APPENDICES TO ACRP REPORT 3: ANALYSIS OF AIRCRAFT OVERRUNS AND UNDERSHOOTS FOR RUNWAY SAFETY AREAS

Appendix A – Understanding Aircraft Overruns and Undershoots

Introduction

The objective of ACRP 4-01 project was to investigate aircraft overrun and undershoot events to assess the protection provided by runway safety areas. Understanding how overrun and undershoot events occur is essential for airport operators and regulators to identify hazards associated with the operations and allow management of risks associated with such events in their facilities. In addition, they will better comprehend how safety areas offer a certain level of protection and may find alternatives to mitigate the consequences of such events.

Runway safety areas (RSA) help mitigate the consequences of undershoot and overrun events. They provide additional smooth surfaces around the runway that aircraft may utilize for stopping or to continue landing.

To understand how overruns and undershoots can happen, it is necessary to know the procedures used and resources available to the pilots during the landing and takeoff phases of the flight. Moreover, it is necessary to understand how weather conditions, runway conditions, and human errors can negatively affect the operations and lead to overruns or undershoots.

Landing

The airspeed and attitude of large transport aircraft are adjusted for landing. The airspeed is kept above stall speed plus a safety margin, and a constant rate of descent is pursued. Just before landing, the descent rate is reduced to a few feet per minute, causing a light touch down. Landing is described in different phases: approach, flare, touchdown, ground roll, and stopping.

Approach

Aircraft should approach according to the glide path for the runway at the reference velocity for the aircraft, based on the configuration selected by the crew. Depending upon actual environmental and runway conditions, pilots select the best configuration for the approach, particularly speed, power, and flap.

Large aircraft on the final approach to the runway normally descend along a documented path which is inclined at about 3° to the horizontal and aligned with the runway. All Instrument Landing Systems (ILS) are based on this approach slope: the term glideslope is usually accepted to refer to the approach slope in such systems.

For larger aircraft, the approach technique is normally to intercept the glideslope at some distance from the runway threshold and to maintain a consistent airspeed and rate of descent throughout a straight-in approach. The rate of descent necessary to maintain the glideslope is controlled by slight power changes and depends on the effect of wind and ground speed.

Maintenance of the glideslope and direction (i.e., the track over the ground following the extended runway line) is critical for a precise approach. Thus, it is also necessary to assess the crosswind component of the wind velocity and make the necessary heading adjustment to compensate for drift.

Types of Approach

Landings are governed by published "Decision Height" (DH) and "Minimum Descent Altitude" (MDA) criteria. A pilot should not continue a descent below DH or descend below MDA unless the required visual reference has been established and maintained. If these criteria are not met, a pilot must execute a missed approach, which requires that the aircraft go around. Some airlines will adopt their own criteria for DH and MDA which are stricter than published ones.

While flying the approach there are various navigational instruments and beacons used to help guide aircraft to the runway. Airports may provide a variety of electronic aids, such as the Non-Directional Beacon (NDB), Very High Frequency Omnirange (VOR), or ILS for approaching aircraft, among other. As a result of the various types of instruments available, there are many types of approaches in use. There are two basic categories—visual and instrument—and instrument approaches are further categorized into non-precision and precision approaches.

Visual approaches may be conducted on an Instrument Flight Rules (IFR) plan which authorizes the pilot to proceed visually and clear of clouds to the airport. The pilot must have either the airport or the preceding aircraft in sight; ceiling must be 500 ft above the appropriate Minimum IFR Altitude for the specific airport and the visibility must greater than 3 nautical miles.

Non-precision approaches are those with guidance in the horizontal plane only. They exclude the approaches when a glideslope is used but include those made with the help of visual slope aids such as Precision Approach Path Indicator (PAPI) and Visual Approach Slope Indicator System (VASIS). The following navigational aids are generally used for non-precision approaches in commercial aviation:

- Localizer (ILS without glideslope)
- VOR
- ADF (Automatic Direction Finder) or NDB (Non-Directional Beacon)
- GPS (Global Positioning System)

The NDB approach requires the use of the Automatic Direction Finder (ADF) in the cockpit for bearing information to the runway. Because of its lack of glideslope (approach path) information, it is considered a non-precision approach.

The VOR is used much the same as the NDB, but it has a greater degree of accuracy. The VOR is used in conjunction with the DME (Distance Measuring Equipment) providing distance to the runway. Since only distance, bearing, and position information is provided, the VOR approach is also considered a non-precision approach.

Precision approaches are able to guide the aircraft in both the horizontal (alignment with the runway) and vertical (altitude). Most common precision approaches and systems include the following:

- ILS
- MLS (Microwave Landing System)
- PAR (Precision Approach Radar, Military)
- GPS (with vertical navigation via WAAS or EGNOS)
- LAAS - Ground Based Augmentation System (GBAS) for Global Satellite Navigation Systems (GNSS)
- JPALS (Joint Precision Approach and Landing System)

The ILS is considered a precision approach. It provides both glideslope (up/down) and localizer (left/right) information via an electronic beam to an instrument in the cockpit. Along this beam there may be up to three markers: Outer Marker, Middle Marker, and Inner Marker. Each of these electronic markers has its own phonetic identifier and provides the distance to the runway. Pilots are often heard reporting their position as they approach or cross a marker.

Modern autopilots use computer software to control the aircraft. The software reads the aircraft's current position, and controls a flight control system to guide the aircraft. In such a system, besides classic flight controls, many autopilots incorporate thrust control capabilities that can control throttles to optimize the airspeed, and move fuel to different tanks to balance the aircraft in an optimal attitude in the air.

A "coupled approach" is one that utilizes the aircraft's autopilot to navigate the aircraft in the approach phase right down to the approach minimums, and, in some cases, on to the runway itself. Beyond these minimums, the pilot will take control of the aircraft after turning the autopilot off.

Instrument aided landings are defined in categories that are dependent upon the required visibility level and the degree to which the landing can be conducted automatically without input by the pilot:

- CAT I - This category permits pilots to land with a decision height (where the pilot takes over from the autopilot) of 200 ft and a forward visibility of 2400 ft.

- CAT II - This category permits pilots to land with a decision height of 100 ft and a forward visibility of 1200 ft.

- CAT IIIa – A decision height lower than 100 ft. Allows full blind landing capability on autopilot. Pilot assumes control on touch down.

- CAT IIIb – Same as IIIa but for decision heights below 50 ft. The runway visual range (RVR) can be as low as 170 ft.

- CAT IIIc - Same as IIIb but with no RVR limitations.

