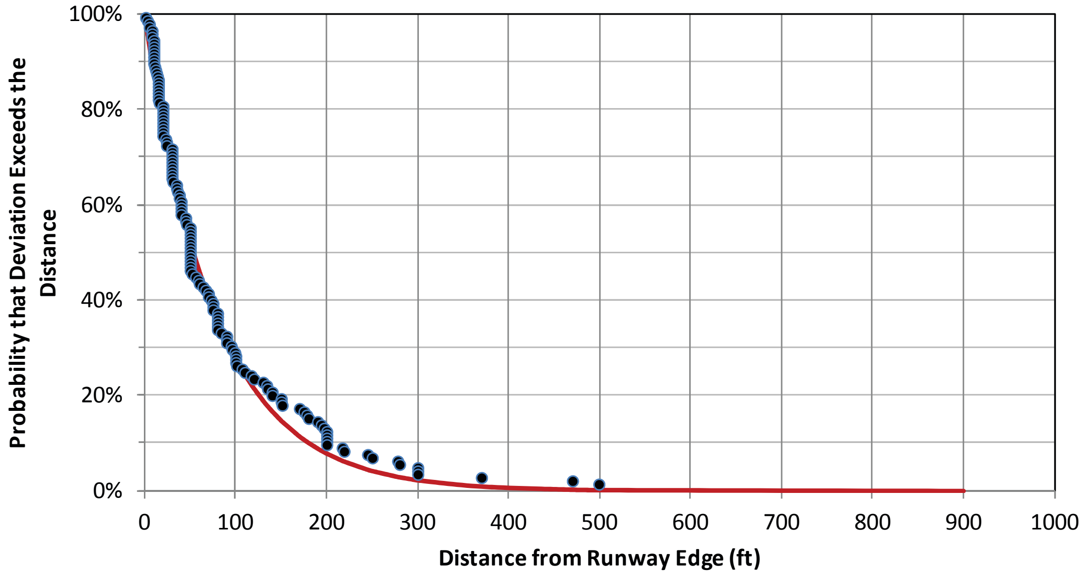


Figure C5. Lateral probability distribution: Subarea 5—distances normalized by RDA.

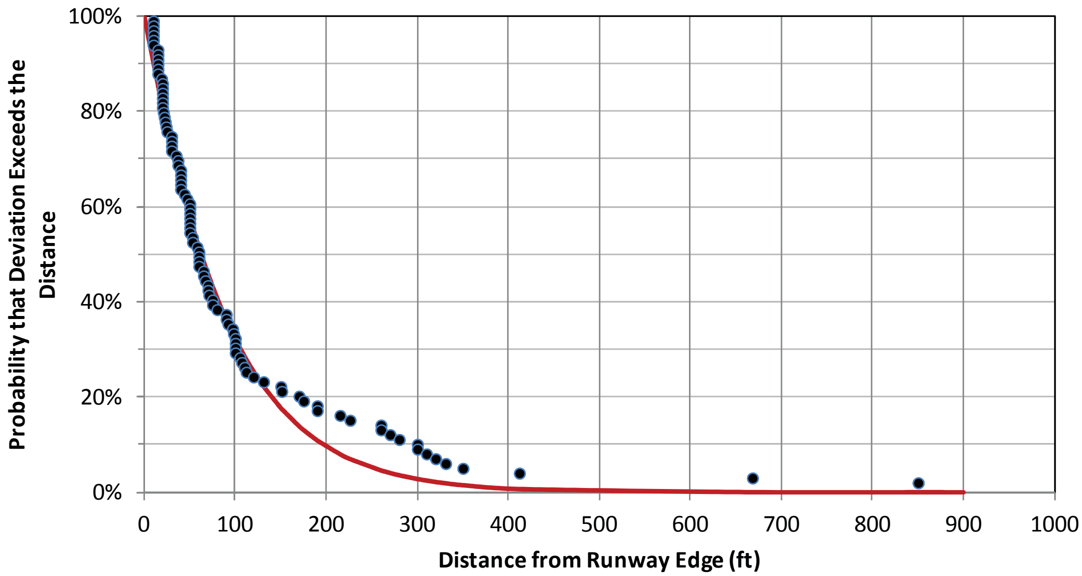


Figure C6. Lateral probability distribution: Subarea 6—distances normalized by RDA.

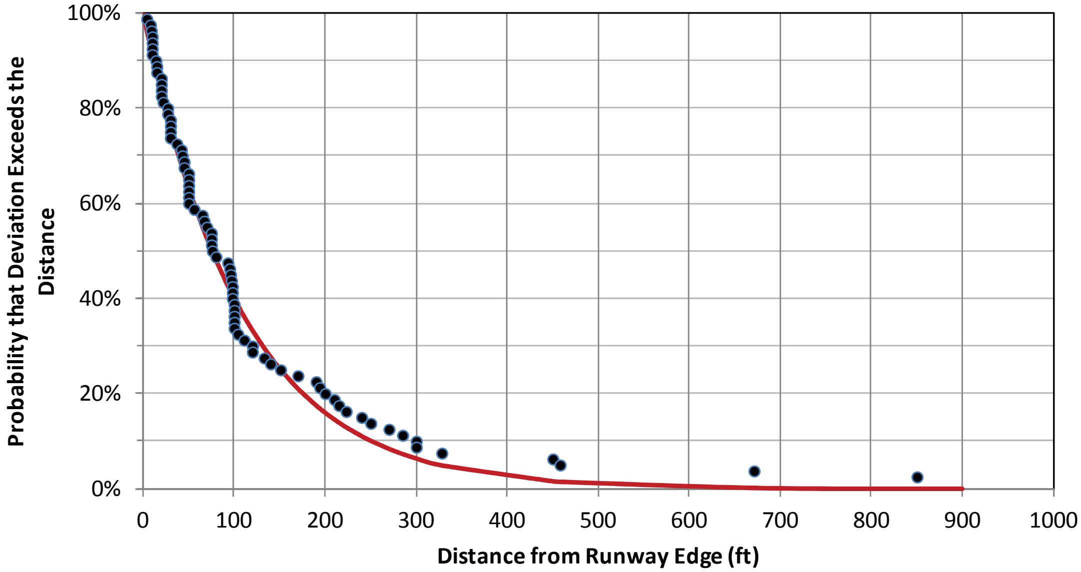


Figure C7. Lateral probability distribution: – Subarea 7—distances normalized by RDA.

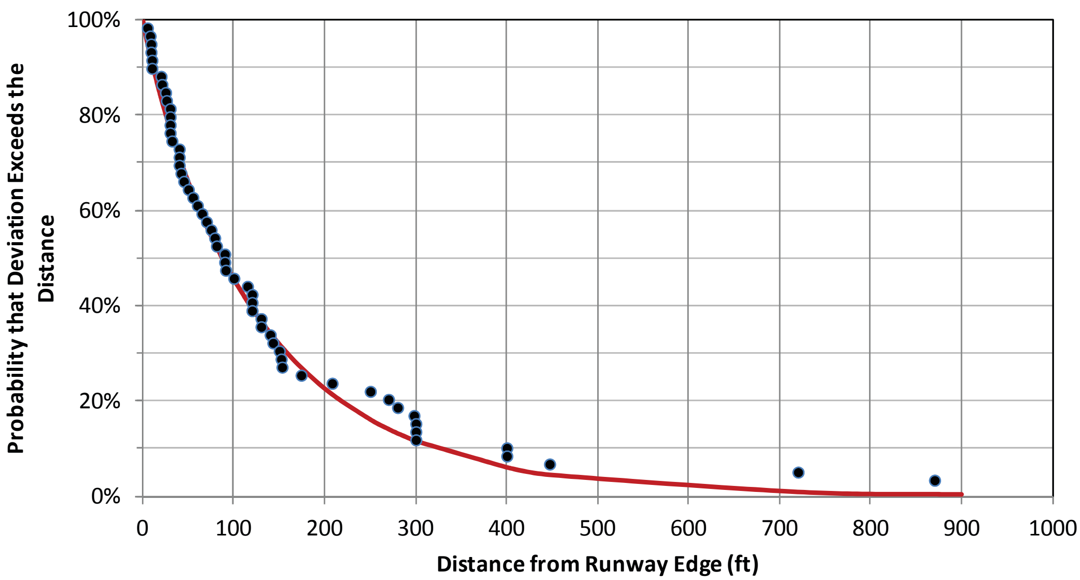


Figure C8. Lateral probability distribution: Subarea 8—distances normalized by RDA.

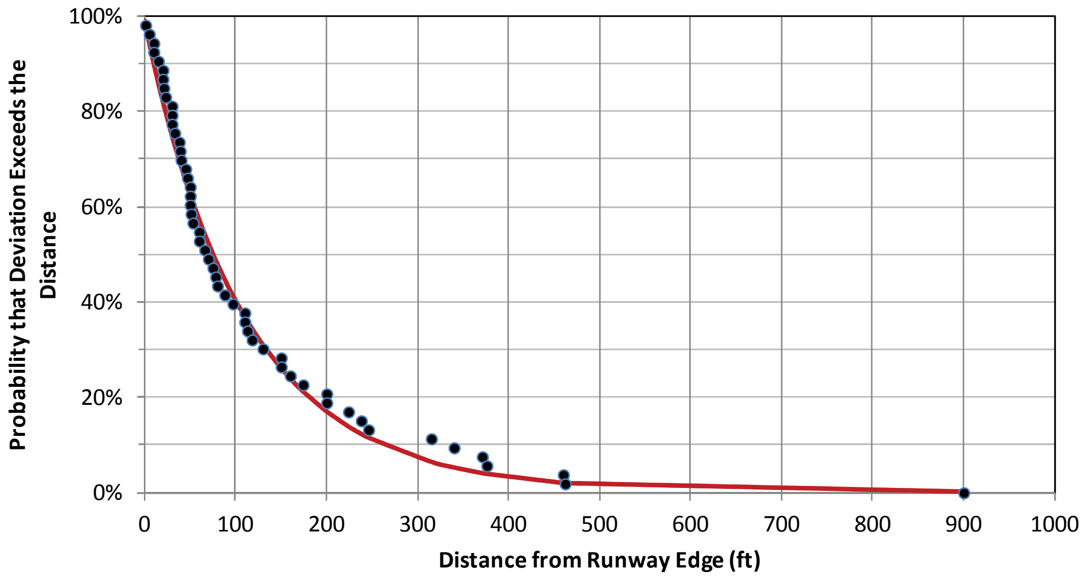


Figure C9. Lateral probability distribution: – Subarea 9—distances normalized by RDA.

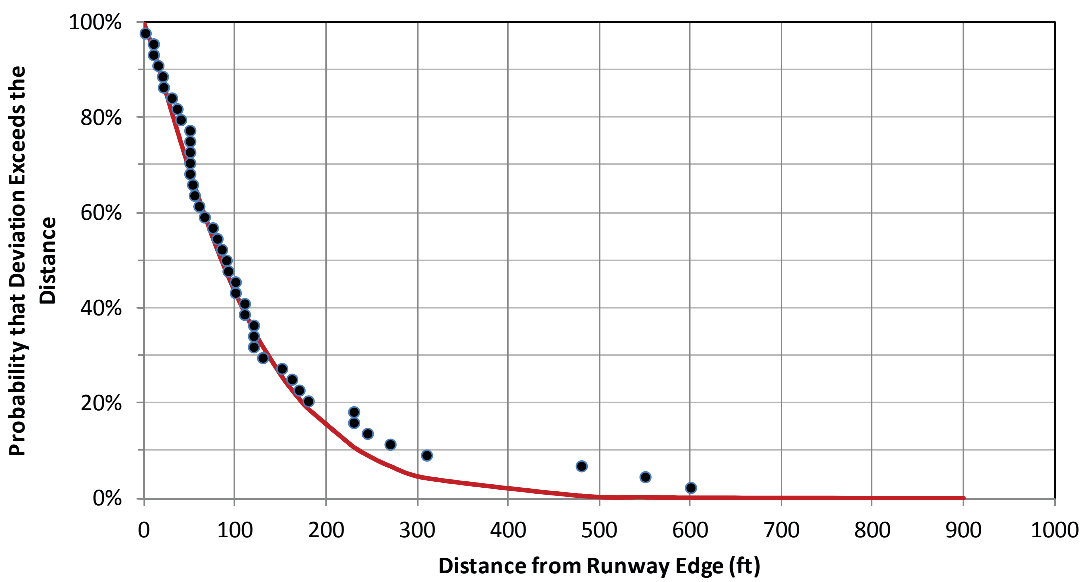


Figure C10. Lateral probability distribution: Subarea 10—distances normalized by RDA.

APPENDIX D

LRSARA User Guide

Runway Veer-Off Location Distribution Risk Assessment Model

Lateral Runway Safety Area Risk Analysis (LRSARA)

Software User's Guide (V1.1)

developed by Airport Safety Management Consultants, LLC
for the Airport Cooperative Research Program (ACRP)

Disclaimer

While every precaution has been taken in the preparation of this analysis tool, the Airport Cooperative Research Program (ACRP) and Airport Safety Management Consultants, LLC (ASMC) assume no responsibility for errors or omissions, or for damages resulting from the use of information contained in this document or from the use of this software. In no event shall ACRP or ASMC be held liable for any loss of profit or any other commercial damage caused or alleged to have been caused directly or indirectly by the use of this software.

The user shall be aware that the software should not be used without adequate knowledge of the contents of ACRP Report 107 and this User Guide for LRSARA Software. Analysis software contains a tool developed to assist with risk analysis associated with the lateral portion of runway safety areas and is not intended to be a substitute for the airport planner professional judgment.

Neither ACRP nor ASMC shall be held liable for any 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 LRSARA software, nor for damage inflicted with respect to any property of the customer or any other loss sustained by said customer. Neither ACRP nor ASMC shall be responsible for the accuracy or validity of the data entered and/or generated by the software.

Lateral Runway Safety Area Risk Analysis (LRSARA)

User Guide – Version 1.0

1. Introduction

This software is being developed as part of the Airport Cooperative Research Program (ACRP) Project ACRP 4-14, "Runway Veer-off Location Distribution Risk Assessment Model" and is intended to serve as a tool to help airport operators evaluate risk associated with their lateral RSA conditions.

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

- Landing veer-off (LDVO)
- Takeoff veer-off (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 lateral limits of the RSA. In the second type of analysis, the user may consider the obstacles inside or in the vicinity of the lateral sections of the RSA to evaluate the risk of an accident (substantial aircraft damage and/or multiple injuries/fatalities).

2. System Requirements

Component	Requirement
Computer and processor	1.0 gigahertz (GHz) processor or higher
Memory	2 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 7, or later operating system
Other	LRSARA utilizes modules from Microsoft Office Suite 2010, particularly Microsoft Access to handle the databases and Microsoft Excel to handle data input and output results. Therefore, the user must have Microsoft Office 2010 with Excel and Access to run LRSARA

3. Using the Guide

To facilitate reading and comprehension of this user 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.

Movements Challenging the Lateral RSA

In a given airport, any movement (landing or takeoff) may challenge the right or left side of the lateral portion of the RSA, in case of a lateral runway excursion (veer-off).

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 in 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.

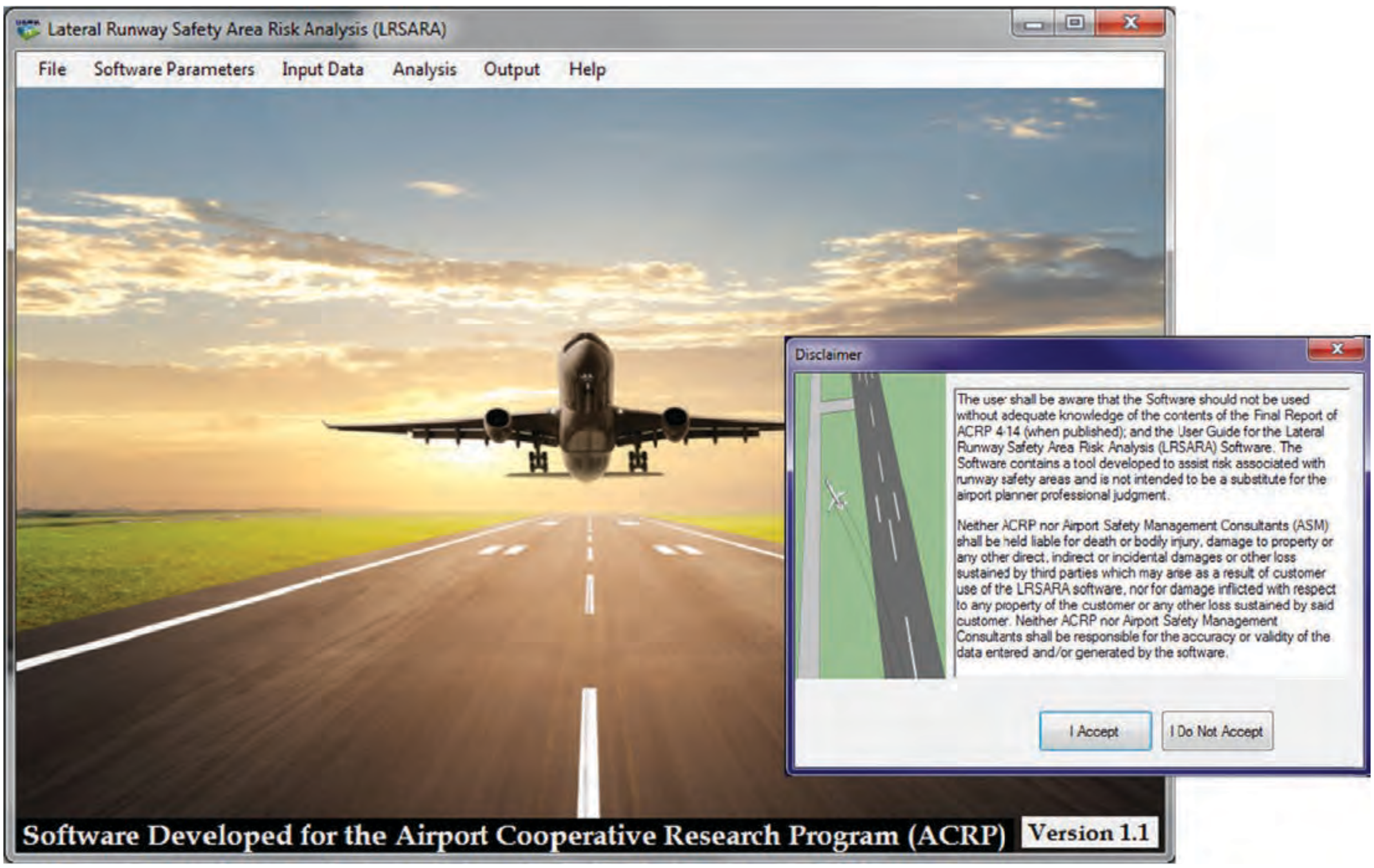
4. Software Installation

The installation of LRSARA uses the same process applied to other Windows programs. Go to the folder where you downloaded (either from the TRB website or the accompanying CD) and unzipped LRSARA, 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 LRSARA. To remove LRSARA, select ***Start/Control Panel*** in your desktop window. Select ***Add or Remove Programs***. When the program list is populated, select ***LRSARA*** and click ***Remove***.