Approach Speed

Vref is the reference landing approach speed; the speed (in calm air) when the aircraft crosses the runway threshold at a desired height of normally 50 ft. It is often used by pilots as a basis from which to calculate airspeeds to be used during landing, and calculated to add a margin over the stall speed - usually 30% above the stalling speed (Vso) or the minimum steady flight speed in the landing configuration (function of weight, wind, flap configuration, airspeed corrections, icing conditions and use of autothrottle mode or autoland for CAT II and III precision approaches).

Low airspeeds may result in undershoots, particularly when there are wind speed variations. High approach speeds will require more landing roll distances to stop the aircraft and may lead to overruns if small safety margins are applied for specific landing conditions.

Stabilized Approach

It is recommended that the approach is stabilized by 1000 ft above the airport elevation for IMC and 500 ft for VMC. In general, the approach is considered stabilized when the aircraft is in the selected landing configuration and:

- The flight path is correct with only minor adjustments to the path (heading and pitch) according to the approach selected
- The airspeed is between Vref + 20 kts and Vref
- The descent rate is lower than 1000 ft/minute
- Power setting is appropriate and higher than the minimum power for approach

A stabilized approach is very important to reduce uncertainties relative to the aircraft position and speed when crossing the threshold. Unstabilized approaches may result in touchdowns before the threshold (undershoots), or in fast and high approaches that may lead to overruns.

Flare, Touchdown, and Ground Roll

In the final approach the aircraft will descend towards the aiming point marked in the runway located at approximately 1200 ft (normally between 1000 and 1500 ft) from the landing threshold. When approaching that point, the aircraft is “flared” so that its attitude is smoothly changed, from the nose down attitude of the approach to a nose high attitude for touching down.

During this “round-out” transition period, power is smoothly reduced to idle, or near idle, and the aircraft's vertical speed is reduced to practically zero, while at the same time its forward speed is also reduced from Vref to about 1.15 × Vso, plus any wind gust allowance.

At the end of the flare maneuver, the aircraft should be flying level just above the surface and decelerating as it approaches the touchdown target. An aircraft close to the surface is in ground effect and a decrease in induced drag will occur. The rate of deceleration slows down and the aircraft tends to “float.” The higher the ground speed is, the longer the float duration, and the greater will be the chance of encountering some difficulty due to wind gusts, lulls, or shifts.

For approaches with a tailwind, the aircraft may float even longer. The drag from fully extended flaps will increase deceleration and reduce float. The duration of the float will be minimized by an approach at the correct airspeed plus a firm, smooth round-out and power reduction.

The touchdown airspeed chosen by the pilot depends on wind conditions and there are two touchdown options. The usual technique is to ease the main wheels onto the surface while closing the throttle, touching down lightly while the aircraft is in a somewhat nose high attitude but still above Vso. This technique is always used in unfavorable wind conditions. Sometimes, rather than the pilot flying the aircraft onto the surface, the aircraft might be held in that attitude just above the surface until airspeed decays and the aircraft lands itself.

Landing Distance

The landing distance required (LDR) is the distance needed to safely bring an aircraft to a full stop on a specific runway. It requires knowledge of the landing distance available (LDA) and the deceleration capability for the landing conditions with no use of thrust reversers and no safety margin added.

LDR depends on meteorological conditions (airport pressure altitude, wind velocity, wind direction, etc.), runway surface conditions, runway slope, aircraft weight, aircraft configuration, approach speed, and planned use of airplane ground deceleration devices. In addition, the landing distance required should incorporate a safety margin (15 percent, as recently established by Federal Aviation Administration – OpSpec/MSpec C082). Flight crews should not base LDR calculation solely on runway friction meter reading because there is no reliable correlation between runway friction under varying conditions, type and severity of runway contaminants and braking capability. Typically, a 1.67 multiplier factor should be applied as a safety margin, and the resulting distance should be increased typically by 1.4 for wet/slippery conditions, by 2.3 for standing water or slush-contaminated, by 1.7 for compacted snow, and by 4 for icy surface. FAA recommends the following factors to apply to dry runway distances calculated for turbojet aircraft.

Table A-1 – Factors on calculated landing distances

Runway Condition	Reported Braking Action	Factor
Dry	No braking report	0.8
Wet Runway, Dry Snow	Good	0.9
Packed or Compacted Snow	Fair/Medium	1.2
Wet Snow, Slush, Standing Water, Ice	Poor	1.6
Wet Ice	Nil	Landing prohibited

These factors assume that maximum manual braking, autospoilers (if available), and reverse thrust will be used. For operations without reverse thrust, these factors are multiplied by 1.2.

In many cases, safety margins for aircraft operations exceed those described above, particularly for smaller planes when the LDA is significantly higher than the LDR at the larger airports. In other cases, the payload and gross weights are below the maximum allowable for the specific runway for reasons other than operational limitations.

The uncertainties for LDR for a specific landing configuration are mostly related to the meteorological conditions, runway surface conditions, and human factors. These may lead to a high touchdown speed, a late touchdown, or a braking performance lower than expected. Examples of the latter cases include runway contamination and delay to apply the correct braking procedures.

In some cases (e.g., wind gusts) the meteorological conditions will make it difficult to keep the aircraft aligned and under control during landing, resulting in a delay to apply the braking procedures. Obviously, any combination of the elements described above will increase the risk of overruns. In addition, failure to use the correct safety margins during the flight planning or differences between actual and estimated weather conditions may contribute to reduce required safety margins for the operation.

In 2006 the FAA began requiring turbojet operators (Operations Specification / Management Specification (OpSpec/MSpec) C082), upon approaching to destination, to make an assessment of required landing distance under the conditions existing at the time of arrival to assure appropriate safety margins are met and determine if the operation should be restricted or suspended. The same specification describes the need to apply a 15 percent safety margin over the actual LDR.

Touchdown

Touchdown should ideally occur between 1,000 and 1,500 ft beyond the threshold. Boeing performance data are based on touchdown occurring 1,200 ft beyond the threshold. It is obvious that touchdown location and speed may contribute to the risk of overruns. A higher touchdown speed relative to the reference speed will require longer distances available in the runway. On the other hand, a late touchdown will reduce the landing distance available after the touchdown, thus increasing the risk of overrun.

Stopping

Upon touchdown, pilots use ground spoilers, wheel brakes (including anti-skid and autobrake systems), and thrust reverser systems to slow down and stop the aircraft.

Spoilers are plates on the top surface of a wing which can be extended upward into the smooth airflow and spoiling it. By doing so, the spoiler significantly reduces lift. For larger aircraft, ground spoilers are normally deployed automatically (if armed) upon touchdown of main gears or activation of thrust reversers. The spoilers are nearly always used at full effect to assist in slowing the aircraft. The increased drag created by the spoilers directly assists the braking effect. However, the real gain comes as the spoilers cause a dramatic loss of lift and hence the weight of the aircraft is transferred from the wings to the undercarriage, allowing the wheels to be mechanically braked with much less chance of skidding.

Wheel brakes provide braking action from friction between the aircraft tires and the runway pavement and may be affected by the aircraft speed, wheel speed, tire condition and pressure and wheel load. Anti-skid systems prevents lockup of tires due to pilot applied pressure, eliminates tire damage and damage to airframe due to tire lockup (blowout) and improves braking performance.

Thrust reversers provide a temporary diversion of an aircraft engine's output so that the thrust produced is directed forward, rather than aft. This acts against the forward travel of the aircraft, providing deceleration. These systems are often used to help slow the aircraft on landing and they provide a deceleration force that is independent of the runway surface condition. They are more effective at higher airspeeds and should be applied as soon as possible after touchdown.

Delay or failure to apply these systems will reduce braking effectiveness and safety margins during the landing roll, thus increasing the risk of overruns. These delays may be caused by human factors or aircraft system malfunction, but it may also happen during attempts to control the aircraft under variable meteorological conditions or loss of friction between aircraft tires and the pavement surface.

Takeoff

In a normal takeoff procedure, the crew will accelerate the aircraft using all the engines to takeoff power. The plane is kept aligned with the runway until the rotation speed (see below) is achieved during the roll. Takeoff distance is defined as that necessary to clear a 35-ft obstacle. Large transport aircraft will usually use a derated power takeoff, where less than full power is applied, with unneeded power held in reserve in case of emergency.

Because commercial jet aircraft have difficulty generating enough lift at low speeds encountered during takeoff, they are fitted with high-lift devices, often including slats and usually flaps, which increase the camber and area of the wing, making it more effective at low speed, thus creating more lift. These are deployed from the wing prior to takeoff, and retracted during the climb.

The minimum allowable runway length required for an airplane to accelerate and stop safely is called the Accelerate-Stop Distance Required (ASDR). It depends on the aircraft weight, speed, prevailing weather and runway conditions. The ASDR must be smaller than the Accelerate-Stop Distance Available (ASDA) for the runway where the operation is taking place.

Takeoff Speeds

Takeoff speeds are a key safety element for takeoff and enable pilot situational awareness and decision making in this very dynamic situation. The use of erroneous takeoff speeds can lead to tail strikes, high-speed rejected takeoffs, or initial climb with degraded performance. The efficiency of such aerodynamic surfaces as the wings (for lift), the rudder, the ailerons, and the elevators, depends on adequate airflow speed. This airflow speed determines the minimum takeoff speeds.

Vmcg (Velocity of Minimum Control on Ground)

During the takeoff roll, it is important to know the minimum speed at which the aircraft will remain controllable, in the event of an engine failure on ground. This is because, in such a case, and if the takeoff is continued, only the rudder will be able to counteract the yaw moment that is generated by asymmetric engine(s) thrust. It is defined as the minimum speed at which an aircraft is “controllable” (lateral excursion lower than 30 feet) after an engine failure on ground. Vmcg mainly depends on the engine(s) thrust and pressure altitude.

V1 (Decision Speed)

V1 is the maximum speed at which a rejected takeoff can be initiated, in the event of an emergency. V1 is also the minimum speed at which a pilot can continue the takeoff after an engine failure. If an engine failure is detected after V1, the takeoff must be continued. This implies that the aircraft must be controllable on ground. Therefore, V1 is always greater than Vmcg.

V2 (Takeoff Safety Speed)

V2 is the minimum speed that needs to be maintained up to acceleration altitude, in the event of an engine failure after V1. Flight at V2 ensures that the minimum required climb gradient is achieved, and that the aircraft is controllable.

Vr (Rotation Speed)

The rotation speed ensures that, in the case of an engine failure, lift-off is possible and V2 is reached at 35 feet at the latest. Therefore, at 35 feet, the actual speed is usually greater than V2. The rotation of the aircraft begins at Vr, which makes lift-off possible, at the end of the maneuver.

Rejected Takeoffs (RTO)

It is estimated that one RTO occurs for every 2000 takeoffs, and most are initiated at speeds less than 80 kts. Approximately 2 percent of the events will occur at speeds higher that 120 kts. An RTO may occur for various reasons, including engine failure, activation of takeoff warning horn, demand from air traffic control, runway incursions, blown tires system warnings, or incorrect aircraft configuration and operation planning. For most incidents and accidents reported due to RTO, the decision to abort the takeoff was made at speeds in excess of V1 and one third occurred on runways that were wet or contaminated (Boeing, 1992).

Basically, the same factors leading to difficulties stopping the aircraft during landing overruns will contribute to cause takeoff overruns.

Runway Surface Conditions

The runway surface may be wet or contaminated by standing water, snow, slush, or ice. The aircraft wheel braking may lose its effectiveness and/or the pilots may have difficulties keeping the aircraft controlled and aligned with the runway axis.

Contamination reduces the friction forces between the tires and the pavement surface and may create a layer of fluid between them that may result in hydroplaning (dynamic or viscous). Typically, the directional control during these undesirable situations is maintained using the rudder or applying differential braking.

Loss of braking capability or directional control will increase the actual landing distance required and reduce the safety margins for a safe stop within the runway limits.

Control of an aircraft during ground operations depends on adequate tire contact and friction between tire and pavement surface. This interaction is relied on for lateral control and to oppose side forces such as cross wind. Equally significant is the retarding force for braking. In situations where tire contact or friction is deficient, there is a loss of directional control and braking capability.

Any water on the runway creates a potential situation for skidding. Crosswind components add to the threat by holding back water in opposition to the pavement crossfall, at the same time increasing the difficulty of directional control during the ground operation. In the case of natural surfaces, low friction and soft ground is a dangerous combination, particularly when the surface is uneven. Runway intersections are particularly dangerous because pavement crossfall is very small causing the water film depth to increase during the rains.

Overruns

The actual stopping distance required for a specific operation will depend on a number of factors, including meteorological conditions (visibility, wind), runway surface condition (surface friction), aircraft configuration, and application of correct procedures by the aircraft crew. Any deviation from the conditions planned at arrival will change the actual landing distance required.

However, there are only a few primary factors that will result in overrun incidents, and these include the touchdown distance from the landing threshold, the touchdown speed, the braking capability, the directional control of the aircraft and rejecting the take-off at high speeds.

Most of the navigational aids in the RSA are frangible and not considered obstacles. However, some NAVAIDS like the approach lights are positioned on structures that may or may not be frangible, and, because of their location, these systems can be hazardous to aircraft that undershoot or overrun the runway.

Ideally, the terrain in the overrun areas should have a reduced bearing capacity to increase the soil/wheel drag and help decelerate aircraft in case of such emergencies. In some cases, availability of areas beyond the runway threshold will require the use of aircraft arresting systems (e.g., arrestor beds).