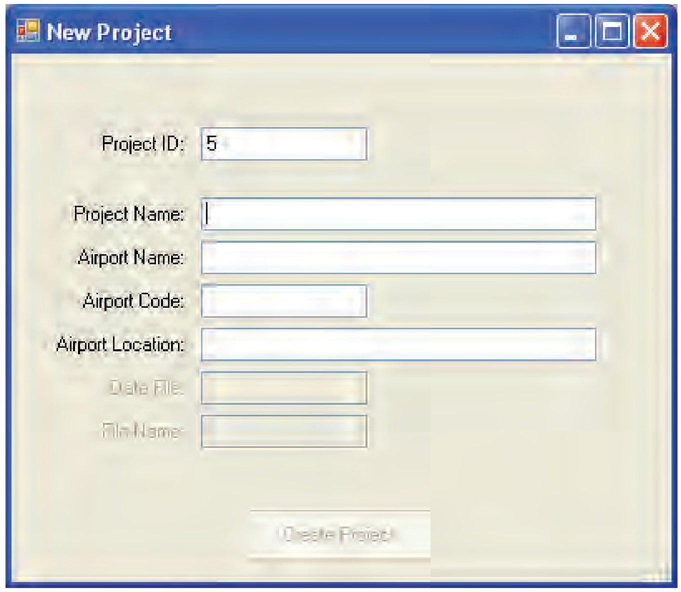
5. Opening the Program

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

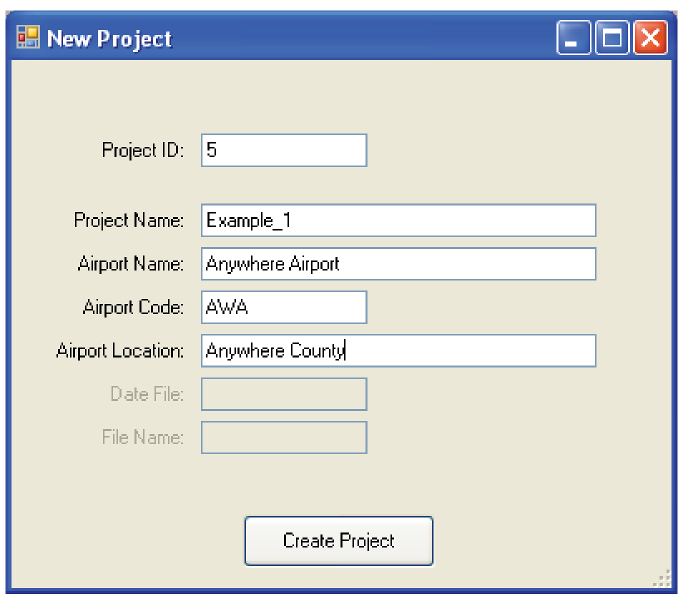


6. Creating a New Project

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



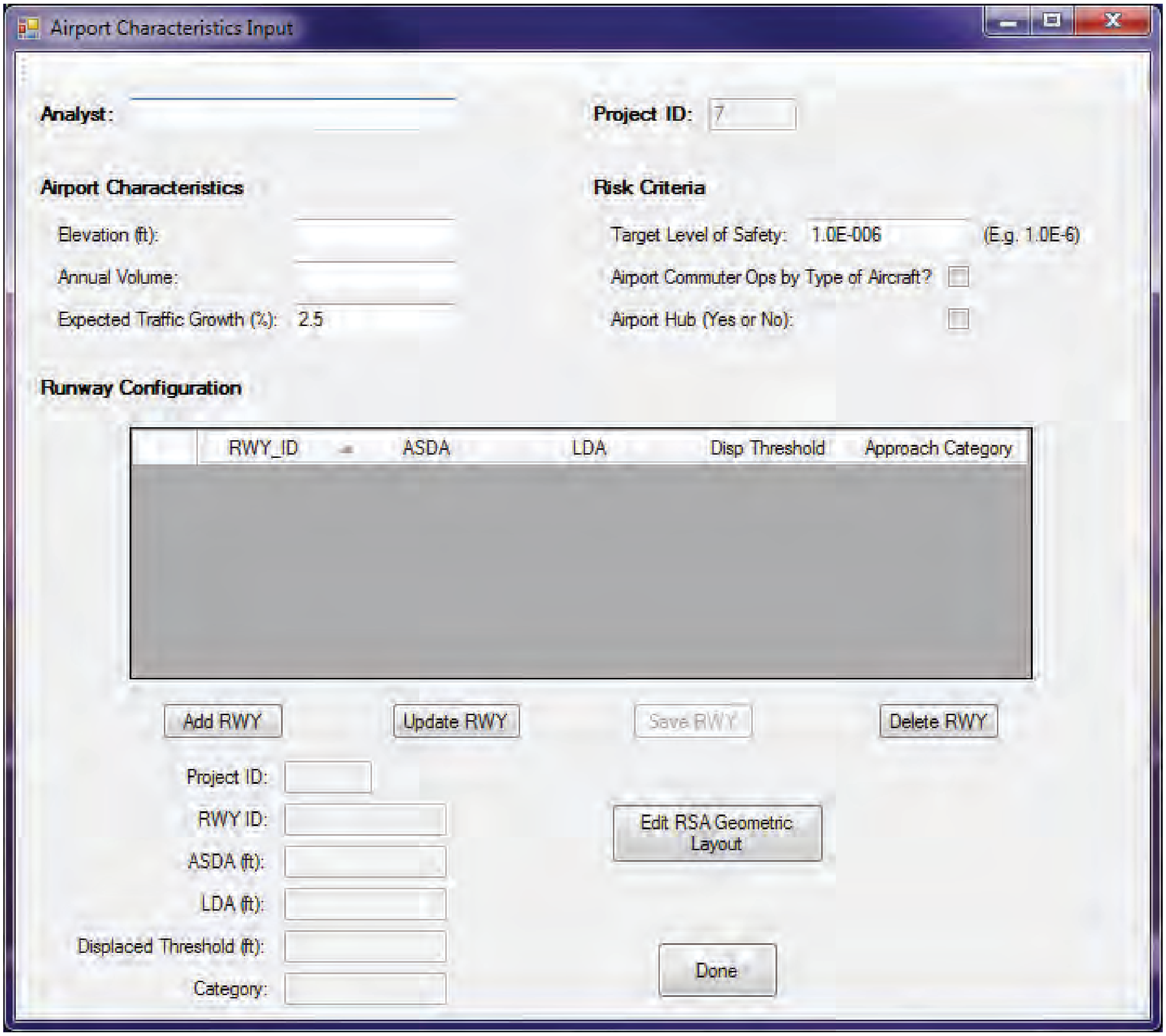
Fill the fields as shown in the example below and click ***Create Project***. The project name cannot have spaces.



7. Entering Data

Defining Airport Conditions

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



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

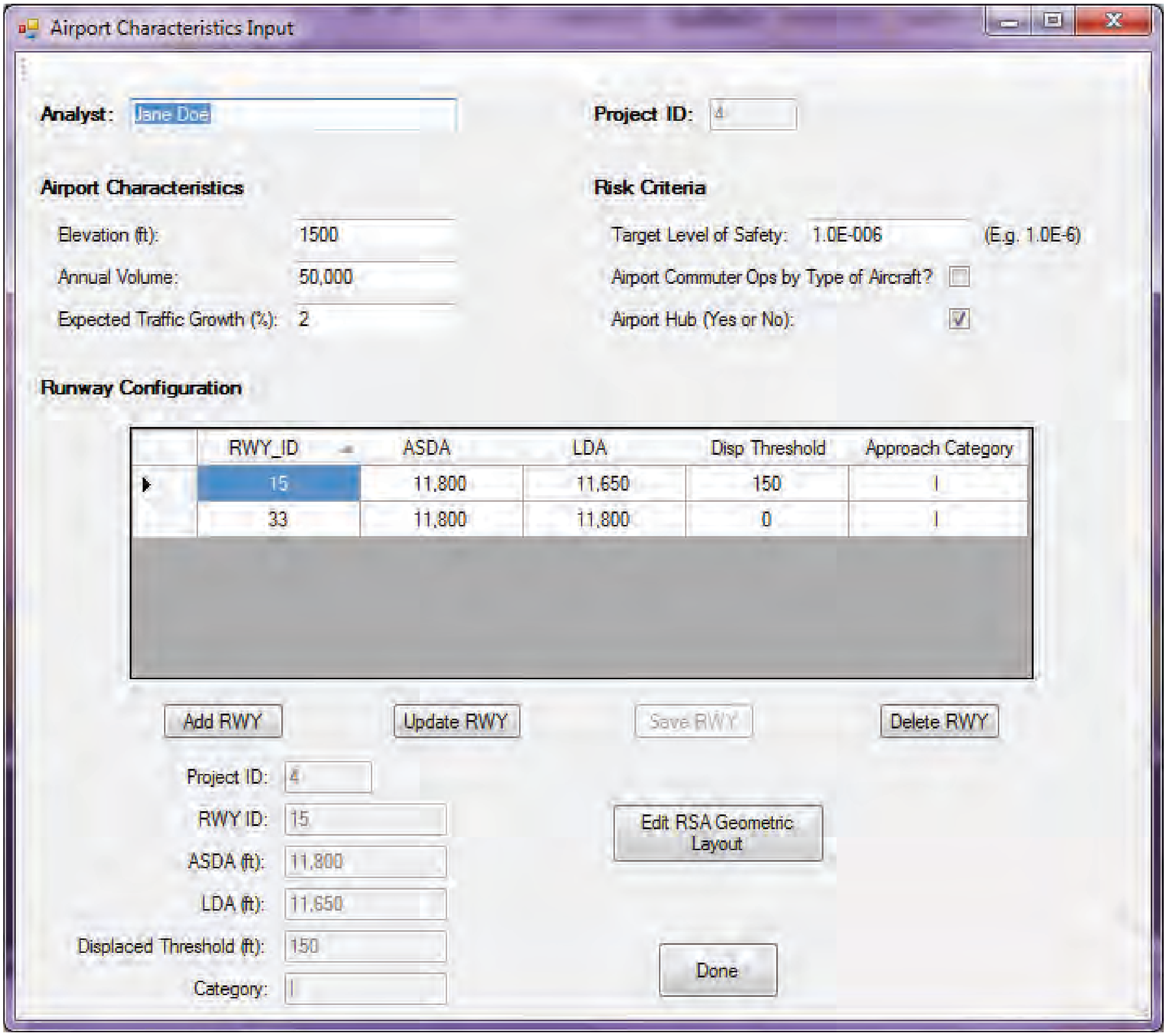
Field	Description	Example	Meaning
Elevation (ft)	The airport elevation, in feet	1500	The highest point on any of the airport's runways is 1,200 ft relative to sea level
Expected Traffic Growth (%)	The average expected annual growth for aircraft movements	2.0	The average annual growth for future years 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 risk is expressed in the form of a TLS or Criteria	1.0E-06	In this case, the acceptable level of risk is 1 accident in 1,000,000 movements, or 0.000001 (or 1.0E-06) 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	☐	If checked, 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 the analysis, each runway direction is treated independently**. To enter the runway information, click on ***Add RWY*** to enable the runway fields. The information required follows.

Field	Description	Example	Meaning
RWY ID	Enter the runway designation	15	This is the designation for runway 15
ASDA (ft)	Accelerate-Stop Distance Available for takeoff, in feet	11800	Runway 15 has an ASDA of 11,800 feet
LDA (ft)	Landing Distance Available, in feet	11650	Runway 15 has an LDA of 11,650 feet. This distance is automatically calculated based on the ASDA and Displaced Threshold
Displaced Threshold (ft)	Distance that threshold is displaced for landing	150	Runway 15 has a displaced threshold of 150 ft
Approach Category	Type of instrument approach available	I	Runway 15 approach category is precision level 1. Other possibilities are: V (visual), NP (non-precision), CAT II and CAT III

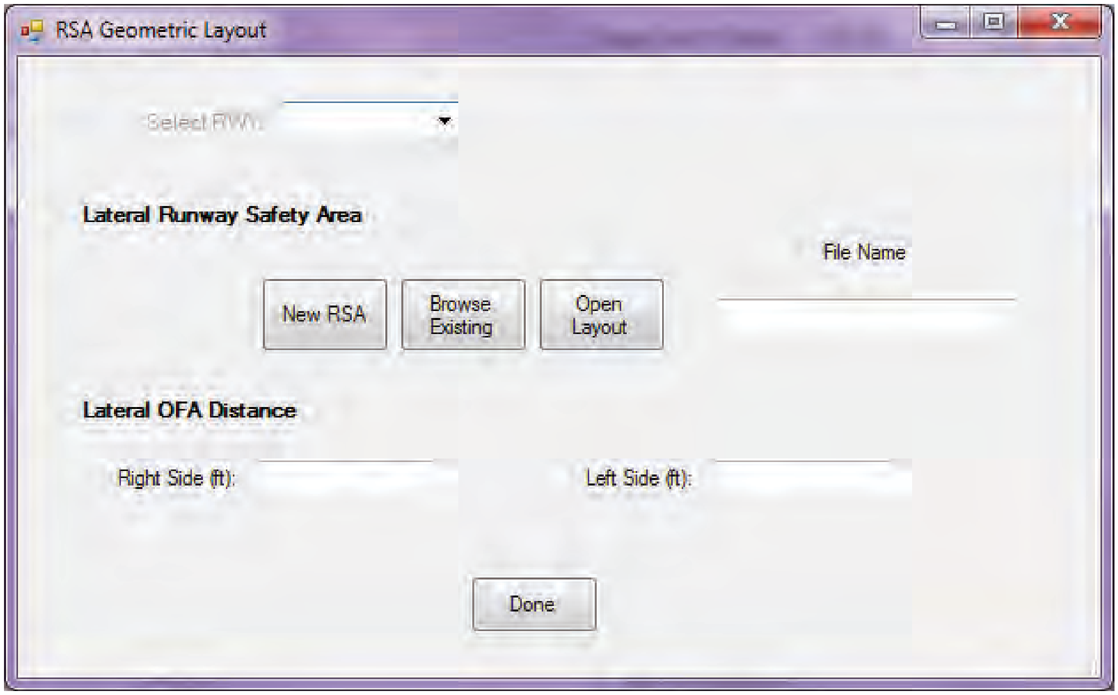
Once the runway fields are filled, save the information by clicking ***Save RWY***. You may continue adding the basic information for each runway before defining the RSA geometry for the runway. Changes to runway declared distances can be made by clicking ***Update RWY*** and saving the changes.

For the Example Project, the information for runways 15 and 33 were entered and the following screen illustrates the example.



Defining Lateral RSA Geometry and Obstacles

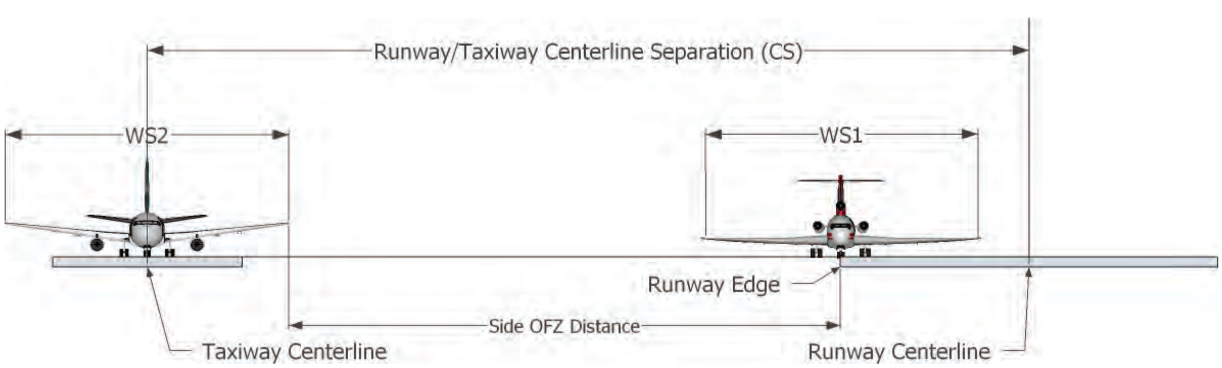
Next, enter the RSA information, including the geometry and existing obstacles. To perform this step, click ***Edit RSA Geometric Layout*** and the following screen will appear.



The dropdown list includes all runways entered. In the example above, runway 15 is selected. The screen contains one set of buttons to define the lateral RSA geometry and the presence of obstacles. The two fields for ***Lateral OFA Distance*** are used to define the **distance from the runway edge** (not from the runway centerline) to the farthest lateral distance to an existing obstacle limiting the available Object Free Area (OFA).

The runway in the example is 150 ft wide, and the RSA limit is 300 ft from the runway edge. The first step is to define the lateral RSA geometry. This area helps protect aircraft veering off runways 15/33.

The ***Lateral OFA Distance*** is the clearance from the runway edge to the nearest obstacle, fixed or movable. LRSARA assumes a ground-level obstacle as default to limit the Lateral OFA Distance. However, in some cases, the object may be a hangar or another fixed object and the user will be required to define a "wing-level" obstacle at the borders, for example, an aircraft located in a parallel taxiway. In this latter case, the ***Lateral OFA Distance*** will be assumed as 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 available lateral distance will be automatically calculated as follows:

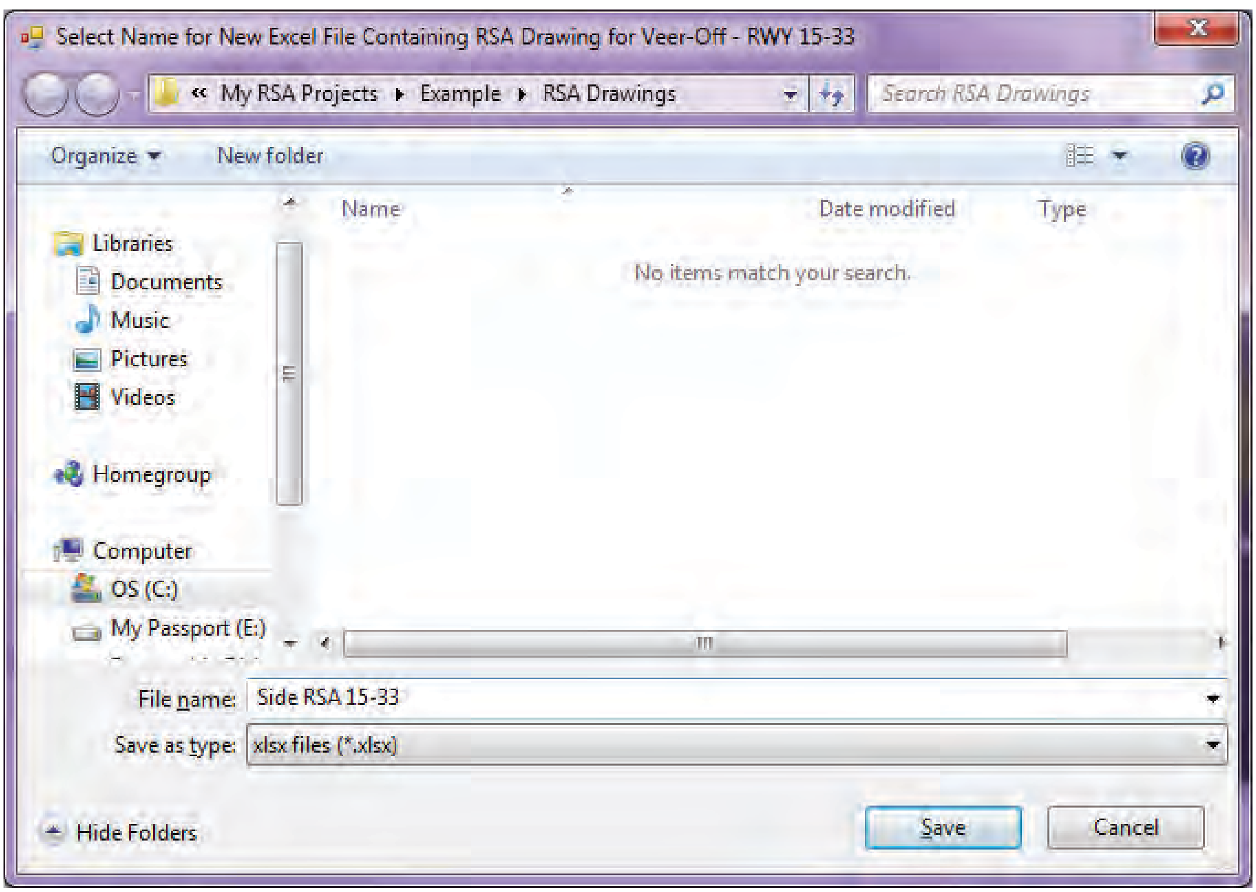
SOFAD = CS-RW/2-WS2/2

Where:

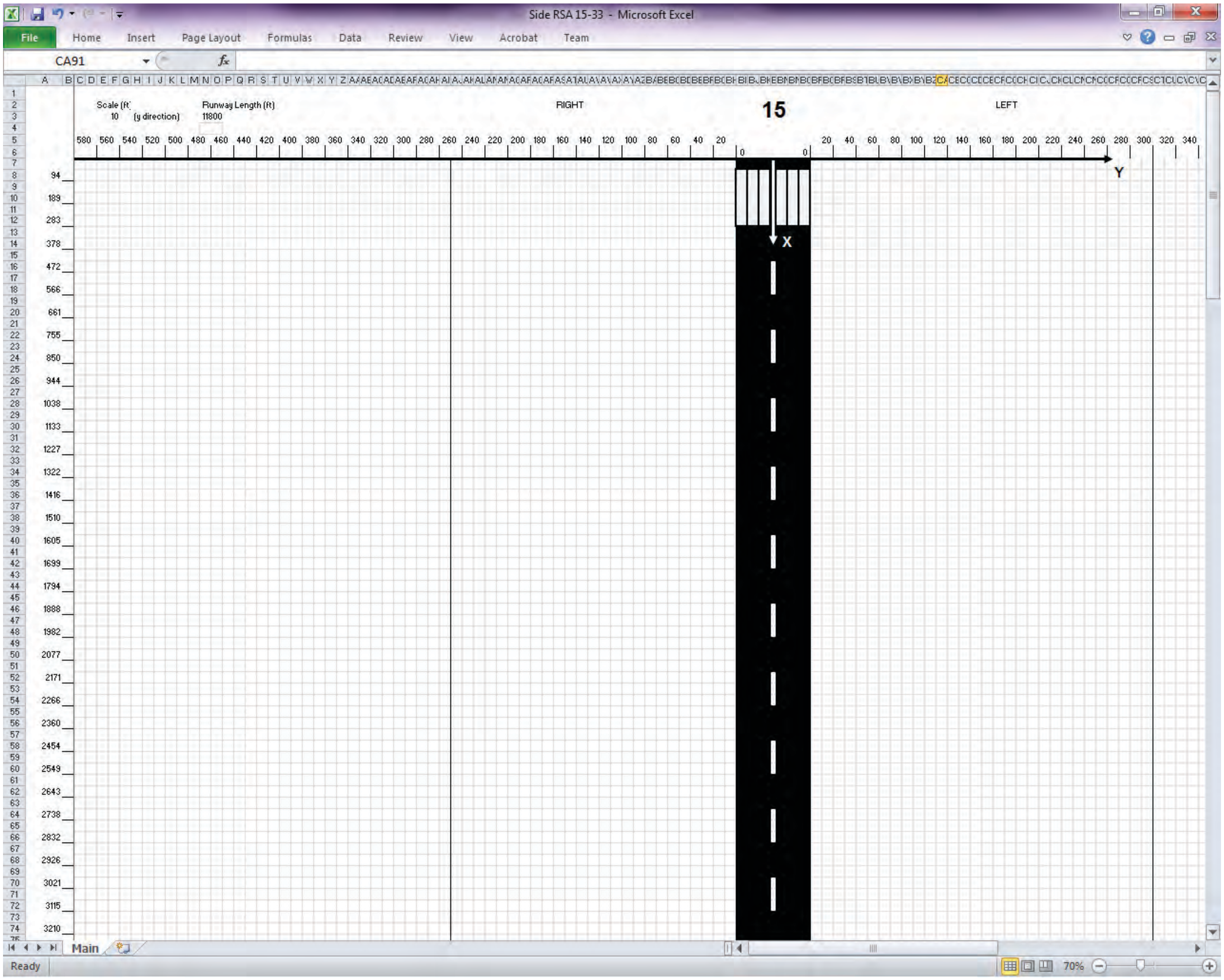
- SOFAD is the lateral cleared distance available
- CS is the runway/taxiway centerline separation
- RW is the runway width
- WS2 is the wingspan of the aircraft in the taxiway, usually characterized by the largest wingspan of the ADG of the airfield

The lateral cleared distance available to the right and to the left are not necessarily the same. In the example, the cleared distance on right side of Runway 15 is 250 ft measured from the runway edge, and the left side is 300 ft wide. LRSARA software takes into consideration the gear width of the aircraft landing or taking off to calculate the cleared distance in the default case. Again, if the user prefers to use a tall obstacle to limit the RSA, a tall obstacle should be placed over the entire distance of the runway, and located at the OFA edge.