It should be noted that a very soft terrain in the safety area is not desirable either. If the wheel/soil drag is too high it may damage the landing gear during the overrun. In addition, such type of terrain will be very hard to be maintained to keep a smooth surface.

Braking is more effective at lower speeds if tires are in the paved area. In grass areas it looses effectiveness. If the grass is wet, there will be little braking or even steering capability on the wheels. The aerodynamic braking is more effective at higher speeds and ineffective at low speeds. For the same speed, the aerodynamic drag will be more effective in higher air density.

The soil drag is higher for weaker soils but there is a limit. Aircraft may be damaged when the wheels penetrate excessively into the soil and the structural capacity of the landing gear exceeded by the dragging forces. Soil drag will depend on the gear configuration and when comparing two aircraft having similar landing gear, the heavier aircraft will take longer to stop. The gear configuration effect depends on the frontal tire area. For example, a triple tandem will have the same frontal area as a single tandem, if the tire sizes are the same. In this case, the difference in the stopping distance will be mostly due to aircraft weight.

Undershoots

Undershoots usually carry far more inertial energy into an accident than overruns. The most common undershoot accident is caused by some form of power loss. Once the power loss occurs, the instinctive pilot reaction is to hold the nose up using the elevator. If the approach is at the proper Vref for its weight, any raising or holding the nose up will result in a loss of airspeed and as a consequence, below Vref, any loss of speed will increase the rate of sink and loss of altitude.

The greater the angle of descent, the better it is to select the touchdown location point over the runway. A low angle, low speed, or unstabilized approach will make the operation vulnerable to misjudgment, turbulence, or wind shear and may lead to undershoots.

On shallow approaches, the pilot is far more likely to wind up behind the power curve, particularly because he is may misjudge the approach and require additional power. The lower the aircraft is relative to the terrain, the less opportunity the pilot will have to exchange altitude for airspeed. Being behind the power curve means that the aircraft nose is high, and it may be so high that even the use of full power may not avoid stopping the sink rate.

Appendix B - Functional Hazard Analysis

Introduction

Increasingly, functional hazard analysis (FHA) is being recommended as a means of performing hazard identification. An FHA is a formal and systematic process for the identification of hazards associated with an activity, typically employed to support risk assessment and management.

The purpose of the FHA in the context of ACRP 4-01 study is to determine relevant causal factors of overrun and undershoot accidents and hazards to aircraft associated with airfield operations (e.g., landing, takeoff roll, and associated fault sequences) and the physical design of airfields. This information will be used to support the data collection exercise and the subsequent development of risk models.

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

A number of FHAs have been undertaken in recent years in support of studies addressing the provision of runway safety areas (RSA). Against that background, it has not been considered necessary to repeat the full FHA process as part of this study. Instead, use has been made of the outputs of the previous FHA coupled with a literature review on causal and contributing factors to overrun and undershoot accidents. These have been reviewed systematically in order to compile a comprehensive set of hazard scenarios relevant to runway safety area provision that is part of this project scope.

Definitions

A few definitions related to the analysis of risks are described below.

Term	Definition
Safety	Freedom from unacceptable risk. Safety is often equated to meeting a measurable goal such as an accident rate that is less than an acceptable target. However, the absence of accidents does not ensure a safe system. To remain vigilant regarding safety, it is necessary to recognize that just because an accident has not happened, does not mean that it cannot or will not happen.
Overrun	An event when an aircraft passes beyond the end of the runway during an aborted takeoff or landing operation. The overrun distance is described by the longitudinal distance traveled beyond the departure end of the runway.

Term	Definition
Undershoot	An event occurring during an approach to landing that results in an inadvertent landing or contact with the ground or an object short of the runway or intended landing area. Normally undershoots occur due to misjudgment of distance, speed, and/or altitude on final approach. It does not include occurrences in which the aircraft could not have reached the intended landing area; i.e., after loss of engine power. The undershoot distance is described by the longitudinal distance by which the aircraft undershoots the intended runway approach end.
Hazard	The inherent characteristic of a material, condition, or activity that has the potential to cause harm to people, property, or the environment.
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.
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, etc.). 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 $1x10^{-7}$).
Consequence	The direct effect of an event, incident or accident. In this study it is expressed as a health effect (e.g., death, injury, exposure) or property loss.
Hazard Analysis	The identification of system elements, events or material properties that lead to harm or loss. The term hazard analysis may also include evaluation of consequences from an event or incident.
Risk Analysis	The study of risk in order to understand and quantify risk so it can be managed.
Risk Assessment or Risk Characterization	Determination of risk context and acceptability, often by comparison to similar risks.
Quantitative Risk Analysis	Incorporates numerical estimates of frequency or probability and consequence.
Relative Risk Analysis	Risk is evaluated in comparison to another risk. The type of risk analysis used should be appropriate for the available data and to the exposure, frequency and severity of potential loss.
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. A critical role of the safety regulator is to identify activities involving significant risk and to establish an acceptable level of risk.
Acceptable Level of Risk	For regulations and special permits is established by consideration of risk, cost/benefit, and public comments. Relative or comparative

Term	Definition
	risk analysis is most often used where quantitative risk analysis is not practical or justified. Public participation is important in a risk analysis process, not only for enhancing the public's understanding of the risks associated with certain activities, but also for insuring that the point of view of all major segments of the population-at-risk is included in the analyses process. Risk and cost/benefit analysis are important tools in informing the public about the actual risk and cost as opposed to the perceived risk and cost involved in an activity.
Press-on-itis or pressonitis	Illogical determination to get to a destination or persistence in a situation when that action is unwise. Typical examples include: • Continuing to destination (as opposed to diversion) despite deteriorating weather conditions or conditions below minima for a given approach; • Acceptance of demanding weather conditions; • Continuing with the approach because of (excessive) management-induced commercial pressures; • Pressure to complete a flight within the prescribed flying duty period; • Continuing the approach when a missed approach or a go-around would normally be executed.

Review of Available Overrun and Undershoot FHAs

As part of the 2001 study by Eddowes et al. for the evaluation of runway safety areas recommended by the International Civil Aviation Organization (ICAO), an FHA was undertaken for a number of airport related operations: takeoff run; rejected takeoff; wheels off (0 to 35 feet climb); takeoff climb; circling; precision instrument approach; missed approach; balked landing; landing. The objective of that study was to identify any incident precursors or other factors that may influence hazard scenarios encountered during airport operations, relevant to the safety margins provided by ICAO Annex 14 specifications. Overrun and undershoot incidents were of specific interest to that study, which identified a number of factors considered to be relevant to the hazards scenarios. The risk register produced during that FHA has been reviewed and an extract, summarizing factors identified as potentially relevant to overrun and undershoot incident scenarios, is presented in Attachment 1 to this appendix.