To define the RSA, click on ***New RSA*** and 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 runways chosen, for instance, the example used here would be 15/33 RSA. Click ***Save*** and the Excel spreadsheet will open, as shown in the following screen. The user should note that each layout will represent the runway in both directions; therefore, it is not necessary to create another template to input information for Runway 33.

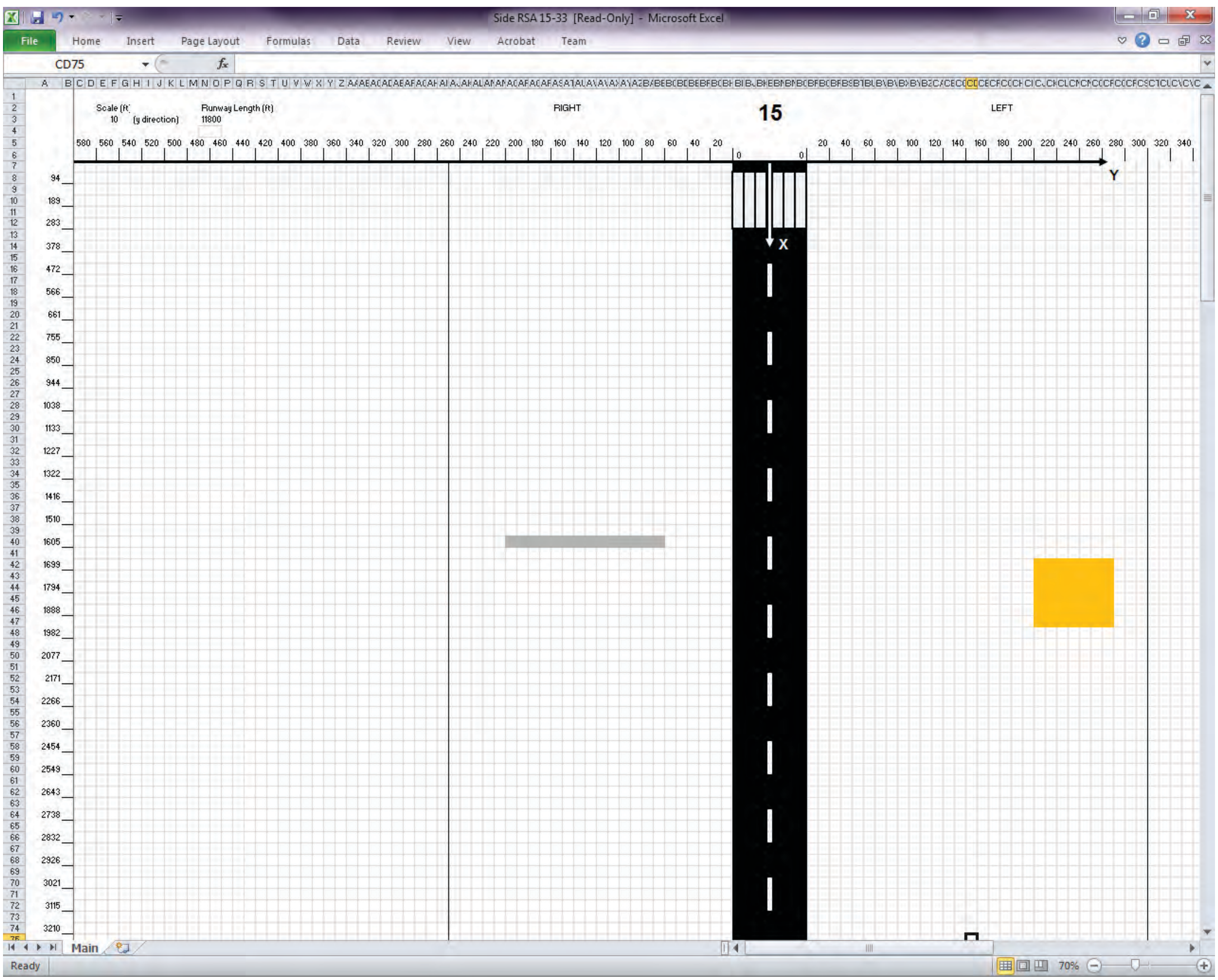


Initially, the spreadsheet contains an "empty" RSA with two lateral lines defining the RSA limits set in the previous step. The number on top of the runway figure represents the runway direction for the approach end. The template has only one folder (*Main*) and is used to define the RSA geometry, and locate existing obstacles.

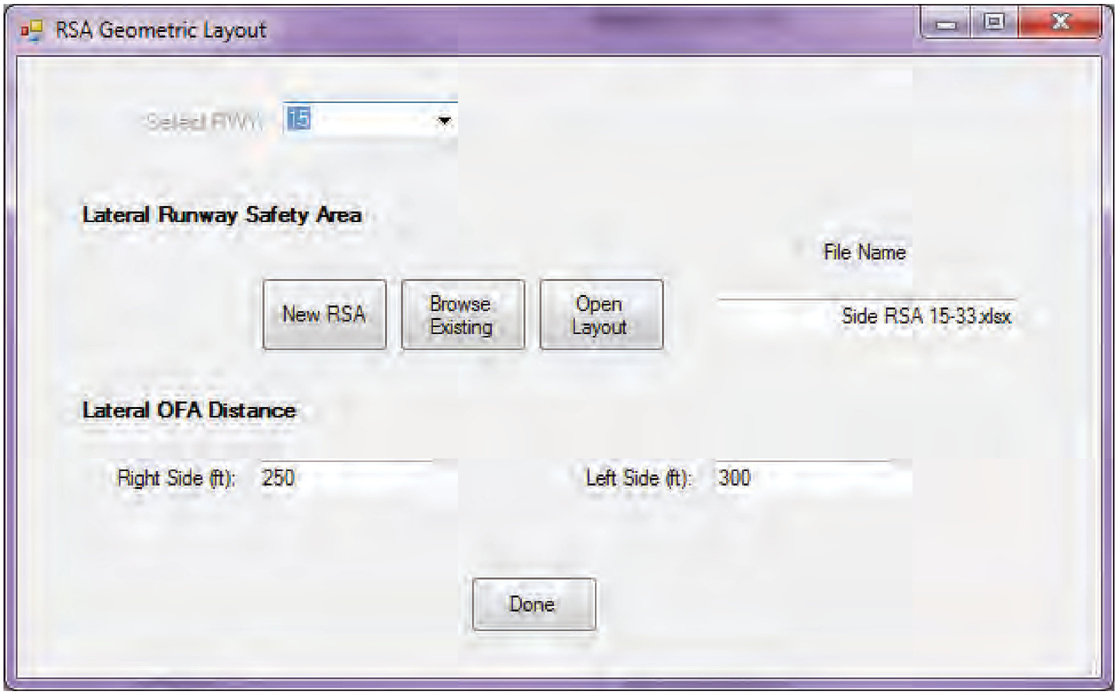
Please note the runway shown is only a representation to facilitate locating its position and may not be on the same scale as the RSA. On the top left portion of the template, appropriate scales (lateral and longitudinal) for representation of each cell are automatically set; the runway width will not match the coordinates used to define the RSA geometry.

The area is automatically defined based on the runway distance available and the lateral distance available making up the RSA. Two types of obstacles may be evaluated in the analysis: ground obstacles and tall obstacles. A ground obstacle is a structure below the ground level (e.g., ditches, uneven terrain, terrain drops, etc.). These obstacles may cause an accident if aircraft gears pass over it and in this case the landing gear dimensions are considered in the analysis. A tall obstacle is a structure above the ground that may lead to an accident if struck by the aircraft. In this case, the wingspan of the aircraft is considered in the analysis.

Two codes are used to define the areas with obstacles: "g" and "w". The letter "g" is used to represent ground-level obstacles and the letter "w" represents tall obstacles. For example, a 140-ft long ditch located on the right side of runway 15, 60 ft from the runway edge is shown below. A second obstacle categorized as "tall" (e.g., a hangar) is located on the left side of the runway, 200 ft from the runway edge as shown in the figure. The obstacle is 70 ft wide and 280 ft long. The longitudinal scale does not allow the user to enter the exact length of the obstacle and it is recommended to be conservative and use a length that is larger than the actual obstacle being represented.



Use the Excel menu to save the RSA geometry for Runway 15/33, and close the spreadsheet. The action will take you back to the ***RSA Geometric Layout*** screen.



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.

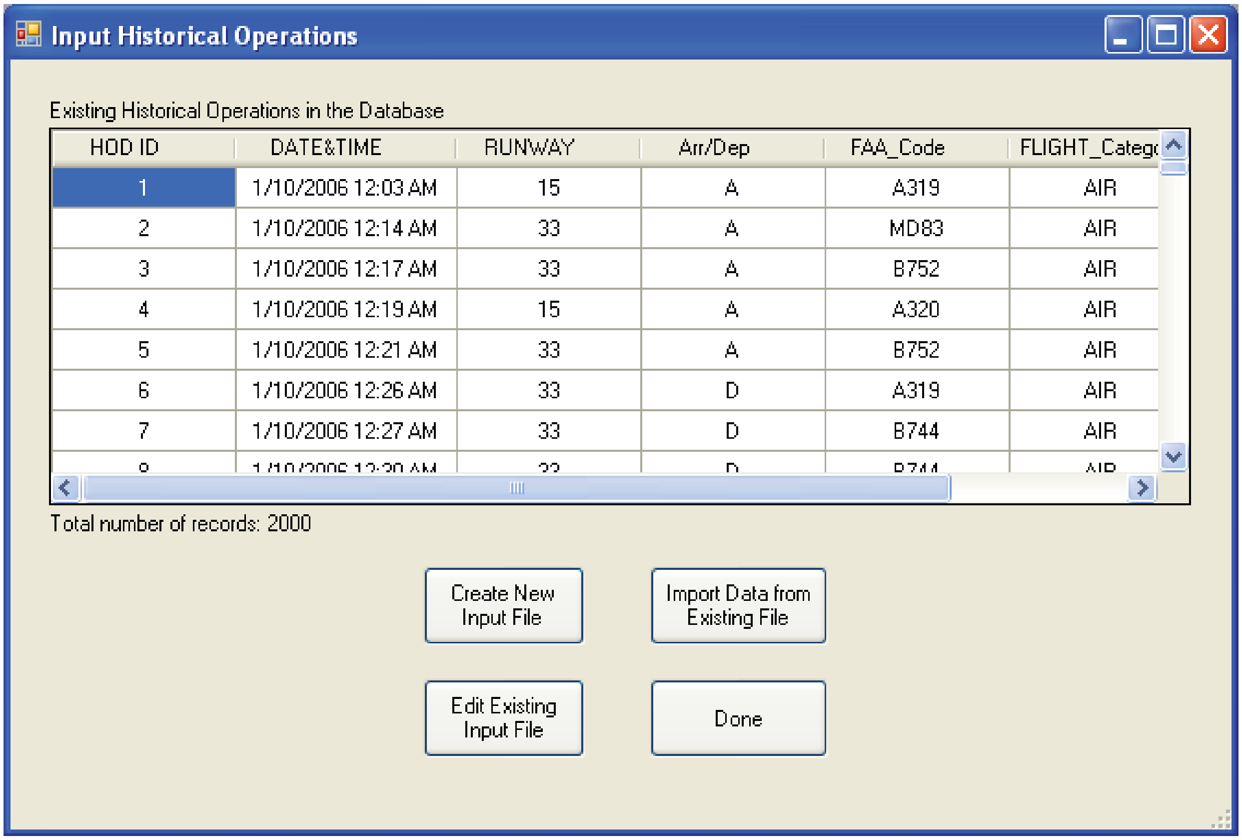
Historical Operations Data (HOD)

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**. LRSARA 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 1-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.

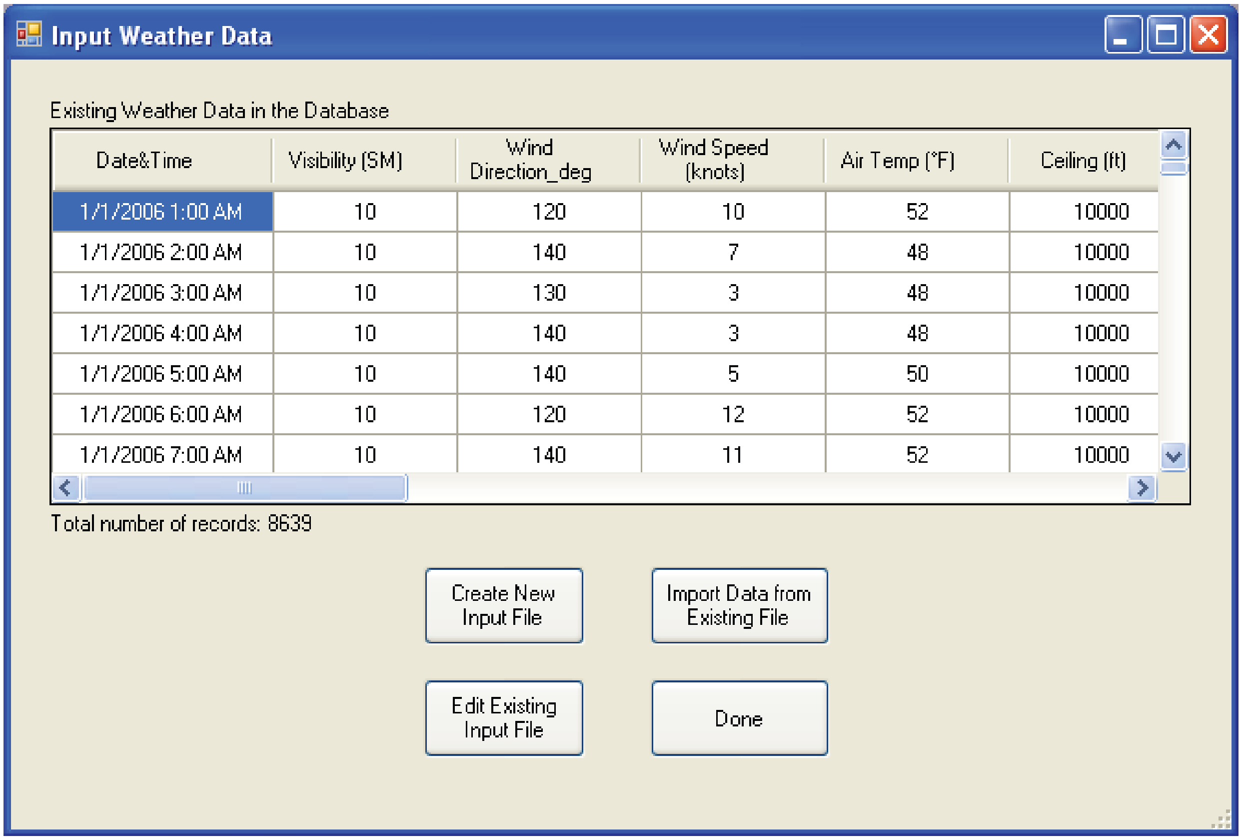


The screen allows the user to create, edit, import, or view the HOD required to run the analysis.

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 for the operational data. The LRSARA 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.

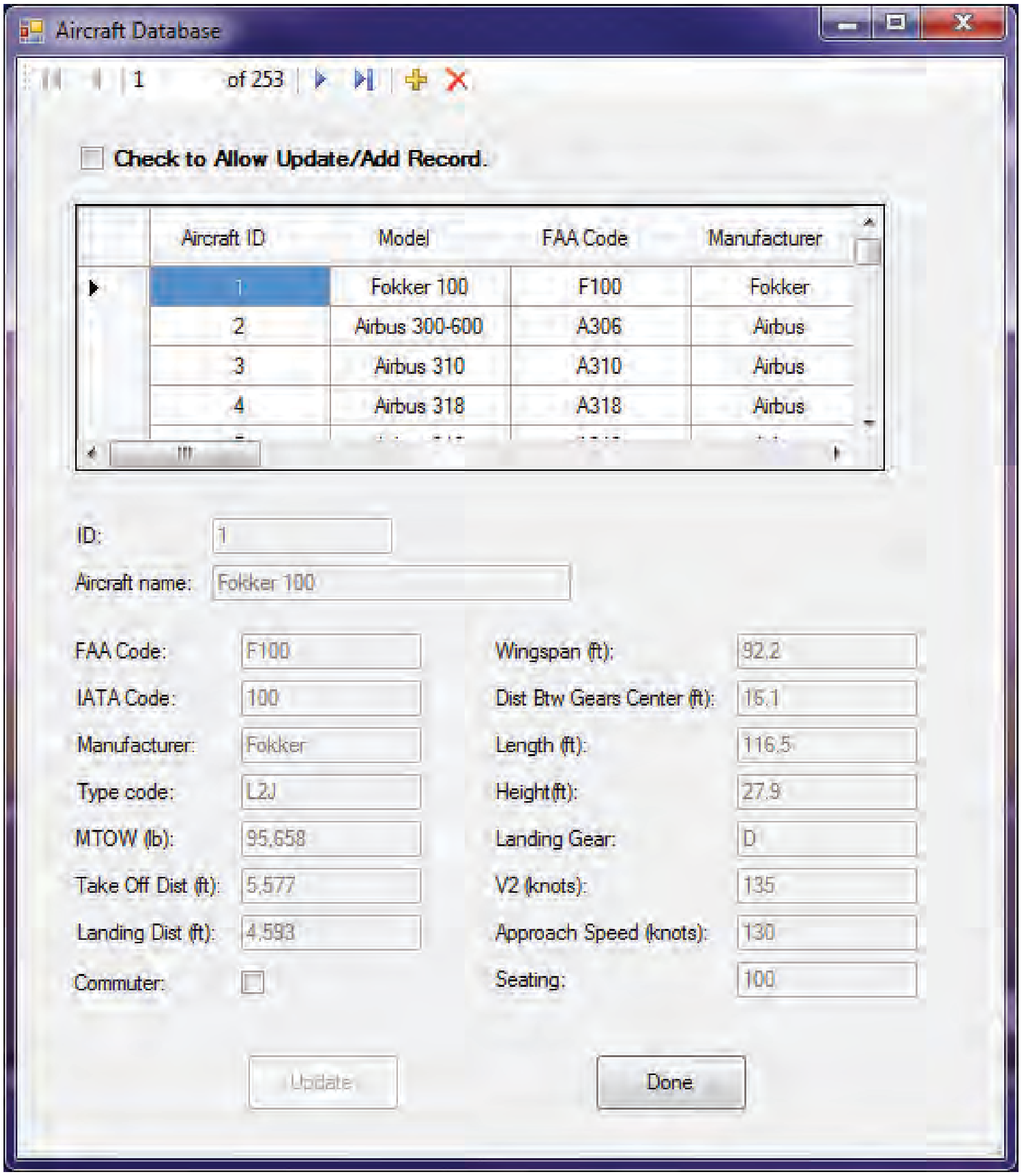
It is important to note that the HWD can be edited using Microsoft Excel, however you **should not change the name of column headers or the tab name that contains the data**. LRSARA uses the labels to identify the type of data to load into the program. The screen to enter the file containing weather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



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

Aircraft Library

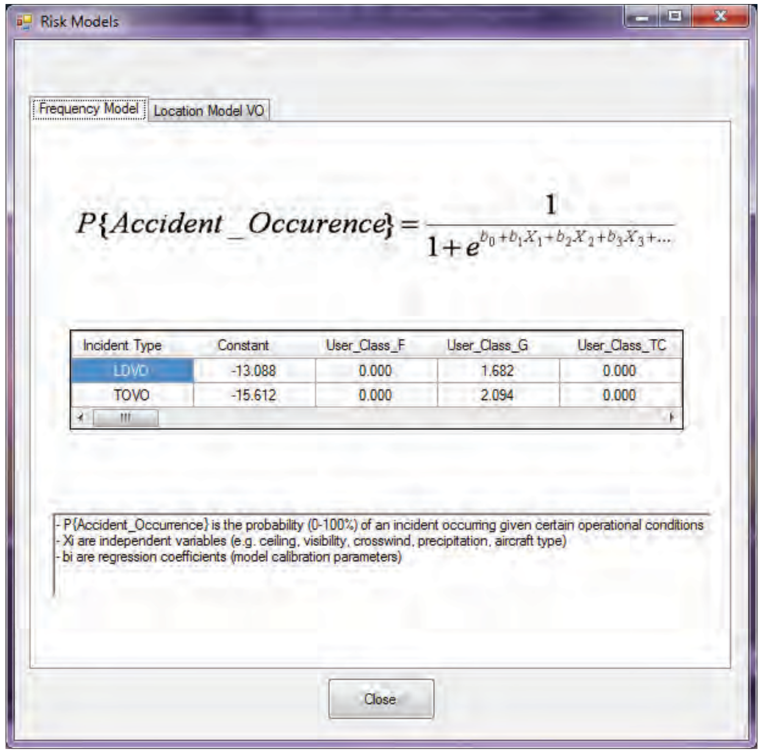
The software contains a basic database of aircraft that may be updated to run the analysis. Click ***Software Parameters/Aircraft Database*** to access the database. The following screen will appear.



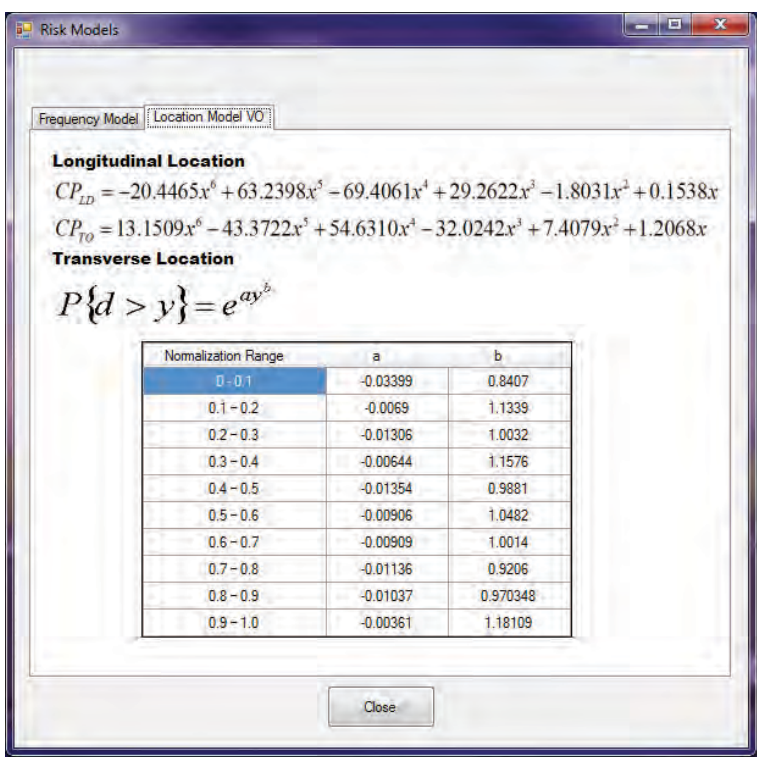
You may edit, update, or add records by clicking the check box on the top left of the screen. Checking that box enables the fields for editing. It is important to note that LRSARA identifies the type of aircraft in the historical information by the aircraft FAA code shown in the third column.

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 frequency models incorporated into the software are those presented in *ACRP Report 51*, and the location models are those developed in ACRP Project 4-14 research. They will be available in this report, *ACRP Report 107*.



This screen contains two tabs. The first shows the frequency models for landing veer-offs (LDVOs) and takeoff veer-offs (TOVO). The second tab presents the location models for longitudinal and transverse distances relative to the runway axis for the same types of events.



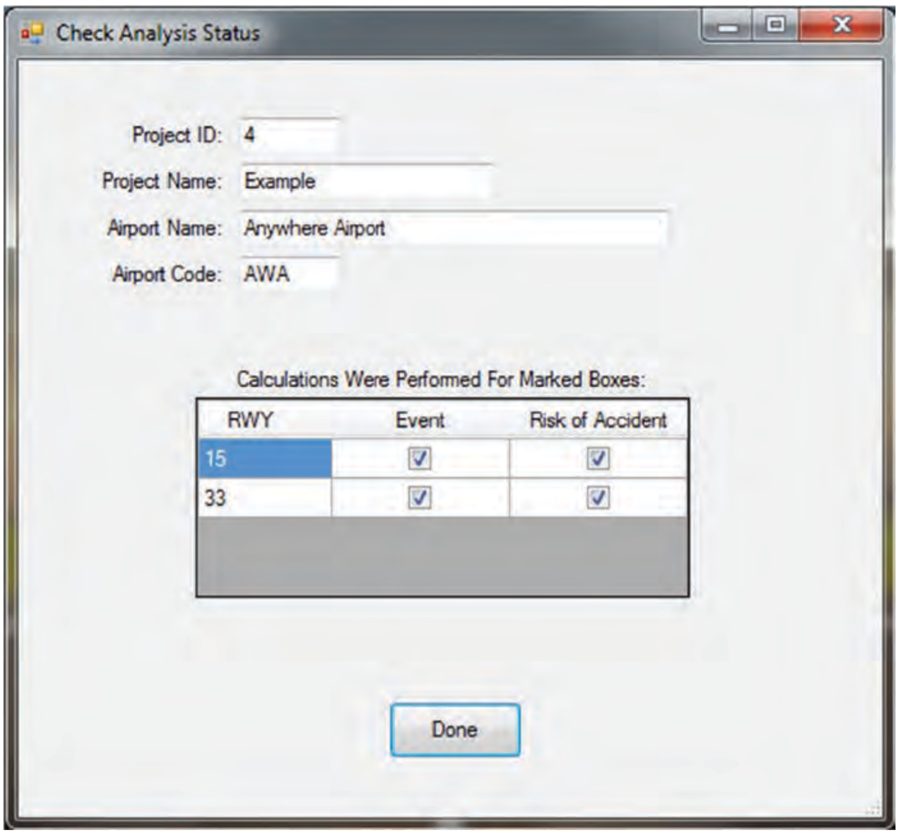
9. Running the Analysis

The analysis menu has four submenus:

- Check Analysis Status
- Run Full Analysis
- Run Simplified Analysis
- Output Missing Data

Check Project Status

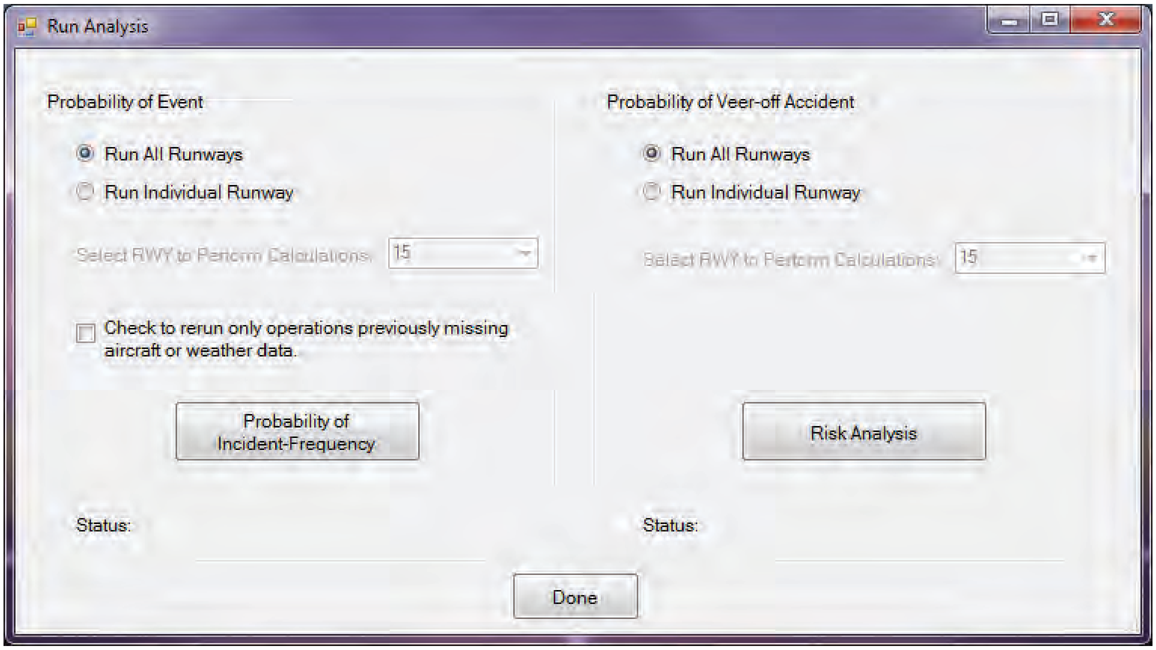
The user may select ***Analysis/Check Project Status*** to check the status of calculations for one or more runways.



In the example presented, both the probability of veer-off and risk of accidents for runways 15 and 33 were estimated.

Run Full Analysis

This type of analysis requires the use of historical operations and weather information for the airport. The information is used to feed the frequency models for landing veer-offs and takeoff veer-offs presented in *ACRP Report 50*. To run the full analysis, select ***Analysis/Run Full Analysis***, and the following screen will appear.



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 two buttons to run the analysis:

- Probability of Incident-Frequency
- Risk Analysis

The analysis is conducted in two steps. First, click on ***Probability of Incident-Frequency***. The program will only estimate the probability of veer-offs occurring for the runways selected. In this case, only the frequency model will be used to calculate the probability of veer-offs, no matter if the event resulted in an accident or not. 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 calculations with the frequency model again.

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 that an accident will occur when the aircraft strikes an obstacle. The lateral limits are assumed to be ground obstacles by default. **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.

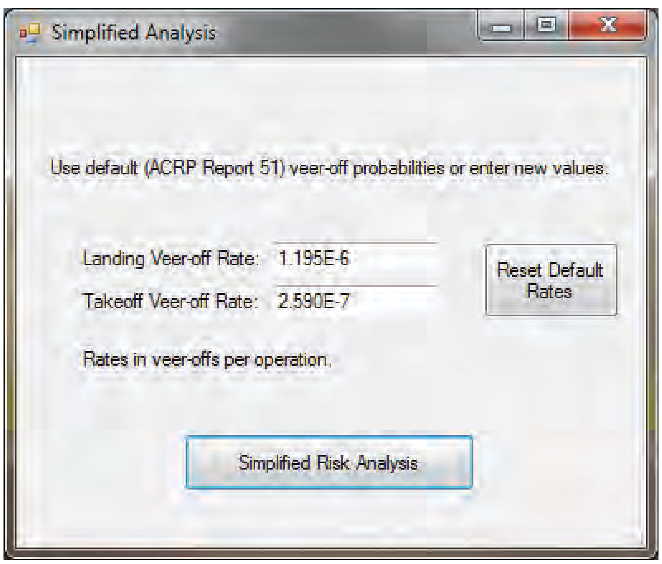
The approach to estimate the risk of accidents uses the following assumptions:

1. Two categories of obstacles are defined as a function of obstacle height.
   a. Ground Obstacle: The width of aircraft landing gear is considered to estimate the probability of collision with the obstacle (e.g., cliff at the RSA border, body of water, ditch, rough terrain, etc.)

b. Tall Obstacle: the aircraft wingspan is used to estimate the probability of collision with the obstacle (e.g., buildings, fences, aircraft, vehicles, etc.)
2. The lateral distribution is random and does not depend on the presence of obstacles. This is a conservative assumption because there are events for which the pilot may have enough directional control to avoid the obstacle.

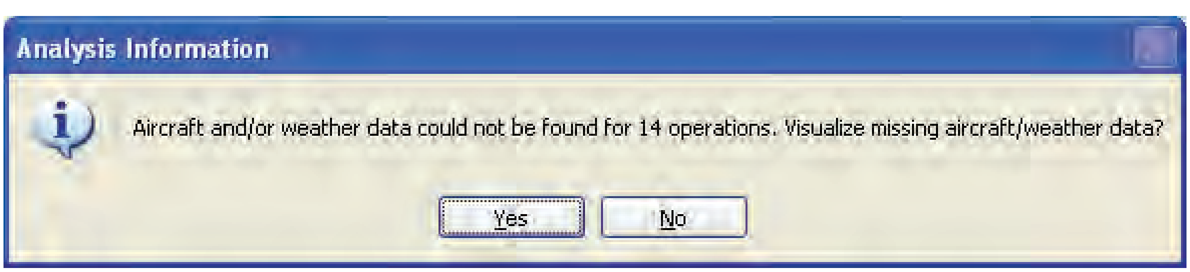
Run Simplified Analysis

For this alternative, no information on historical operations and weather for the airport are required. The probability of veer-off is estimated from default or user-defined values, which are fixed for each type of veer-off: landing and takeoff. Default values are those presented in *ACRP Report 51* however, the user may change the default values as necessary. To run the simplified analysis, select ***Analysis/Run Simplified Analysis***, and the following screen will appear.

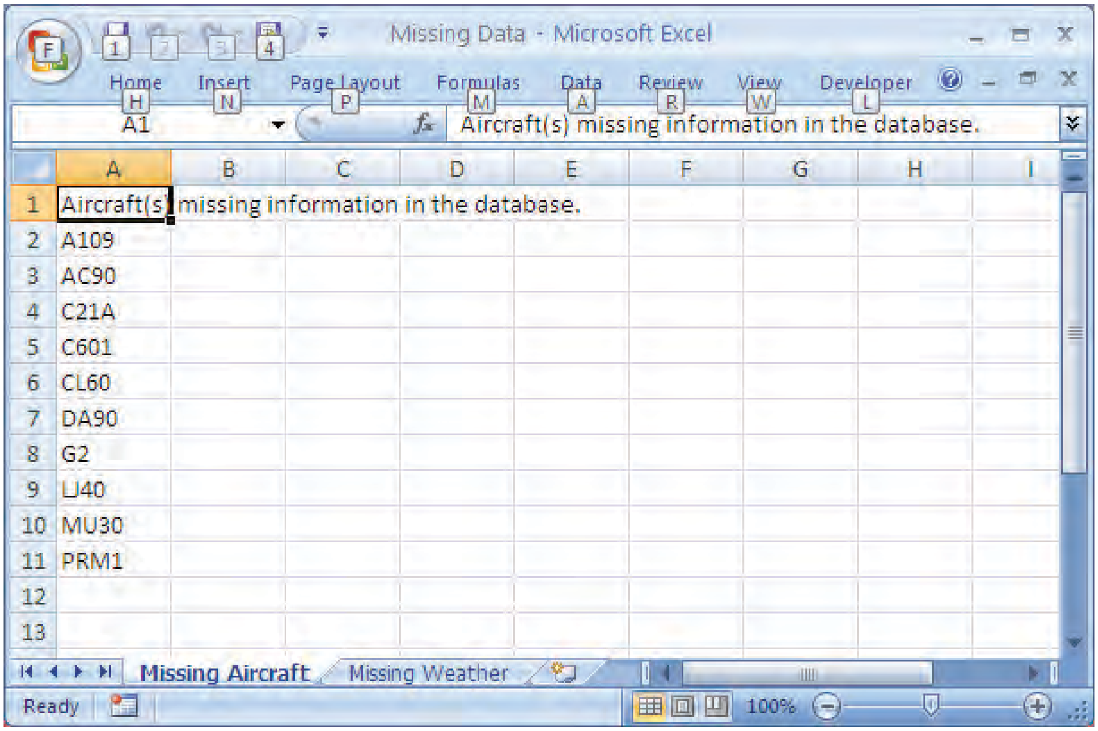


Output Missing Data

When running the analysis for a given runway for the first time, the program checks for missing records, either aircraft or weather. The analysis cannot be completed for specific records that have missing information. One common occurrence is a record for an aircraft not being listed in the aircraft database. In most cases, the 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.



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***.



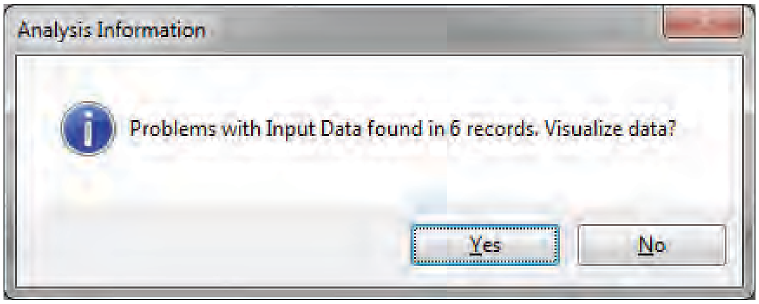
The user may ignore the list of records with missing data if the list contains only a few records; however, it is possible to fix the problems with such records and rerun a faster analysis with only the missing records for all runways or individual runways.

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.

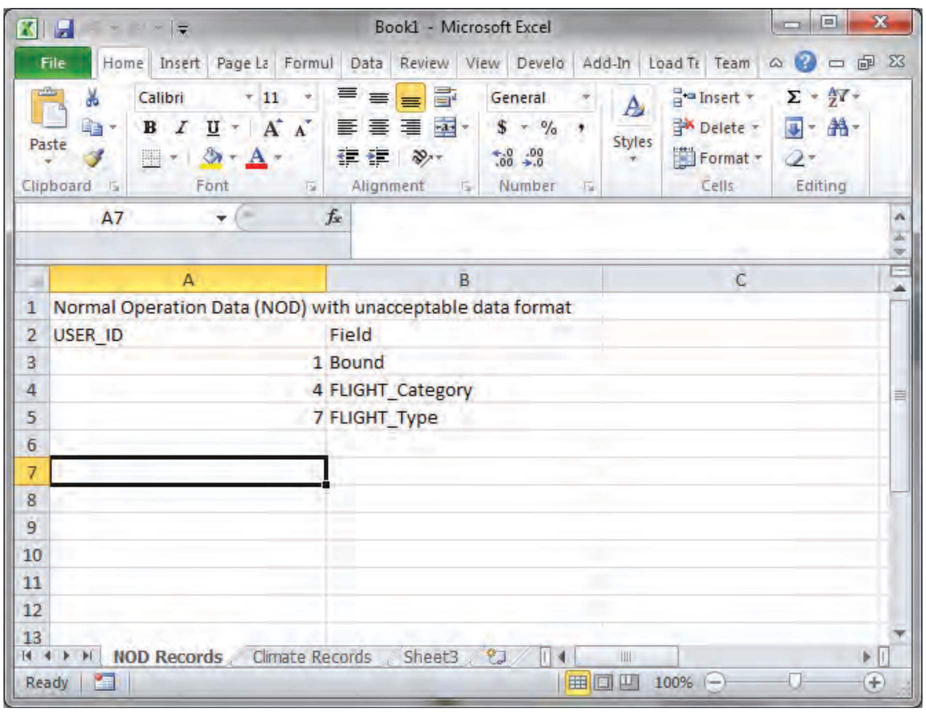
If weather data is missing, the user may correct the file by clicking ***Analysis/Input Data/Weather Database*** and then ***Edit Existing Input File*** to make the necessary corrections.

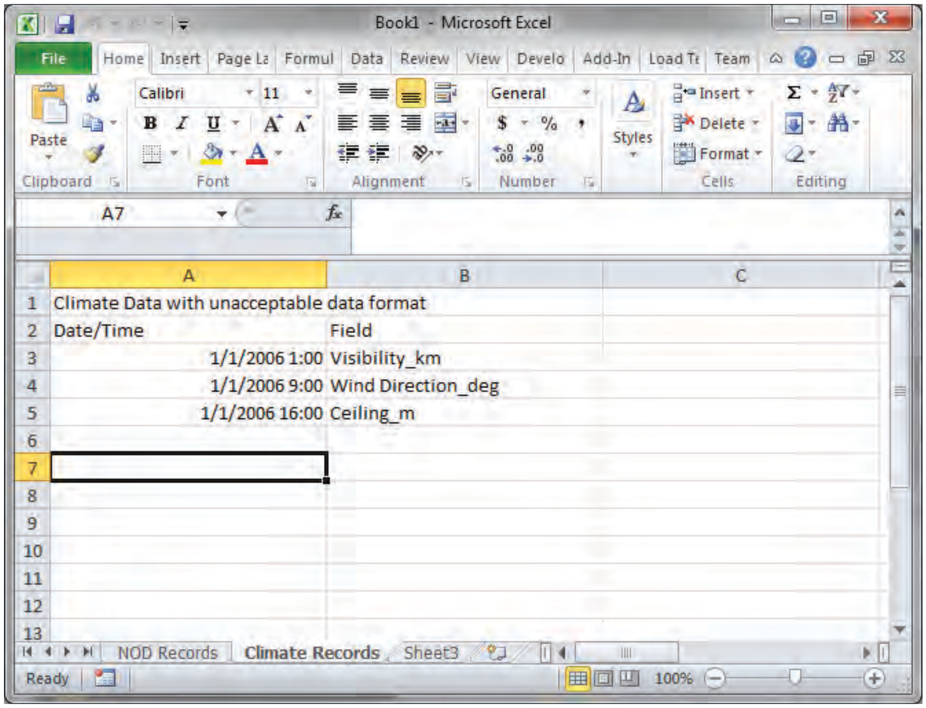
After the corrections are made, the user may run the analysis only for the revised records. This will save time, particularly for the analysis of larger airports with many historical records. To rerun the analysis for the revised records, the user must check the option ***Check to rerun fixed missing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

In addition to checking missing data, LRSARA also checks inconsistencies in input data. The preliminary check is automated and is executed in the MS Excel templates used to create HOD and HWD. Prior to performing the calculations, LRSARA will recheck data to warn of data outside the expected ranges. An example of the message warning the user is shown below.