The formal process used for hazard identification was similar to that adopted in hazard and operability ("HAZOP") studies. The technique is very effective for identifying potential hazards in the aviation and other industries. The basic HAZOP technique involves gathering together a multi-disciplinary team, with the purpose of identifying hazards by brainstorming in a workshop. The key principle of the process is that it is a team effort, in which the brainstorming technique stimulates creativity, encourages expansive thinking and generates ideas.

Structure in the workshop is provided by an experienced team leader or facilitator whose role is to guide the team through the HAZOP or FHA systematically. The process is broken down into “nodes” or parts of the process to make the process manageable, and hazards are identified by the application of a set of keywords or prompts which help to ensure that the process is explored in detail and in a comprehensive way.

The FHA developed by Eddowes et al. (2001) was conducted in a 3-day workshop, and the participants provided a broad range of expertise and knowledge, including pilots, airside operations, and flight operations. Each hazard identified was classified according to its severity and likelihood. The team adjusted the classification from the original study to reflect the criteria established by FAA (1988, 2006). The FAA severity definitions and likelihood levels, in addition to a risk classification matrix, are provided in Attachment 1.

A number of more specific risk assessment studies (AEA, 1999; AEA, 2002; AEA, 2007; AEA, 2006; AEA, 2005) of runway safety provision at individual airports also have been undertaken. FHAs carried out as part of these studies have focused more specifically on the identification of factors relevant to overrun and undershoot incident scenarios. Moreover, additional information was gathered from a literature review and incorporated in this analysis. The outputs from these FHAs were reviewed, and a consolidated risk register summarizing the factors identified is presented in Attachment 2.

Finally, Attachment 3 provides a table consolidating the major factors leading to overrun and undershoot incidents, as determined from a literature review and results from previous FHAs.

Summary of Findings

A wide variety of factors that may influence overrun and undershoot risk were identified from the literature review. These are of differing significance, and it would be impractical to take detailed account of all of them in subsequent phases of the project. To facilitate the use of the data derived from the FHA, the primary points identified have been summarized.

A number of categories of factors that may be relevant to overrun and undershoot risk can be identified, as follows:

- Aircraft characteristics
- Airfield characteristics
- Weather characteristics
- Airfield system faults
- Aircraft system faults
- Pilot related issues

Within each of these different categories, a number of different factors can be identified. These are discussed further below. At this initial stage, we have not sought to determine the likely significance of these factors or identify priorities. However, Attachment 3 highlights some of the most relevant factors, as we intend to compare those factors to the ones identified from the accident/incident data.

Aircraft characteristics

- The basic performance characteristics (e.g., Accelerate-Stop Distance Required vs. Accelerate-Stop Distance Available), taking account of operating conditions (atmospheric conditions and aircraft weight)
- Use of reduced thrust on takeoff – reduced safety margin for overrun
- Safety margins applied, e.g. public service performance safety factors
- Takeoff speed
- Approach speed
- Stall speed
- Weight
- Reverse thrust availability
- Aircraft age/condition
- Operation with malfunction for which account is taken in performance calculation

Aircraft system faults

- Primary flight instruments
- Engine failure – single and multiple
- Brake system
- Landing gear
- Control surfaces
- Electrical system
- Hydraulic system
- Operation with unknown damage

Airfield characteristics

- Runway length, relative to operational requirements (ASDA vs. ASDR etc.)
- Runway surface condition – friction characteristics
- Runway surface condition – drainage characteristics
- Runway profile – hump near touchdown zone increasing landing overrun risk
- Runway dimensions – non-standard
- Altitude

Airfield system faults

- Lighting
- Instrument approach aids
- Glide slope indicator
- External agents – Bird strike, foreign object damage (FOD)

Weather characteristics

- Visibility – e.g., affecting aircraft positioning
- Precipitation (rain, hail, snow) – affecting runway surface condition or visibility
- Wind direction and strength (e.g., tailwind/crosswind)
- Variability/consistency of wind speed and direction –airport specific conditions
- Wind shear – airport specific conditions
- Bright sun light – causing pilot distraction or illusion
- Ceiling
- Temperature

Pilot-related issues

- Training/competence
- Availability and adherence to defined procedures
- Experience of airport
- Fatigue
- Communications error or misinterpretation of reported conditions
- Use of wrong runway/intersection
- Visual illusion
- "Press-on-itis"
- "Over-consideration" for comfort (i.e., the pilot's attempt to land as smooth as possible, leading to a long flare and touchdown, thus reducing the runway length available for landing roll. Flare is the landing phase when the rate of descent will be reduced by transitioning to a stall attitude.)

During the FHAs undertaken for airport operators, attention was given to the identification of measures in place that are intended to manage the overrun and undershoot risk. In many instances, measures were seen to be in place and, where these are effective, the risk associated with the factors concerned may be low and of lesser concern. However, where incidents occurred despite the potential availability of measures to manage the risks, there may be some merit in assessing what measures were in place and why these failed to provide for adequate safety.

Attachment 1 to Appendix B: Risk Register Extract from Airfield Design Study

Risk is the composite of the predicted severity and likelihood of the outcome or effect (harm) of the hazard. To assess the risk associated with a hazard, one must determine severity and likelihood. Severity is the measure of how bad the results of an event are predicted to be. One determines severity by the worst credible outcome. One does not consider likelihood when determining severity. Table B1-1 provides FAA (1988; 2006) specific definitions of severity.

Table B1 - 1 – FAA severity definitions

Hazard Severity Classification				
No Safety Effect 5	**Minor 4**	**Major 3**	**Hazardous 2**	**Catastrophic 1**
- No effect on flight crew - No effect on safety - Inconvenience	- Slight increase in flight crew workload - Slight reduction in safety margin or functional capabilities - Physical discomfort of occupants	- Significant increase in flight crew workload - Significant reduction in safety margin or functional capability - Physical distress possibly including injuries	- Large reduction in safety margin or functional capabilities - Serious or fatal injury to small number of occupants or cabin crew - Physical distress/ excessive workload	- Hull loss - Multiple fatalities

Likelihood is an expression of how often one expects an event to occur. One must consider severity in conjunction with the determination of likelihood. Likelihood is determined by how often one can expect the resulting harm to occur at the worst credible severity. Table B1-2 shows FAA likelihood definitions. A risk classification (high, medium, or low) is also provided based on the FAA risk matrix shown in Figure B1-1 and the likelihood and severity scenario for each hazard.