If the user selects ***Yes*** to visualize inconsistent data, an MS Excel file will open, as shown in the following figures, for HOD and HWD, respectively.





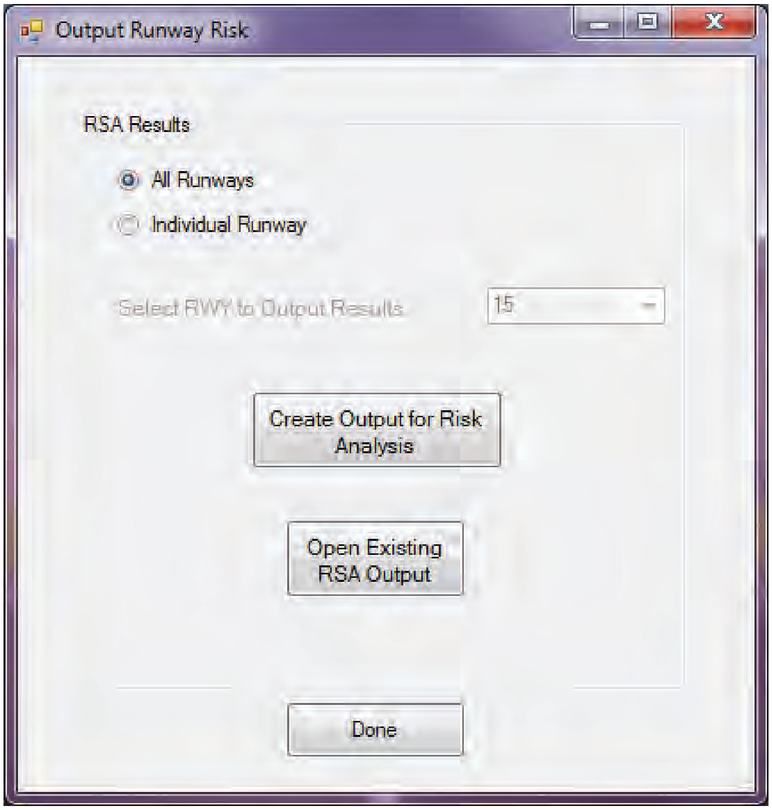
The user should correct the inconsistent data before running the risk analysis; otherwise the analysis will not be completed.

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

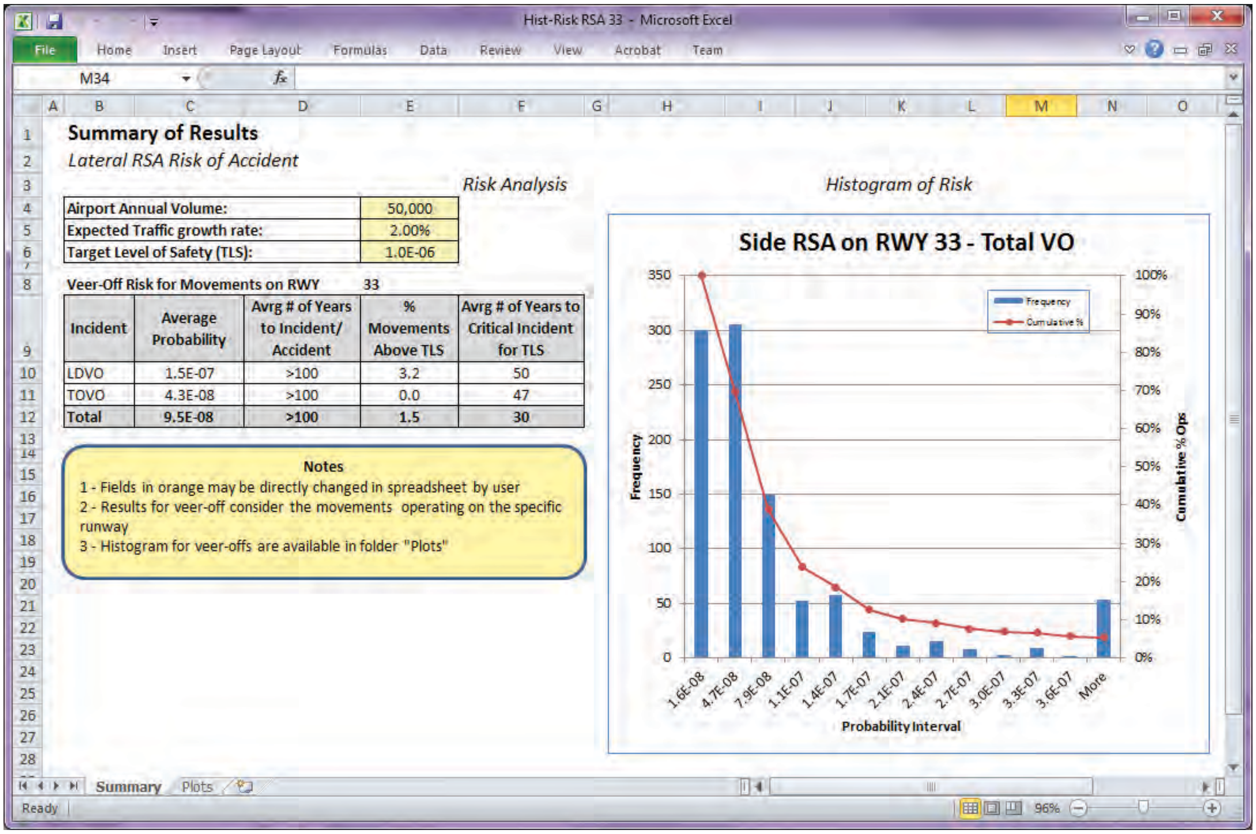
To see the results for all or individual runways, select ***Output/Runway*** and the following screen will appear.



The output file for the selected runway or all runways is created by clicking ***Create Output for Risk Analysis***. The results are stored internally in the program. Creating the output in this step is necessary to transfer the data 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 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 spreadsheets created will open automatically when creating the output files.

If the user has run the analysis and created outputs, the files can be opened by clicking ***Open Existing RSA Outputs***, and selecting the desired file.



Results are presented in both tabular and graphical format. Each set of results 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*** tab 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 piece of information, the ***Target Level of Safety (TLS)***, may also be modified in the spreadsheet and the value will impact 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 titled ***Veer-Off Risk for Movements*** for the selected runway contains results for veer-off only. This is necessary because it is a different area and is composed of the lateral safety areas between the runway ends. The configuration of this table is similar to the one presenting the results for the RSA (second table).

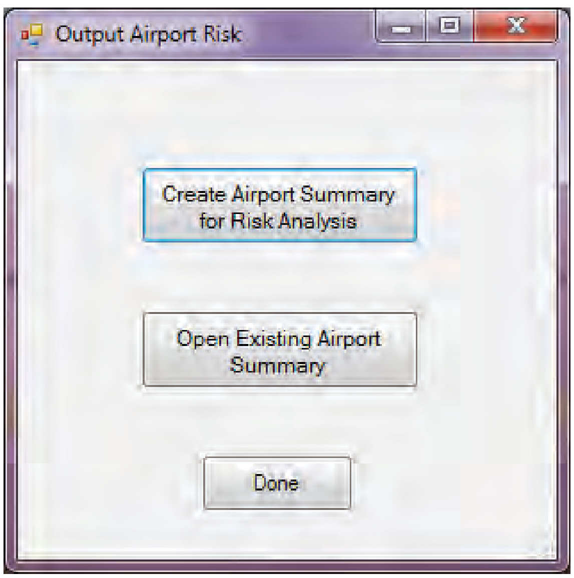
Veer-Off Risk for Movements on RWY 15

Incident	Average Probability	Avrg # of Years to Incident/ Accident	% Movements Above TLS	Avrg # of Years to Critical Incident for TLS
LDVO	2.2E-07	>100	6.7	52
TOVO	5.6E-08	>100	0.2	45
Total	**1.3E-07**	**99**	**3.1**	**30**

The histogram shown in the ***Summary*** tab contains the probability data for each movement challenging the lateral RSA. Similar histograms for each individual type of operation (landing and takeoff) are available in the ***Plots*** tab.

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 Existing Airport Summary*** to view the results in a spreadsheet as shown in the screen below.

ACRP

Risk of Accident - Summary of Results

Overall Results *Risk Analysis*

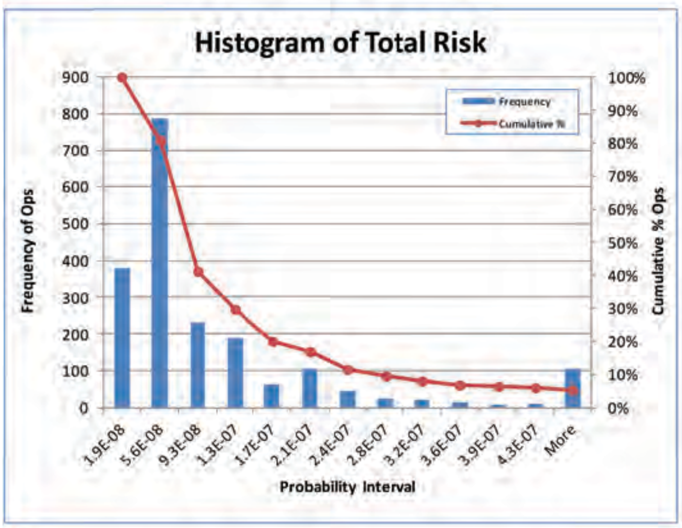
Summary Table

Accident	Average Risk of Accident	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDVO	2.0E-07	81	5.1	30
TOVO	5.8E-08	>100	0.3	30
Total	**1.2E-07**	**73**	**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: 7/12/2013
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 - The total risk for the airport is per movement (landing and taking off)
3 - Each takeoff and landing will challenge the lateral safety areas for veer-offs
4 - Histogram for the whole airport is for any type of event and includes each movement challenging the LRSA

Summary of Results by Runway

Probability of Event per Operation

Type of Accident	RSA	
	15	33
LDVO	5.78E-07	5.54E-07
TOVO	1.21E-07	1.55E-07

Risk of Accident in Events per Operation

Type of Accident	RSA	
	15	33
LDVO	1.95E-07	2.07E-07
TOVO	5.37E-08	6.21E-08

Average # of Years Between Accidents

Type of Accident	RSA	
	15	33
LDVO	>100	>100
TOVO	>100	>100

Percent Events Above 1.0E-06

Type of Accident	RSA	
	15	33
LDVO	5.59	4.67
TOVO	0.18	0.38

Summary of Operations Challenging the RSAs

Movements Challenging each RSA

Type of Accident	RSA	
	15	33
LDVO	447	471
TOVO	548	520
Total	995	991

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*** tab 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 LDVOs, 4.9% 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.

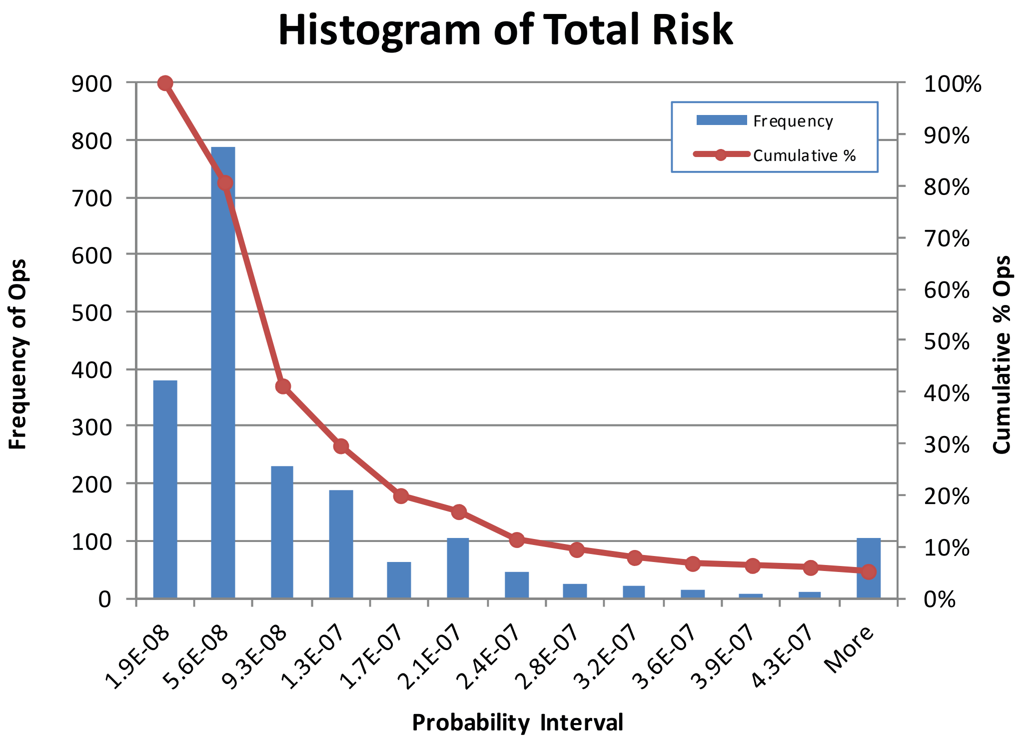
Overall Results *Risk Analysis*

Summary Table

Accident	Average Risk of Accident	Avrg # of Years to Critical Incident	% Ops Above TLS	Avrg # of Years to Critical Incident for TLS
LDVO	2.0E-07	81	5.1	30
TOVO	5.8E-08	>100	0.3	30
Total	**1.2E-07**	**73**	**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. Each bar that makes up the histogram of risk represents a given risk level as shown in the x-axis. The number of operations for each bar is read on the left y-axis. The segmented line is associated with the right y-axis and indicated the percentage of movements that have a risk higher than the value read in the x-axis [e.g., approximately 20% of movements are subject to risk higher than 1.7E-07 (or one event in 5,880,000 movements)].



Additional tables are shown on the right of the main table. The first table presents the probability of runway veer-offs for each runway and each type of operation.

Summary of Results by Runway

Probability of Event per Operation

Type of Accident	RSA	
	15	33
LDVO	5.78E-07	5.54E-07
TOVO	1.21E-07	1.55E-07

The second table presents the average risk level for each type of event and the associated runway direction challenged by the movements.

Risk of Accident in Events per Operation

Type of Accident	RSA	
	15	33
LDVO	1.95E-07	2.07E-07
TOVO	5.37E-08	6.21E-08

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

Average # of Years Between Accidents

Type of Accident	RSA	
	15	33
LDVO	>100	>100
TOVO	>100	>100

The fourth table in the group shows the percentage of movements challenging each runway direction that are subject to risk level higher than 1 accident in 1 million operations.

Percent Events Above 1.0E-06

Type of Accident	RSA	
	15	33
LDVO	5.59	4.67
TOVO	0.18	0.38

The final table shows the total number of movements that challenge each runway direction. 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
LDVO	447	471
TOVO	548	520
Total	995	991

Below is an example output for simplified analysis. For this case the probability of accident will depend only on the category of aircraft and no histogram of risk is generated. The user may change the percentage of operations for each category of aircraft directly in the spreadsheet and the average risk results will change accordingly. There is no need to use the Output submenu to obtain the report for simplified analysis; the file with the results will open automatically upon completion of the analysis.

AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP

Simplified LRSA Risk Analysis

Summary Table

Accident	Average Risk of Accident	Avrg # of Years to Critical Incident
LDVO	3.4E-07	56
TOVO	1.1E-07	92
Total	**4.5E-07**	**30**

Airport Annual Volume[1]:	50,000
Expected Traffic growth rate:	2.50%

1. Assumed 50% Landing and 50% Take-off

Airport:

Date of Analysis:

Analyst:

Notes

1 - Fields in orange may be directly changed in spreadsheet by user

2 - The total risk for the airport is per movement (landing and taking off), based on traffic distribution provided by the analyst.

3 - Each takeoff and landing will challenge the lateral safety areas for veer-offs

Landing Distribution (%)

Aircraft Category	RWY	
	15	33
I	16.6%	16.6%
II	16.6%	16.6%
III	16.7%	16.7%
IV	16.7%	16.7%
V	16.7%	16.7%
VI	16.7%	16.7%
	100%	100%

Take-off Distribution (%)

Aircraft Category	RWY	
	15	33
I	16.6%	16.6%
II	16.6%	16.6%
III	16.7%	16.7%
IV	16.7%	16.7%
V	16.7%	16.7%
VI	16.7%	16.7%
	100%	100%

Probability of Landing Veer-off Accident

Aircraft Category	RSA	
	15	33
I	1.24E-07	1.67E-07
II	1.31E-07	1.75E-07
III	1.39E-07	1.86E-07
IV	1.49E-07	1.99E-07
V	1.53E-07	2.06E-07
VI	1.62E-07	2.19E-07

Probability of Take-off Veer-off Accident

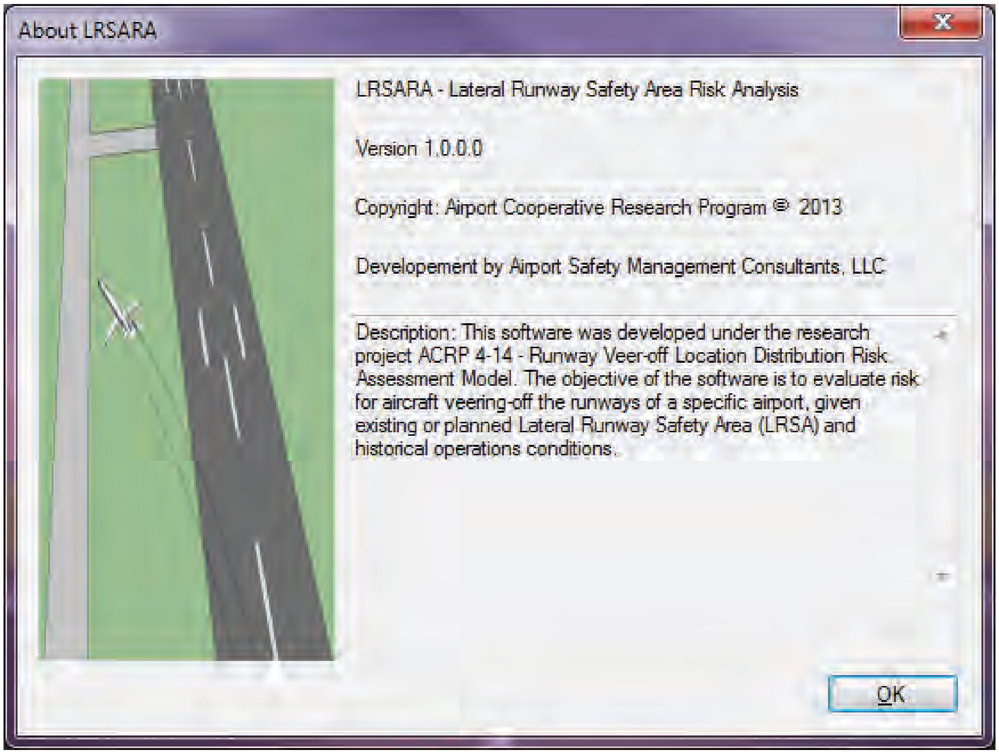
Aircraft Category	RSA	
	15	33
I	5.21E-08	4.32E-08
II	5.52E-08	4.56E-08
III	5.97E-08	4.90E-08
IV	6.52E-08	5.32E-08
V	6.86E-08	5.58E-08
VI	7.51E-08	6.03E-08

Average # of Years Between Accidents

Aircraft Category	RSA	
	15	33
I	>100	>100
II	>100	>100
III	>100	>100
IV	>100	>100
V	>100	>100
VI	>100	>100

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.



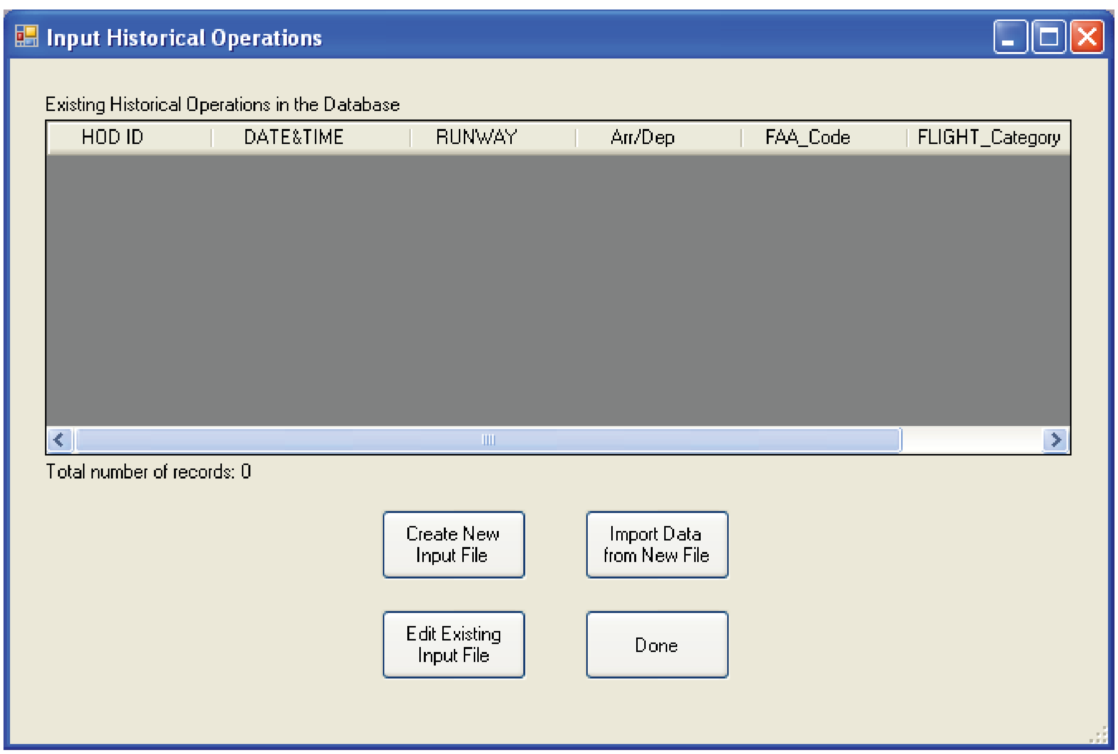
ATTACHMENT A

Historical Operations Data

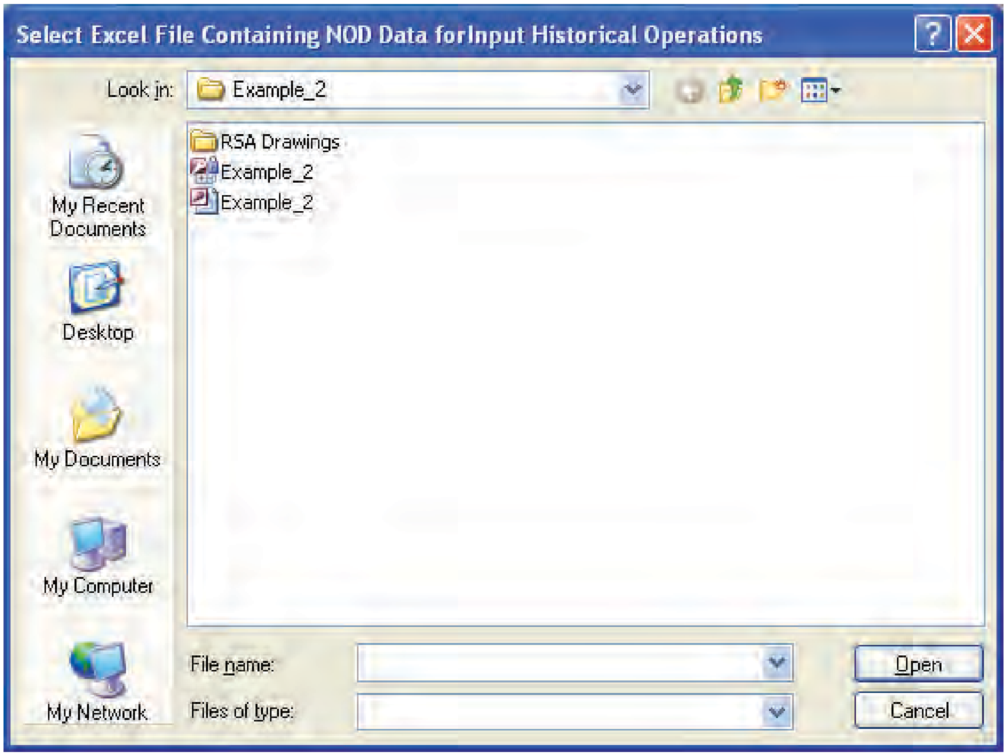
This section describes the procedure to prepare historical operations data for the airport. The historical operations data provided is consolidated internally in the program with the weather information provided (see Attachment B). The process is used to characterize the sample operations for the airport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

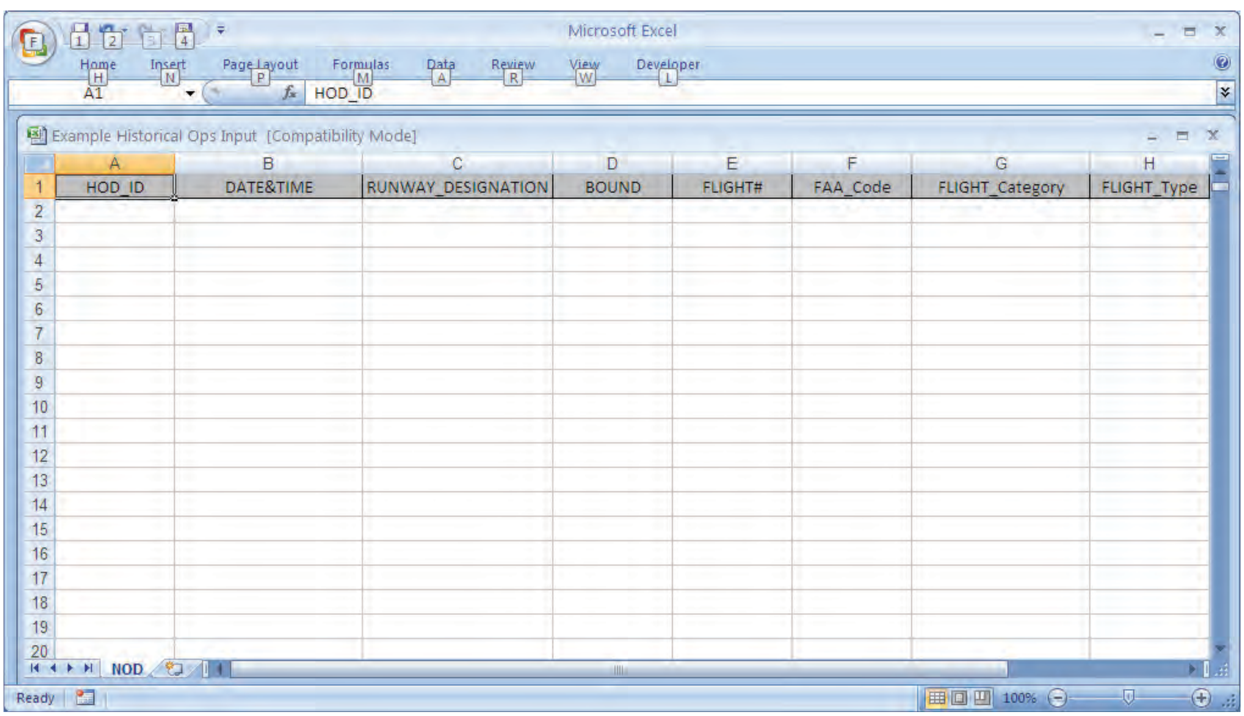
A Microsoft Excel (2010 or later) spreadsheet is used to enter the Historical Operations Data and create the sample. To create this database, select Input Data/Historical Operations Database and the following screen will open.



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



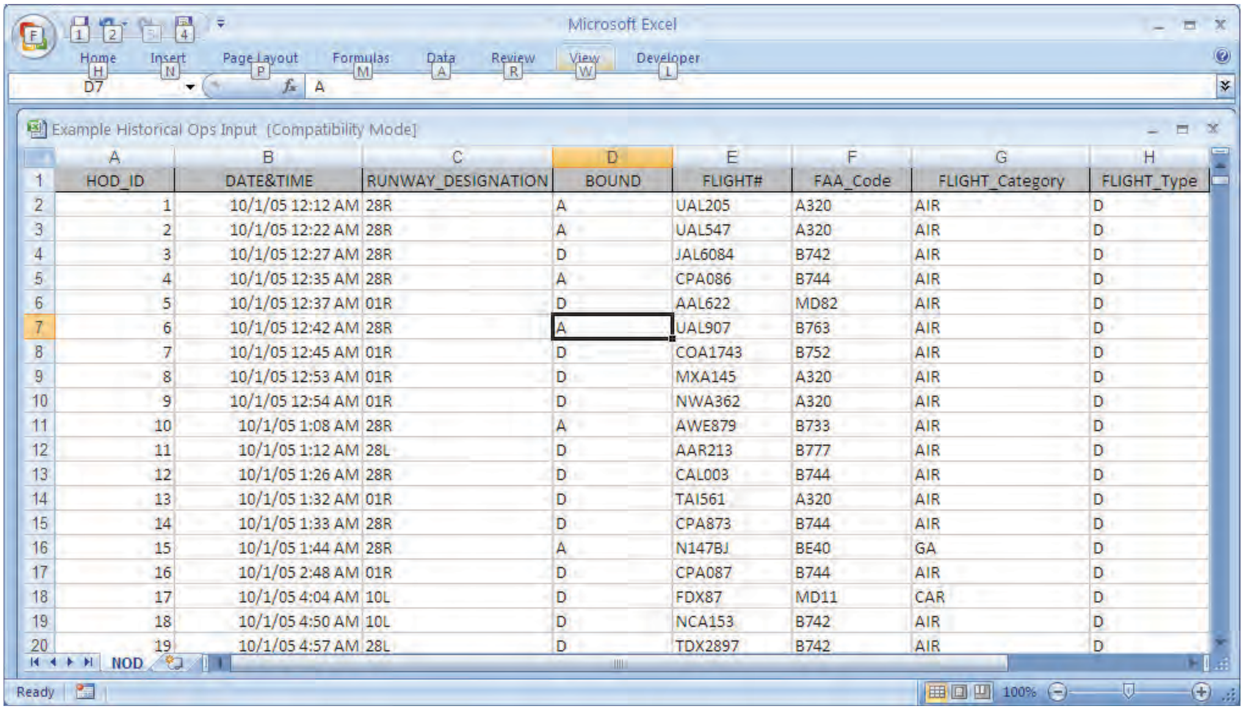
Please enter a file name and the Excel spreadsheet will open with eight columns as shown below.



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

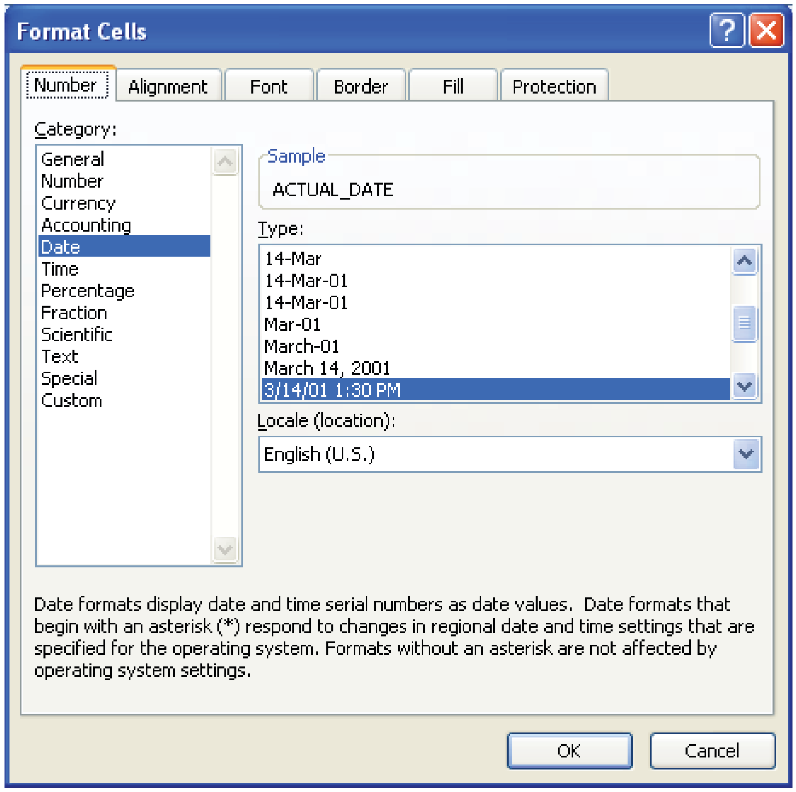
Field	Description	Format
HOD_ID	This is an ID for the record and any reference may be used by the person creating the database. We suggest entering a number, starting from 1 to the last record number, as shown in the example below.	Any format may be used. This information is not used by the program and 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 fixed 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. 15 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.



	A	B	C	D	E	F	G	H
1	HOD_ID	DATE&TIME	RUNWAY_DESIGNATION	BOUND	FLIGHT#	FAA_Code	FLIGHT_Category	FLIGHT_Type
2	1	10/1/05 12:12 AM	28R	A	UAL205	A320	AIR	D
3	2	10/1/05 12:22 AM	28R	A	UAL547	A320	AIR	D
4	3	10/1/05 12:27 AM	28R	D	JAL6084	B742	AIR	D
5	4	10/1/05 12:35 AM	28R	A	CPA086	B744	AIR	D
6	5	10/1/05 12:37 AM	01R	D	AAL622	MD82	AIR	D
7	6	10/1/05 12:42 AM	28R	A	UAL907	B763	AIR	D
8	7	10/1/05 12:45 AM	01R	D	COA1743	B752	AIR	D
9	8	10/1/05 12:53 AM	01R	D	MXA145	A320	AIR	D
10	9	10/1/05 12:54 AM	01R	D	NWA362	A320	AIR	D
11	10	10/1/05 1:08 AM	28R	A	AWE879	B733	AIR	D
12	11	10/1/05 1:12 AM	28L	D	AAR213	B777	AIR	D
13	12	10/1/05 1:26 AM	28R	D	CAL003	B744	AIR	D
14	13	10/1/05 1:32 AM	01R	D	TAI561	A320	AIR	D
15	14	10/1/05 1:33 AM	28R	D	CPA873	B744	AIR	D
16	15	10/1/05 1:44 AM	28R	A	N147BJ	BE40	GA	D
17	16	10/1/05 2:48 AM	01R	D	CPA087	B744	AIR	D
18	17	10/1/05 4:04 AM	10L	D	FDX87	MD11	CAR	D
19	18	10/1/05 4:50 AM	10L	D	NCA153	B742	AIR	D
20	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 1:30 PM*** in the ***Type*** box, as shown in the screen below.



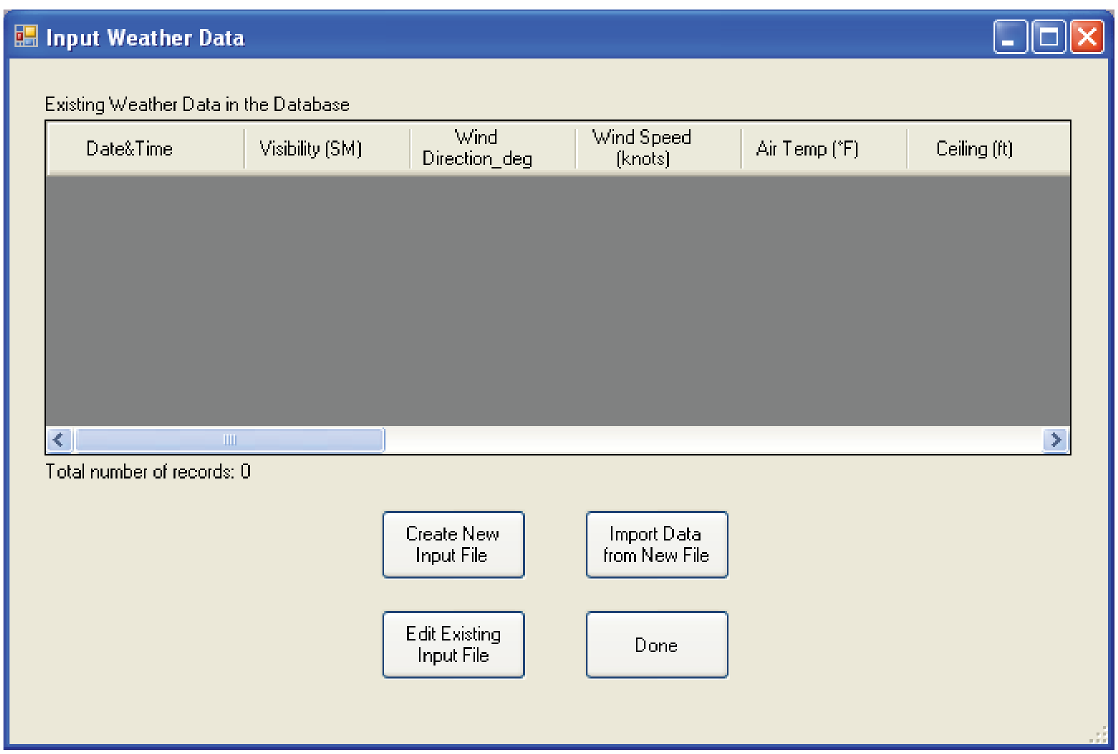
ATTACHMENT B

Historical Weather Data

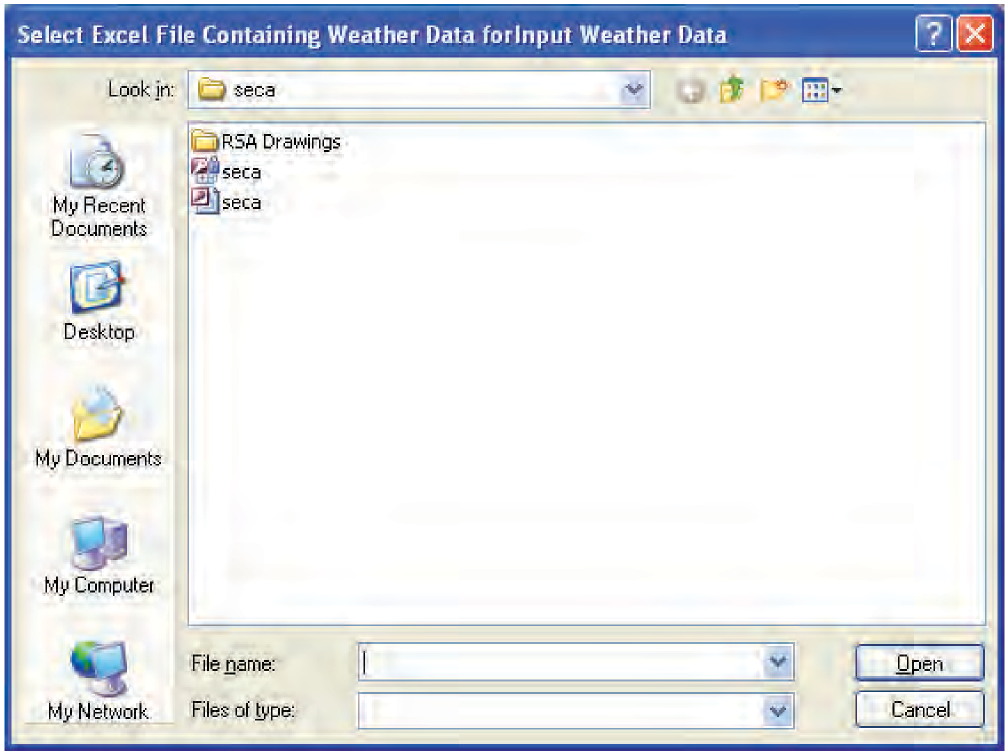
This section describes the procedure to prepare historical weather data for the airport. The historical weather data provided are consolidated internally in the program with the historical operations information provided (see Attachment A). The process is used to characterize the sample operations for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

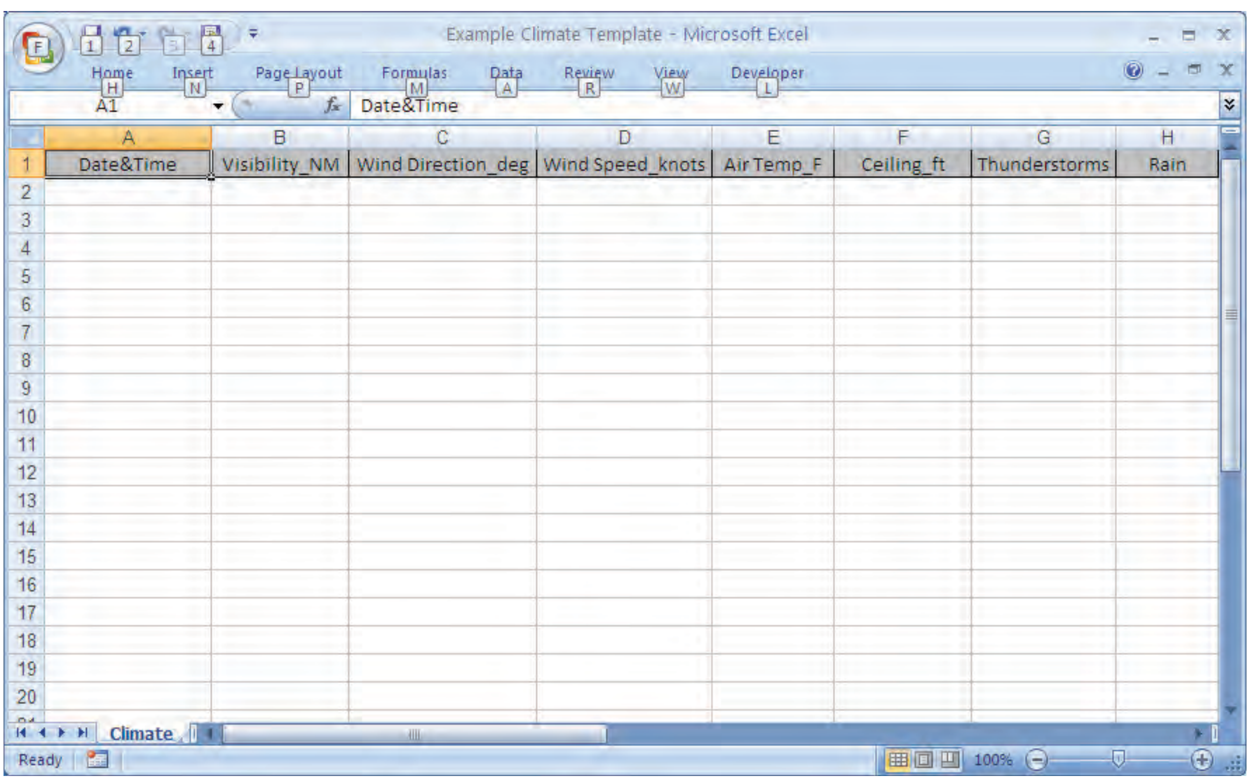
A Microsoft Excel (2010 or later) spreadsheet is used to enter the Historical Operations Data and create the sample. To create this database, select Input Data/Weather Database and the following screen will open.