For developing an FHA for aircraft overrun and undershoot accidents, the identification and qualitative assessment of the risks associated with each operational phase was recorded on a "Risk Register" software tool. The completed risk register for overruns and undershoots is presented in Table B1-3. Four types of operation were identified that may lead to overrun or undershoot occurrences:

- Takeoff roll
- Rejected takeoff
- Wheels-off (0 to 35')
- Landing

It should be noted that the original study (Eddowes et al., 2001) was adapted to reflect FAA definitions of severity and likelihood, as shown in Tables B1-1, B1-2 and Figure B1-1.

Table B1 - 2 – FAA likelihood levels

	National Airspace System			**Flight Procedures**	**Operational**	
	Quantitative[1]	Qualitative				
		Individual Item/System	ATC Service/ NAS Level System[2]		Per Facility[3]	NAS-wide[4]
Frequent A	Probability of occurrence per operation is equal to or greater than $1x10^{-3}$	Expected to occur frequently for an item	Continuously experienced in the system	Probability of occurrence per operation is equal to or greater than $1x10^{-5}$	Expected to occur more than once per week	Expected to occur every 1-2 days
Probable B	Probability of occurrence per operation is less than $1x10^{-3}$, but equal to or greater than $1x10^{-5}$	Expected to occur several times in the life of an item	Expected to occur frequently in the system		Expected to occur about once every month	Expected to occur several times per month
Remote C	Probability of occurrence per operation is less than $1x10^{-5}$ but equal to or greater than $1x10^{-7}$	Expected to occur sometime in the life cycle of an item	Expected to occur several times in system life cycle	Probability of occurrence per operation is less than $1x10^{-5}$ but equal to or greater than $1x10^{-7}$	Expected to occur about once every 1 -10 years	Expected to occur about once every few months
Extremely Remote D	Probability of occurrence per operation is less than $1x10^{-7}$ but equal to or greater than $1x10^{-9}$	Unlikely but possible to occur in an item's life cycle	Unlikely but can reasonably be expected to occur in the system life cycle	Probability of occurrence per operation is less than $1x10^{-7}$ but equal to or greater than $1x10^{-9}$	Expected to occur about once every 10-100 years	Expected to occur about once every 3 years
Extremely Improbable E	Probability of occurrence per operation is less than $1x10^{-9}$	So unlikely, it can be assumed that it will not occur in an item's life cycle	Unlikely to occur, but possible in system life cycle	Probability of occurrence per operation is less than $1x10^{-9}$	Expected to occur less than once every 100 years	Expected to occur less than once every 30 years

Note: Occurrence is defined per operation (used for discreet events such as per landing, per departure, etc.)

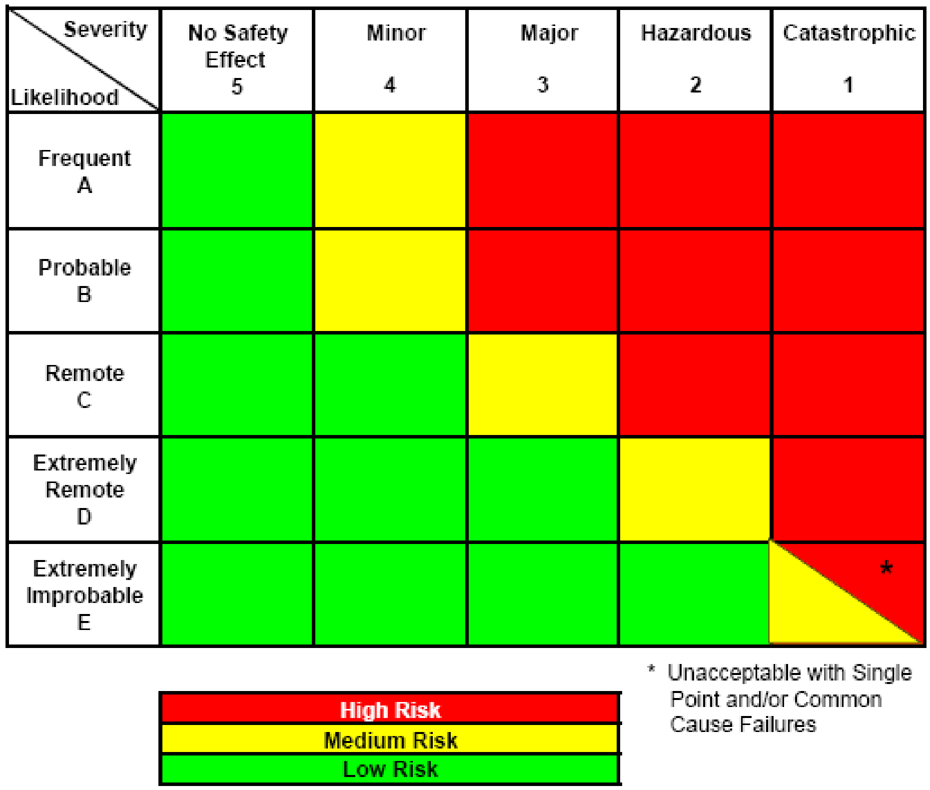

Figure B1 - 1 – FAA risk matrix (FAA, 1988; 2006)

Table B1 - 3 – Risk register table

Operation	**Threat**	**Hazard / Issue**	**Incident type**	**Likelihood**	**Severity**	**Risk Classification**	**Comments**
1		**Takeoff roll**	OR Overrun, US Undershoot				
1	1	Loss of runway lights	OR	D	2	M	
1	2	Engine Failure(s)	OR	D	2	M	
1	3	Loss of aircraft primary flight instruments	OR	E	2	L	Problems will occur during climb out. However partial loss is more probable than total loss. May lead to a rejected takeoff.
1	4	Landing gear failure	OR	C	2	H	e.g. tire blow out
1	5	Failure of flight controls	OR	D	1	H	
1	6	Communication misunderstanding (within flight crew)	OR	C	1	H	
1	7	Bright sunlight	OR	A	3	H	Reflection off surface & windscreen glare
1	8	Bird strike	OR	C	2	H	Consequences as engine failure
1	9	Heavy rain	OR	B	3	H	Mainly a problem combined with strong crosswinds
1	10	Snow	OR	A	3	H	
1	11	FOD	OR	D	1	H	