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



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



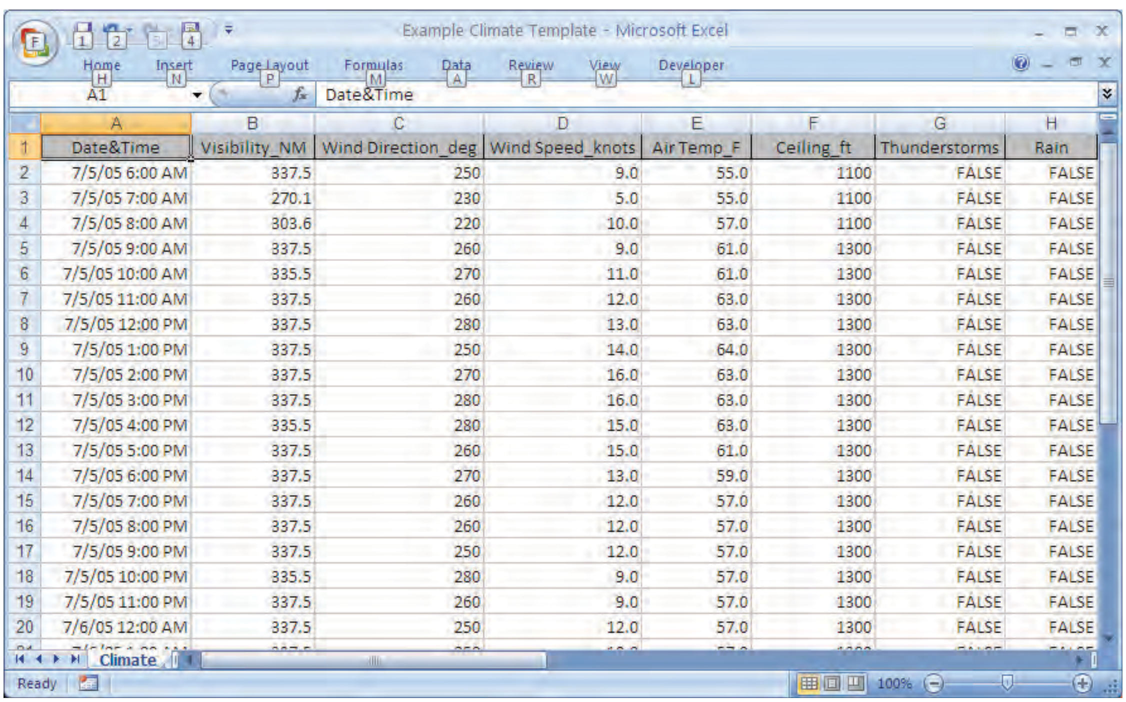
Each line in the spreadsheet should correspond to one record. The following table contains a description of each field.

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 average forward horizontal distance that a prominent unlighted object can be seen and identified by day from the cockpit of an aircraft in flight.	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 (kt)
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)
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).

(Continued).

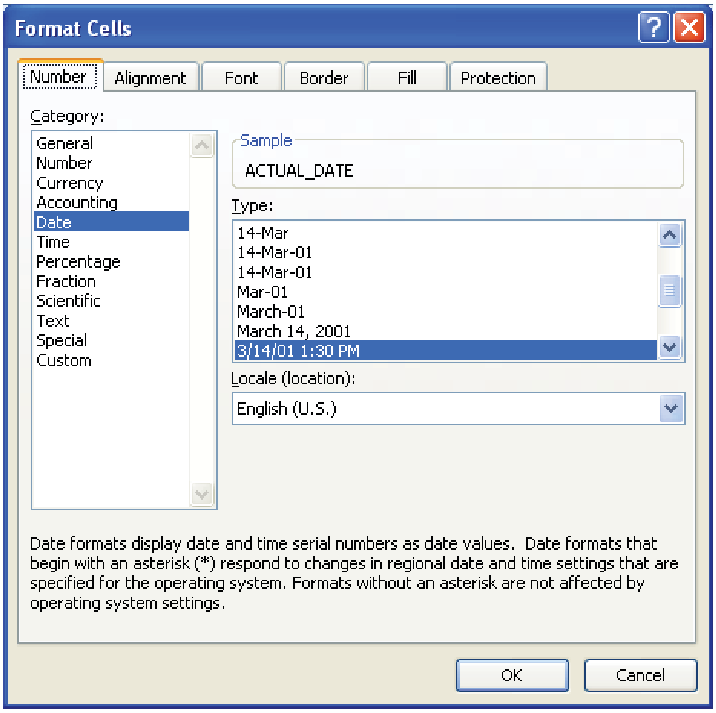
Field	Description	Format
Ice Crystals	A barely visible crystalline form of ice that has the shape of needles, columns, or plates. Ice crystals are so small that they seem to be suspended in air. Ice crystals occur at very low temperatures in a stable atmosphere.	Presence (TRUE) or not (FALSE).
Snow Showers	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 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 1:30 PM*** in the ***Type*** box, as shown in the screen below.



APPENDIX E

Summary of Accidents and Incidents for Validation

Rec #	Date	Source	Country	Type or Veer-Off	Event Class	Aircraft Code
1	27-Jul-85	NTSB	US	LDVO	ACC	CE425
2	01-Jun-04	ASRS	US	TOVO	INC	LR35
3	15-Sep-04	ASRS	US	LDVO	INC	BE1900
4	01-Mar-00	ASRS	US	LDVO	INC	LR25
5	09-Apr-08	AIDS	US	LDVO	INC	BE2000
6	29-Mar-09	NTSB	US	LDVO	ACC	CE550
7	11-Nov-06	AIDS	US	LDVO	INC	B727
8	11-Nov-07	AIDS	US	TOVO	INC	LR60
9	28-Nov-97	AAIB	UK	TOVO	INC	SF340
10	19-Jul-91	NTSB	US	TOVO	ACC	DC3C
11	08-Feb-09	BEA	FRAN	LDVO	INC	A321
12	05-Oct-90	NTSB	US	LDVO	ACC	BE18
13	05-Feb-08	NTSB	US	TOVO	ACC	SA226
14	16-Feb-09	NTSB	US	LDVO	ACC	BE65
15	12-Sep-05	TSB	NETH	LDVO	INC	SA227
16	28-Feb-09	AAI	SING	LDVO	INC	B777
17	20-Feb-85	NTSB	US	LDVO	ACC	BE58
18	12-Oct-90	AIDS	US	LDVO	INC	BE1900
19	21-Sep-04	TSB	CAN	LDVO	ACC	SA227
20	15-Aug-06	ASRS	US	TOVO	INC	BA125
21	01-May-01	ASRS	US	LDVO	INC	B737
22	10-Jan-00	NTSB	US	TOVO	ACC	BE18
23	15-Mar-04	NTSB	US	LDVO	ACC	BE190
24	01-Sep-96	ASRS	US	LDVO	INC	CA212
25	14-Jul-07	ATSB	US	TOVO	INC	B737
26	18-Dec-02	NTSB	US	LDVO	ACC	SA226
27	22-Jan-99	MITRE	US	LDVO	ACC	BE190
28	24-Jan-97	AIDS	US	LDVO	INC	C500
29	07-Aug-07	AIDS	US	LDVO	INC	C650
30	01-Oct-90	ASRS	US	LDVO	INC	LW
31	01-Dec-04	TSB	CAN	LDVO	ACC	B300
32	29-Jul-98	NTSB	US	TOVO	INC	EMB135
33	12-Feb-08	NTSB	US	LDVO	INC	SA227
34	14-May-00	NTSB	US	LDVO	ACC	BE18
35	02-Mar-02	ASRS	US	LDVO	INC	GIV
36	05-Feb-99	NTSB	US	LDVO	ACC	BE58

Rec #	Date	Source	Country	Type or Veer-Off	Event Class	Aircraft Code
37	16-Feb-03	NTSB	US	LDVO	ACC	SA226
38	15-Jan-10	ASRS	US	LDVO	INC	G200
39	20-Aug-08	NTSB	US	TOVO	ACC	441
40	10-Jul-01	AAIB	UK	LDVO	INC	ANT12
41	06-Sep-99	NTSB	US	LDVO	ACC	BE95
42	09-Mar-09	NTSB	US	LDVO	ACC	PA42
43	20-Dec-04	MITRE	US	LDVO	ACC	LR25
44	02-Jan-96	ASRS	US	LDVO	INC	LW
45	18-Jan-02	NTSB	US	LDVO	ACC	RK500
46	11-Nov-91	AIDS	US	LDVO	INC	BE1900
47	11-Nov-85	NTSB	US	LDVO	ACC	AE600
48	13-Dec-85	NTSB	US	LDVO	ACC	BE60
49	22-Mar-11	NTSB	US	TOVO	ACC	CE414
50	01-Dec-91	ASRS	US	TOVO	INC	LW
51	22-Jan-99	MITRE	US	LDVO	ACC	CE650
52	24-Jun-92	NTSB	US	LDVO	INC	CE212
53	13-Apr-07	AIDS3	US	LDVO	INC	FC328
54	05-Jan-02	AIDS	US	LDVO	INC	B737
55	01-Jun-08	NTSB	US	LDVO	ACC	BE18
56	01-May-86	NTSB	US	LDVO	ACC	CE404
57	09-Dec-11	NTSB	US	LDVO	ACC	CE421B
58	08-Jun-99	NTSB	US	TOVO	ACC	CE402
59	26-Dec-05	TSB	CAN	LDVO	INC	A319
60	10-Jan-02	AIDS	US	LDVO	INC	LR35
61	25-Nov-07	AIDS	US	LDVO	INC	GA7
62	11-Jul-09	NTSB	US	TOVO	ACC	AC70
63	21-Jul-04	NTSB	US	TOVO	ACC	SA226
64	20-Feb-07	NTSB	US	LDVO	ACC	CE402
65	03-Apr-85	NTSB	US	LDVO	ACC	DHC6
66	03-Oct-04	NTSB	US	TOVO	ACC	BE18
67	05-Jun-00	AIDS	US	LDVO	INC	MD80
68	21-Mar-91	NTSB	US	TOVO	ACC	BE55
69	30-Jan-90	NTSB	US	LDVO	ACC	SA226
70	11-Oct-99	NTSB	US	LDVO	ACC	SA227
71	01-Jul-88	ASRS	US	TOVO	INC	LW
72	01-Mar-89	ASRS	US	LDVO	INC	LW
73	17-Feb-99	NTSB	US	LDVO	ACC	DC3
74	24-Dec-04	TSB	CAN	LDVO	ACC	BE100
75	19-Nov-99	BEA	FRAN	TOVO	ACC	B737
76	01-Mar-96	ASRS	US	LDVO	INC	LW
77	24-May-09	AAIB	UK	LDVO	INC	BE55
78	26-Sep-03	TSB	CAN	LDVO	INC	G100
79	23-Oct-87	NTSB	US	LDVO	ACC	CE402
80	09-Feb-10	NTSB	US	TOVO	ACC	BE58
81	01-May-01	ASRS	US	LDVO	INC	LW
82	15-Feb-08	ASRS	US	LDVO	INC	CL65
83	28-Sep-02	NTSB	US	LDVO	ACC	CE421
84	22-Dec-09	NTSB	US	TOVO	ACC	CE402
85	01-Feb-88	ASRS	US	TOVO	INC	LW
86	17-Jan-04	NTSB	US	LDVO	INC	CL600
87	11-Feb-87	NTSB	US	LDVO	ACC	BE99
88	01-Jan-88	ASRS	US	LDVO	INC	LW
89	31-Jan-94	NTSB	US	TOVO	ACC	DC3
90	01-Jun-92	ASRS	US	LDVO	INC	LW
91	01-Jun-83	NTSB	US	LDVO	ACC	CE401

APPENDIX F

Accidents and Incidents at Airports Selected for Validation

Date	Country	City, State	Event Class	Event Type	Airport Code	Aircraft Code
12/26/1987	US	FORT LAUDERDALE, FL	Incident	LDVO	FXE	WW24
3/31/2004	US	WALKER'S CAY, FL	Accident	LDVO	FXE	C402
10/14/1988	US	ANCHORAGE, AK	Incident	LDVO	ANC	VC10
8/28/1993	US	FORT LAUDERDALE, FL	Incident	LDVO	FXE	LJ24
4/7/2001	US	ANCHORAGE, AK	Incident	TOVO	ANC	B190
11/29/1994	US	SPOKANE, WA	Incident	TOVO	GEG	B737
8/9/2003	US	FORT LAUDERDALE, FL	Incident	LDVO	FXE	SBR1
3/2/2002	US	ANCHORAGE, AK	Incident	LDVO	ANC	G-IV
8/16/1999	US	FORT LAUDERDALE, FL	Accident	LDVO	FXE	CL60
5/23/2008	US	FORT LAUDERDALE, FL	Incident	LDVO	FXE	SBR1
12/19/1995	US	SAINT LOUIS, MO	Incident	LDVO	STL	DC93
6/6/2006	US	FORT LAUDERDALE, FL	Incident	TOVO	FXE	SW3
10/30/1986	US	SAINT LOUIS, MO	Accident	LDVO	STL	GLF
2/24/1983	US	ANCHORAGE, AK	Incident	LDVO	ANC	LJ24
9/17/1996	US	MIAMI, FL	Incident	TOVO	MIA	BE9L
10/16/2000	US	SAINT LOUIS, MO	Incident	LDVO	STL	MD80
6/15/2002	US	FORT LAUDERDALE, FL	Incident	LDVO	FXE	SW3
7/1/1998	US	ANCHORAGE, AK	Incident	LDVO	ANC	LT
4/17/2003	US	FORT LAUDERDALE, FL	Incident	LDVO	FXE	SBR1
10/15/1981	US	SAINT LOUIS, MO	Incident	LDVO	STL	DC6
7/27/1994	US	SIOUX FALLS, SD	Incident	LDVO	FSD	SW3
12/1/2005	US	SIOUX FALLS, SD	Incident	LDVO	FSD	T18C
2/4/2007	US	MIAMI, FL	Incident	LDVO	MIA	DC-8-71F

APPENDIX G

Location Models for Other Normalization Alternatives

Three alternatives to normalize the longitudinal distances for veer-off path were evaluated in this study: runway distance available (RDA), raw distances, and runway distance required (RDR). Only the models for RDA were presented in the body of the report and this appendix shows the results for the remaining two alternatives.

Normalization Alternative 2—Raw Distances

For this scenario, the raw longitudinal and lateral distances were used in the modeling process. To model the longitudinal probability distributions, 10 subareas were defined, each with length of 800 ft, with the last segment comprising all distances above 7200 ft.

Longitudinal Probability Distribution

Figure G1 illustrates the longitudinal probability distribution for both landing and takeoff veer-offs when using raw longitudinal distances. Figures G2 and G3 represent the longitudinal probability distributions for landing and takeoff veer-offs, respectively.

The cumulative probability plot and corresponding polynomial model is represented in Figure G4. It should be noted that this model was developed based on a maximum longitudinal length of 10,000 ft. The application of this model to runways with more than 7,200 ft should assume a linear trend for the last subarea; however, it should be recognized that this is a fundamental weakness of the approach using raw distances. The cumulative probability model (R^2 = 100%) is represented by the following equation.

$$CP = 4.3285E^{-24}D^6 - 2.2632E^{-19}D^5 + 4.2519E^{-15}D^4 - 3.6387E^{-11}D^3 + 1.2812E^{-07}D^2 + 3.5830E^{-05}D$$

where

D is the longitudinal distance from the beginning of the runway and

CP is the cumulative probability that a veer-off will occur within *D*.

Lateral Probability Distribution

The lateral deviation models were developed using the mathematical structure described for the previous set of lateral deviation models. A model was developed for each subarea using the lateral deviations identified for each landing veer-off and takeoff veer-off event challenging the specific subarea. Table G1 summarizes the model coefficients for each subarea. Figures illustrating the mathematical models with the actual data used for modeling are presented in Appendix D.

Based on the lateral deviation models, risk contour lines were derived to cover the subareas defined, as shown in Figure G5. The contour lines in this figure represent both sides of the runway. Aircraft deviations are referenced to the center point of the aircraft between the main gears. The ISO-risk lines can be used to estimate the probability that an aircraft exceeds the lateral distance in a given subarea.

It should be noted that the risk contour curves presented in Figure G5 are applied to individual subareas and it is not possible to calculate the risk of an accident for a given scenario where the safety area may have limits and some obstacles may be present. However, it is possible to combine the lateral deviation models with the probability that an aircraft will challenge specific subareas of the runway. Figure G6 combines the results from Figure G5 and the lateral deviation models in Table G1, where the probabilities for a given distance are multiplied by the subarea probability.

In this case, the contour lines represent the probabilities that an aircraft will exceed a given lateral distance during a runway excursion.

The two previous plots present very high variability as a function of the raw distance, particularly for the outer contour lines. This is an indication that using raw distances may not be very accurate and not the best alternative for modeling.

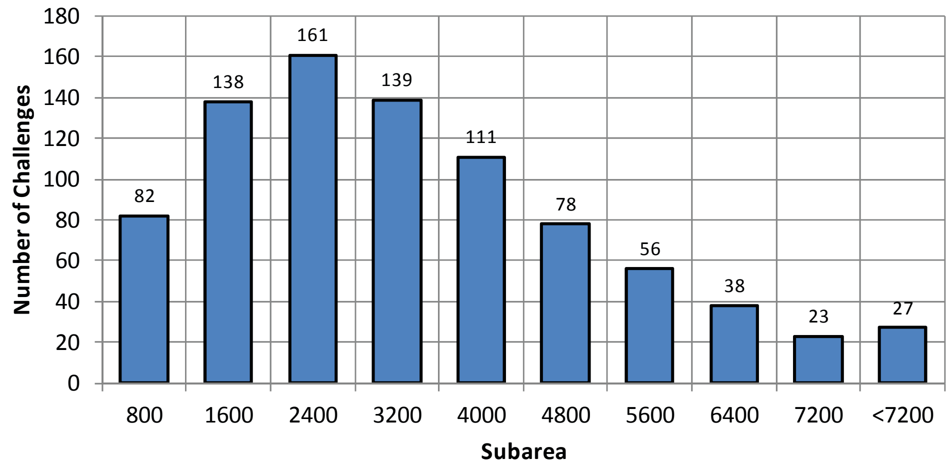


Figure G1. Longitudinal probability distribution: both landing and takeoff veer-offs—raw distances in feet.