Operation	Threat	Hazard / Issue	Incident type	Likelihood	Severity	Risk Classification	Comments
1	12	Winter contaminants	OR	A	3	H	
1	13	Request from ATC to takeoff before aircraft ready	OR	B	3	H	Can lead to rejected takeoff
1	14	Too fast for abort	OR	C	1	H	
1	15	Miscalculation of take-off weight leading to takeoff roll too slow	OR	D	2	M	
1	16	Loss of takeoff roll speed due to runway surface conditions	OR	B	3	H	Reduced margin for obstacle clearance.
1	17	Takeoff with unknown aircraft exterior damage	OR	D	2	M	Consider degrees of potential damage
1	18	Use of wrong runway/ intersection	OR	D	2	M	
1	19	Variable wind direction and speed	OR	A	3	H	
1	20	Cross and tail winds	OR	A	3	H	
1	21	Inaccurate or misunderstood declared distances	OR	C	2	H	
1	22	Performance characteristics of aircraft	OR	A	3	H	Consequences of large aircraft entering a fault situation with insufficient safety margins around runway
1	23	Runway undulations	OR	C	2	H H	Could lead to premature lift-off. Structural damage to aircraft. Impact not immediate but could effect subsequent operations
1	24	Temporary surfaces during WIP	OR	C	2	H	As above
1	25	Loss of friction	OR	A	3	H	Contaminants, drainage of water
1	26	Quality of runway material	OR	B	3	H	
1	27	Newly resurfaced runway (oil from bitumen)	OR	C	3	M	
1	28	Contamination from de-icer	OR	B	3	H	
1	29	Different surface material along runway	OR	B	3	H	
2		**Rejected takeoff**	OR Overrun, US Undershoot				
2	1	Reverse thrust relatively less effective than prop	OR	A	3	H	Should be taken into account in aircraft performance graphs. For jet aircraft available margins at airfield will be not much greater than required by regulations. Veer off in conjunction with engine failure and subsequent asymmetric power. Surface conditions. For fire situation reverse thrust may lead to fanning of fire.
2	2	Impaired or brake failure	OR	D	1	H	
2	3	Loss of runway lights	OR	D	2	M	Can be initiating event and also a compounding issue leading to veer off.
2	4	Engine Failure(s)	OR	C	2	H	Initiating event. Problem of perceived

Operation	Threat	Hazard / Issue	Incident type	Likelihood	Severity	Risk Classification	Comments
							engine failure.
2	5	Landing gear failure	OR	C	2	H	e.g. tire blow-out, initiating event
2	6	Loss of hydraulic power	OR	D	1	H	Initiating event
2	7	Loss of aircraft electrical power	OR	D	2	M	Initiating event
2	8	Heavy rain	OR	B	3	H	May be a problem combined with strong crosswind
2	9	Snow	OR	A	3	H	
2	10	Too fast for reject	OR	C	1	H	
		Cross wind leading to deviation of takeoff roll	OR	A	3	H	
2	11	Notification from ATC of aircraft exterior damage	OR	D	2	M	Initiating event. Impact will be dependent on the extent of the damage.
2	12	Inadequate crew competency	OR	B	2	H	
2	13	Inaccurate or misunderstood declared distances	OR	C	2	H	
2	14	Surface contaminants/ reduced friction	OR	A	2	H	Also condition of surrounding surfaces, e.g. RESA.
2	15	High momentum/kinetic energy	OR	A	3	H	Performance tables take into account aircraft size, mass etc. Veer worse for high momentum, more stable less prone to cross winds, longer to correct, potential for overrun greater
3		**Wheels-off (0 to 35')**	OR Overrun, US Undershoot				
3	1	Engine Failure(s)	OR	D	2	M	
3	2	Loss of aircraft primary flight instruments	OR	D	2	M	Problems will occur during climb out. Partial failure is more probable than total loss
3	3	Failure of flight controls	OR	D	1	H	
3	4	Loss of takeoff roll speed due to runway surface conditions	OR	B	3	H	Reduced margin for obstacle clearance.
3	5	Takeoff with unknown aircraft exterior damage	OR	D	2	M	Consider degrees of potential damage
3	6	Use of wrong runway/ intersection	OR	D	2	M	May lead to reduced obstacle margins, if any
3	7	Inaccurate or misunderstood declared distances	OR	C	2	H	
3	8	Runway undulations	OR	C	2	H	Could lead to premature lift-off. Structural damage to aircraft. Impact not immediate but could effect subsequent operations
4		**Landing**	OR Overrun, US Undershoot				
4	1	High momentum/kinetic energy	OR	A	3	H	Relative to normal approach speed and landing mass for each aircraft type
4	2	Low momentum/kinetic energy	US	A	3	H	Inverse of above
4	3	Stall speed	US	A	3	H	Higher stall speed increased height loss
4	4	Incorrect flaring (leading to	US	C	2	H	

Operation	Threat	Hazard / Issue	Incident type	Likelihood	Severity	Risk Classification	Comments
		aircraft damage)					
4	5	Failure/maintenance of visual glide slope indication	US	D	3	L	Worse case is incorrect indication.
4	6	Failure of ILS	US	D	4	L	Safety impact based on loss of ILS after missed approach point.
4	7	Wind shear	US, OR	A	2	H	Copy H to normal
4	8	Loss of aircraft flaps	OR	B	2	H	Approx 1 in 20,000 movements.
4	9	Aircraft without reverse thrust	OR	A	3	H	Combined with loss of friction on runway
4	10	Partial loss of brakes	OR	C	2	H	
4	11	Total loss of brakes	OR	D	1	H	
4	12	Accuracy of promulgated information from ATC	US, OR	A	2	H	Safety impact will depend on aircraft type
4	13	Landing in darkness with runway lighting failure	US, OR	D	3	L	
4	14	Too fast for landing	OR	B	3	H	Caused by misjudgment, unexpected tail wind, steep approach
4	15	Too slow for landing	US	C	1	H	Caused by misjudgment, unexpected head wind
4	16	Snow, ice, rain or other contaminants leading to reduced runway friction	OR	C	2	H	
		Cross winds	OR	C	2	H	Loss of control may delay thrust reverse and braking action to regain control
4	17	Icing of control surfaces	US, OR	C	3	M	
4	18	Tail winds	OR	C	4	L	Should be accounted for in performance calculations. More common when can only make ILS approach from one direction. Up to 5knots frequent - large effort to redirect traffic to opposite end of runway. Safety impact on 5 knot tailwind, see also "too high speed".
4	19	Variable wind direction and speed	US, OR	C	3	M	

Attachment 2 to Appendix B: Summary of Outputs from Airport Specific Runway End Safety Studies

Table B2-1 presents a summary of specific FHAs conducted in support of aeronautical studies addressing the provision of RSAs (AEA, 1999; AEA, 2002; AEA, 2007; AEA, 2006; AEA, 2005). Three operational phases were evaluated during those studies:

1. Takeoff – before aircraft is airborne
2. Landing – approach
3. Landing – touchdown

For each operational phase, the hazards were classified according to the categories relevant to each phase: weather, aircraft condition, runway condition, aircraft malfunction, pilot error, and other.