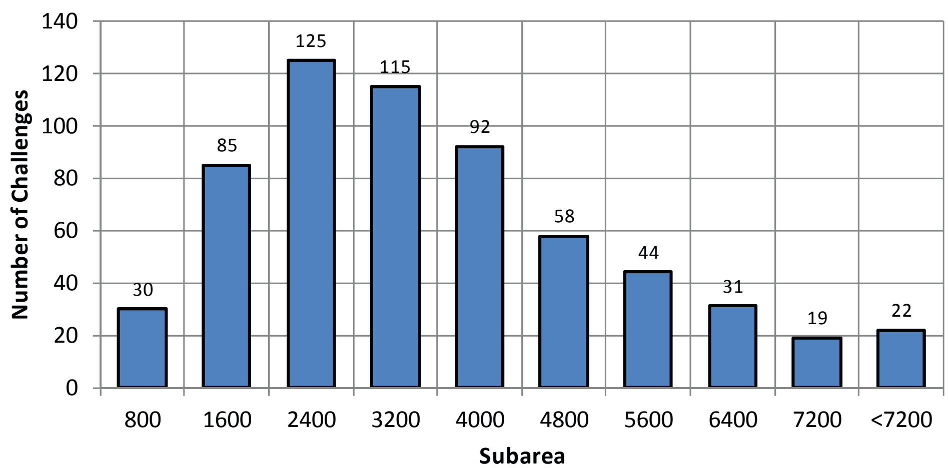


Figure G2. Longitudinal probability distribution: landing veer-offs only—raw distances in feet.

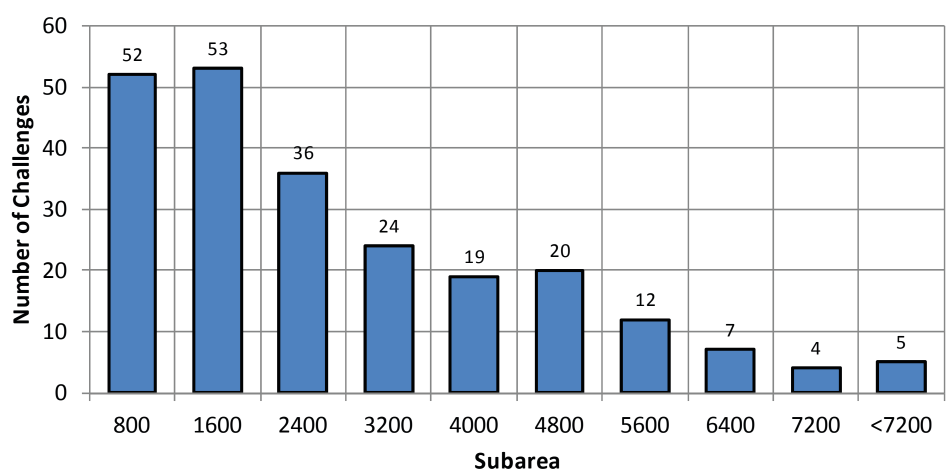


Figure G3. Longitudinal probability distribution: takeoff veer-offs only—raw distances in feet.

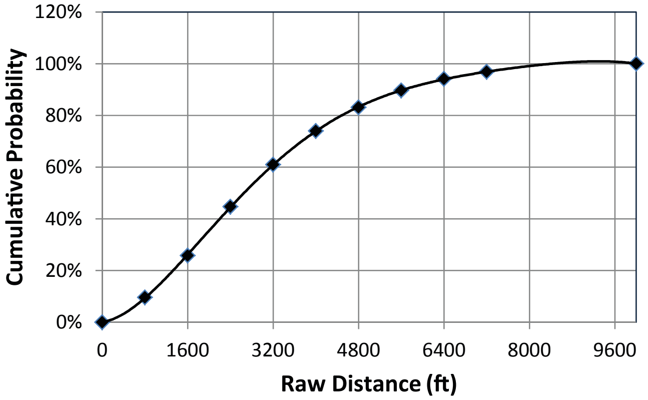


Figure G4. Longitudinal cumulative probability distribution—raw distances.

Table G1. Lateral deviation models using raw distances.

Subarea	Range	a	b	R^2
1	0–800 ft	-0.02092	0.92906	98.1%
2	800–1,600 ft	-0.00718	1.072515	99.6%
3	1,600–2,400 ft	-0.00837	1.094611	98.5%
4	2,400–3,200 ft	-0.00314	1.288615	98.8%
5	3,200–4,000 ft	-0.00908	1.049775	98.3%
6	4,000–4,800 ft	-0.02169	0.811623	99.0%
7	4,800–5,600 ft	-0.00510	1.128748	99.2%
8	5,600–6,400 ft	-0.00315	1.126453	98.4%
9	6,400–7,200 ft	-0.00916	0.971838	98.4%
10	Above 7,200 ft	-0.00265	1.108277	98.7%

Normalization Alternative 3—Runway Distance Required

For this scenario, the raw longitudinal distances were divided by the runway distance required (RDR) by the aircraft involved in the event under its specific operational conditions. To model the longitudinal probability distributions, 10 subareas were defined. Subareas 1 through 7 had a length of 0.2*RDR each; the 8th segment had a length of 0.4*RDR; the 9th segment had a length 0.8*RDR; and the last segment comprised all distances above 2.4*RDR. The length of segments was selected such that the longitudinal probability distribution could be characterized with at least 5% of occurrences in each segment in the consolidated frequency histogram.

In addition to the basic RDR by each aircraft under ISO conditions (sea level, 15 degrees Centigrade), the following corrections were applied to RDR for each event:

- Elevation,
- Air temperature, and
- Longitudinal Runway slope.

Longitudinal Probability Distribution

Figure G7 illustrates the longitudinal probability distribution for both landing and takeoff veer-offs when using longitudinal distances normalized for RDR. Figures G8 and G9 depict the longitudinal probability distributions for landing and takeoff veer-offs, respectively.

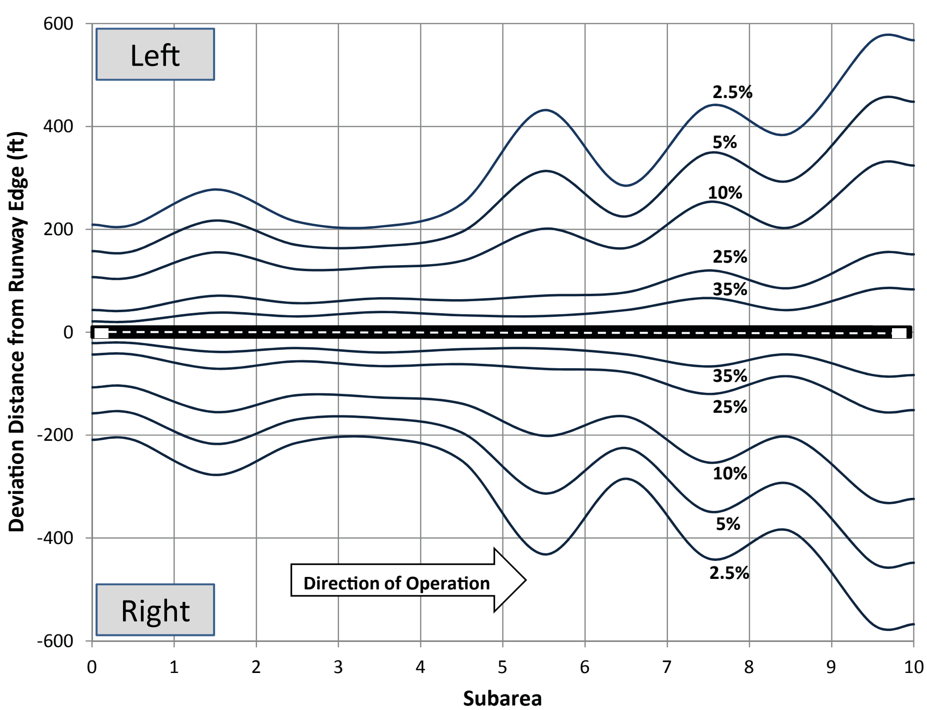


Figure G5. Risk contours: – probability of deviations exceeding a given distance L_1 for each subarea—raw distances.

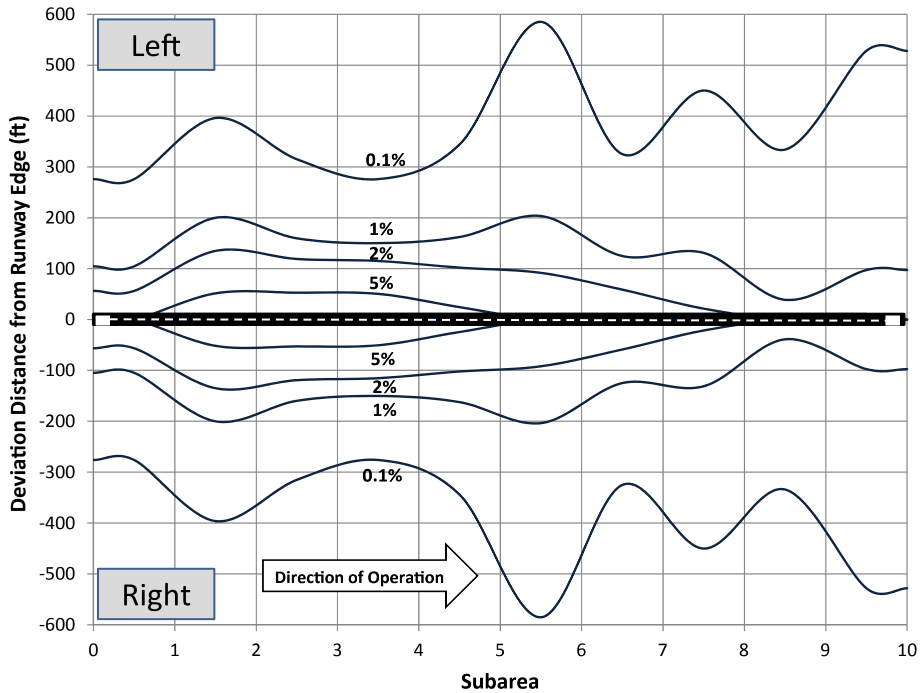


Figure G6. Risk contours: adjusted probability of deviations exceeding a given distance L_1—raw distances.

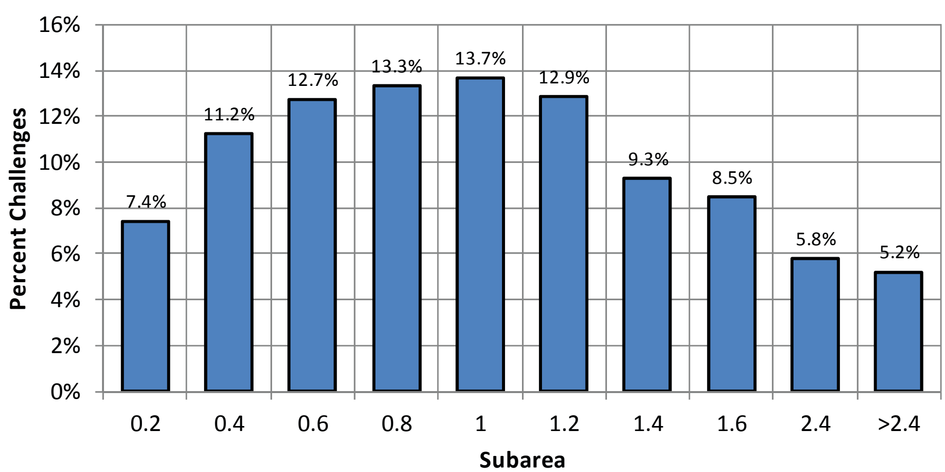


Figure G7. Longitudinal probability distribution: both landing and takeoff veer-offs—distances normalized by runway distance required.

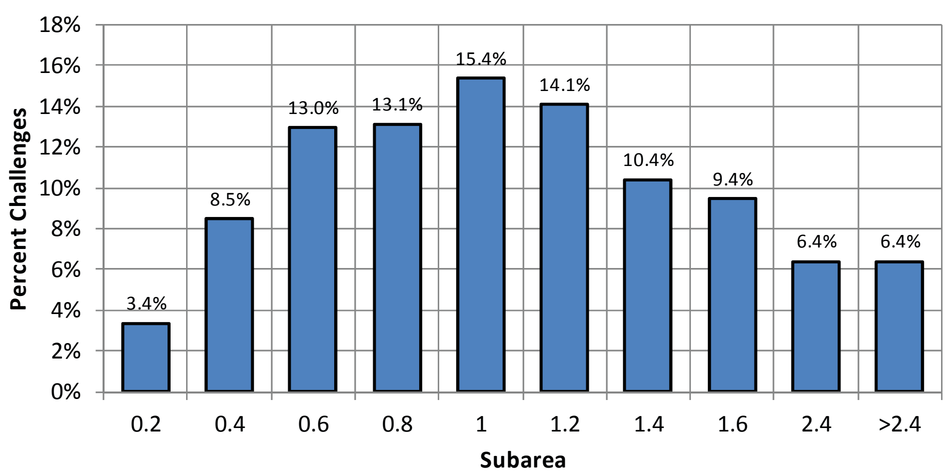


Figure G8. Longitudinal probability distribution: landing veer-offs only—distances normalized by runway distance required.

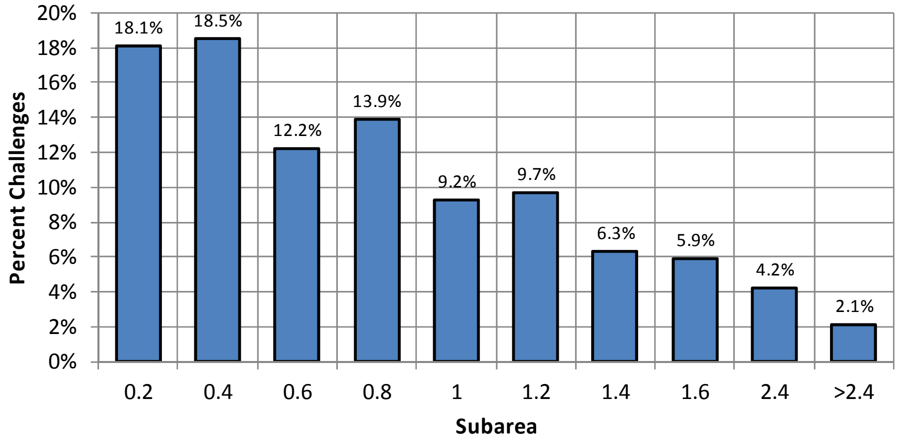


Figure G9. Longitudinal probability distribution: takeoff veer-offs only—distances normalized by runway distance required.

Based on the results presented in Figure G7 for both landing and takeoff veer-offs, the cumulative probability distribution curve for the runway distance required was developed and is shown in Figure G10. No mathematical model was developed for this scenario. If necessary, a polynomial of degree higher than 6 may be applied for the modeling. As indicated in ensuing paragraphs, this alternative for normalization was not selected for incorporation in the analysis software.

Lateral Probability Distribution

Similar to previous normalization alternatives, exponential models were developed for each subarea using the lateral deviations identified for each landing and takeoff veer-off event challenging the specific subarea. Table G2 summarizes the model coefficients for each subarea and the figures presented in Appendix E illustrate the mathematical models with the actual data used for modeling. The last column in Table G2 shows the models' R^2.

Risk contour lines were also derived for this normalization scenario, as shown in Figure G11. It should be noted that the contour lines represent both sides of the runway. Aircraft deviations are referenced to the center point of the aircraft between the main gears. The ISO-risk lines can be used to estimate the probability that an aircraft exceeds the lateral distance in a given subarea.

It can be noted from Figure G11 that the contour lines are quite variable. This trend may be an indication that this normalization alternative may lead to larger errors if these risk contour curves are applied to individual subareas. Combining the lateral deviation models with the probability that an aircraft will challenge specific subareas of the runway makes it possible to obtain Figure G12. In this figure, the probabilities for a given distance are multiplied by the subarea probability. In this case, the contour lines represent the probabilities that an aircraft will exceed a given lateral distance during a runway excursion.

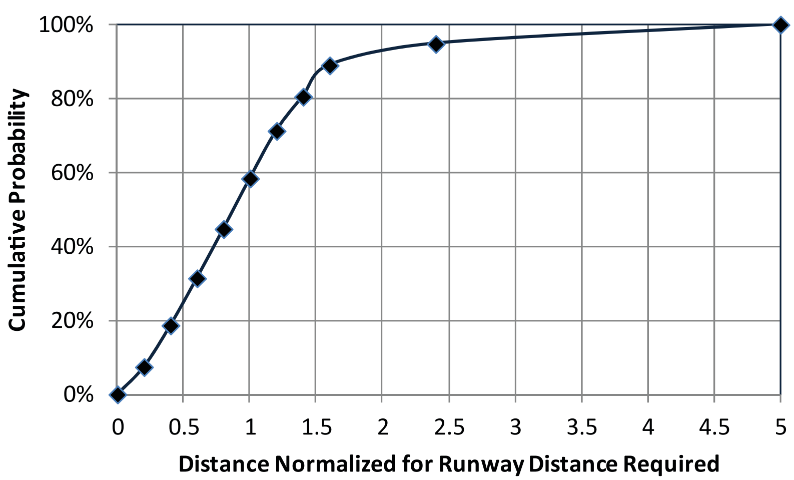


Figure G10. Longitudinal cumulative probability distribution: distances normalized by runway distance required.

Table G2. Lateral deviation models—normalization using RDR.

Subarea	Range	a	b	R^2
1	0 – 0.2*RDR	-0.03258	0.8837	98.2%
2	0.2–0.4*RDR	-0.01392	0.9496	99.5%
3	0.4–0.6*RDR	-0.00905	1.0568	99.5%
4	0.6–0.8*RDR	-0.00811	1.0989	99.2%
5	0.8–1.0*RDR	-0.00766	1.0869	99.6%
6	1.0–1.2*RDR	-0.01757	0.8890	99.2%
7	1.2–1.4*RDR	-0.02405	0.8434	99.3%
8	1.4–1.8*RDR	-0.01238	0.9301	98.5%
9	1.8–2.4*RDR	-0.02139	0.8632	98.6%
10	> 2.4*RDR	-0.00716	1.1380	98.4%

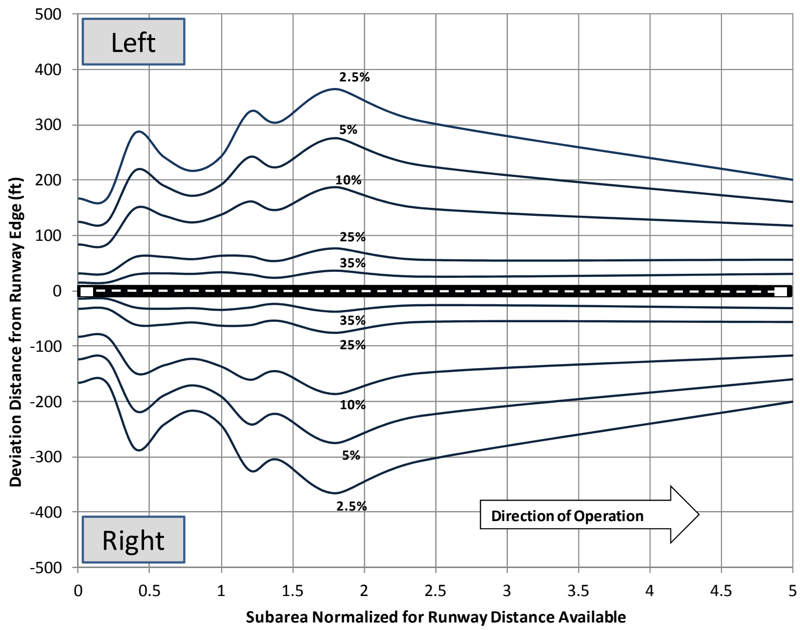


Figure G11. Risk contours:—probability of deviations exceeding a given distance L_1 for each subarea—distances normalized by RDR.

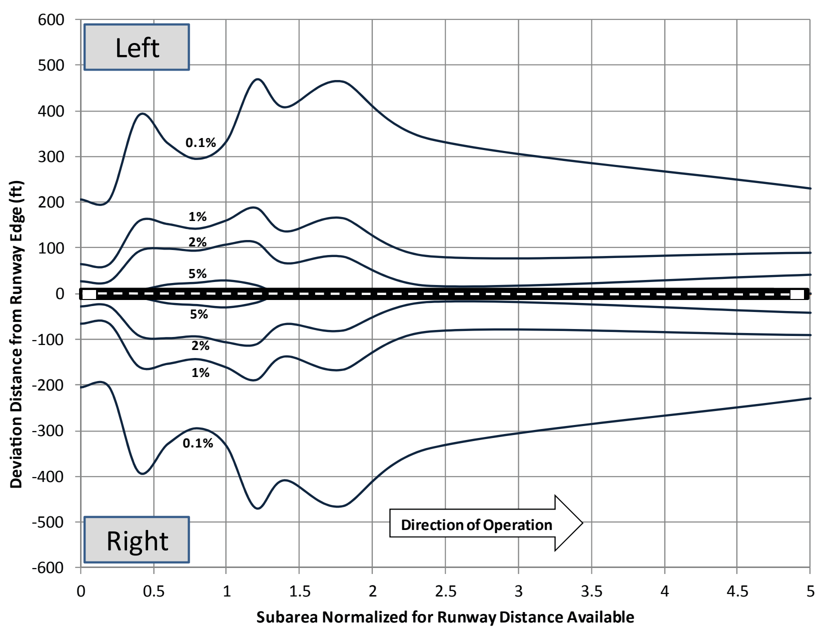


Figure G12. Risk contours:—adjusted probability of deviations exceeding a given distance L_1—distances normalized by RDR.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
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	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
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
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