Table B2 - 1 – Summary of FHA outputs

Causes	Consequences	Comments
Operation: 1 Takeoff – before aircraft is airborne		
Weather		
Cross wind	Control problems	Typically takeoff is suspended if winds are too high but if winds are variable, takeoff may already be underway. Limits are set by operators and include factors of safety. More likely to be result in lateral veer-off than overrun and more likely an issue on landing than takeoff.
Tail wind	Increased possibility of overrun.	Tail wind is heavily factored into performance calculations. Some airports adopt noise mitigation policies with preferential use of one runway up to an identified tail wind limit. Some airports are particularly susceptible to variable winds (e.g., due to local topography) and wind speed measurements at one location may not necessarily be representative of conditions experienced by aircraft.
Low visibility.	Loss of visual reference	Likelihood limited by visibility limits given for runways with and without centre line lighting. More likely to result in lateral veer-off than overrun.
Rain	Wet runway increasing braking distances.	Relevant in event of aborted takeoff. More critical for runway limited aircraft. Performance calculations intended to maintain acceptable braking distance. Runway conditions are typically regularly inspected and accurately reported (potential for human error and sudden environmental changes).

Causes	Consequences	Comments
		May apply also to other weather related contaminants – e.g., hail snow.
Operation: 1 Takeoff – before aircraft is airborne		
Aircraft Condition		
Variable handling characteristics	Failure to effect rapid braking	Potentially more significant at airports with shorter runway length. Crew awareness of characteristics should mitigate this risk to some extent.
Old aircraft may have less effective brakes	Reduced braking effect – longer runway distance needed.	Crew awareness is a mitigating factor as above.
Long taxi to start of takeoff	Brakes over-heated	Applies to steel but not carbon brakes.
Modern regional jets replacing propeller aircraft	More runway critical aircraft movements	A potentially significant concern at shorter runways at least. Aircraft design characteristics are expanding into airfield limit, leading to increased overrun risk. Operations should still be carried out within normal minimum safety limits but reduced additional margin.
Operation: 1 Takeoff – before aircraft is airborne		
Runway Condition		
Poor runway drainage	Aircraft operates in contaminated situation	Mitigated by runway inspections and reporting of runway state. Runway surface condition may influence drainage efficiency and friction (e.g., grooved concrete surface).
Water drainage impaired by wind		Some runways may be susceptible to accumulation of rainwater when cross wind prevents drainage.
Water based contaminants (snow, slush, ice, standing water over 3mm)	Aquaplaning	Mitigated by runway inspections and reporting of runway state. Takeoff recommended not to be performed in contaminated conditions (in accordance with performance tables).
	Increased drag on takeoff	As for aquaplaning
Operation: 1 Takeoff – before aircraft is airborne		
Aircraft Malfunction		
Multiple engine failure	Aborted takeoff	Mitigated by pre-flight checks
Bird strike or other ingestion		Mitigated by effective bird control measures
		Mitigated by runway surface inspections and sweeping
Control restriction	Aborted takeoff	Mitigated by pre-flight checks
Brake failure	Failure to stop on aborted takeoff	Mitigated by pre-flight checks
Burst tire	Aborted takeoff	
Errors in ground handling	Aborted takeoff	Misloading / wrong fuel / doors or flaps not closed.

Causes	Consequences	Comments
Engine failure on a single engine aircraft	Pilot must land immediately.	Most multi-engine aircraft would continue with takeoff but some, not using public transport performance safety factors, may have difficulties.
Operation: 1 Takeoff - before aircraft is airborne		
Pilot Error		
Aircraft still on runway when it should be airborne. Late take off abort.	Overrun	Should be addressed by training/use of standard operating procedures. Pilot experience and awareness of (or lack of) local conditions is a potential risk factor.
Unauthorized runway incursion	Aborted takeoff	Mitigated by ATC visual monitoring of ground movement and read-backs from aircraft.
Ground movement intrudes runway	Aborted takeoff	Mitigated by effective ground movement control. Driver training.
Operation: 1 Takeoff - before aircraft is airborne		
Other		
Reduce thrust on takeoff	Reduced safety margin for overrun	Where there is runway length available in excess of the nominal minimum requirement, some operators employ reduced thrust so as to operate with a balanced takeoff field length in which the takeoff distance required and accelerate stop distance required are essentially equivalent and matched to the available runway. This reduces wear and tear and thus enhances aircraft life. Accordingly, aircraft will routinely use a greater percentage of the runway length than the minimum necessary, which has implications for takeoff overrun risk.
Operation: 2 Landing - approach		
Weather		
Low visibility/cloud base (on minima)	Aircraft approach may be incorrect and arrive at the wrong place and the wrong height/speed	Mitigation by adhering to the correct descent profile and procedures (Missed Approach Procedures (MAP) if needed, stabilized approach criteria)
Strong wind/wind shear	Aircraft groundspeed affected. Undershoot or overshoot. Stall warning device triggered causing distraction to pilot and corrective action (which may compound difficulties)	Should be accommodated to some extent by approach procedures for high winds (increased approach speed) supported by wind sheer warnings. Use of increased approach speed to accommodate wind sheer (to reduce undershoot risk) may increase overrun risk. Some airports have specific wind sheer problems due to local topography or large buildings on approach. Variability of wind strength on approach may be a specific problem at some airports due to local topography.
Locally heavy rain/sleet/snow (sudden visibility reduction) or other local	Distractions impeding pilot skill and accurate flying of approach.	

Causes	Consequences	Comments
variations in visibility.		

Causes	Consequences	Comments
Operation: 2 Landing - approach		
Aircraft Malfunction		
Primary instrument failure	Inadvertent departure from course	Incorrect positioning may lead to undershoot or overrun if approach is continued – pilot should elect to go-around if correct position cannot be confirmed.
Operation: 2 Landing - approach		
Pilot error		
Pilot distraction caused by close-in moving and large obstacles	Potential loss of concentration and slight over-control	Obstacles illustrated on airport chart
Operation: 3 Landing - touchdown		
Weather		
Issues here have been adequately covered in takeoff (low visibility not an issue as landing will not take place)		
Operation: 3 Landing - touchdown		
Aircraft Condition		
Aircraft carrying a malfunction	Safety margin eroded by accepting gross performance factored by a factor depending on the malfunction status	Although this is infrequent it may present a relatively high risk of overrun if it occurs, according to type of malfunction. Very infrequent opportunity for this to happen.
Modern regional jets replacing propeller aircraft	More runway critical aircraft movements	Should be addressed by performance calculations – see discussion of this factor under takeoff.
Operation: 3 Landing - touchdown		
Runway Condition		
See takeoff risk log where same hazards apply		
Runway profile	Landing long / overrun	Where there is a significant "hump" part way along the runway (near the touchdown zone) such that there is an up slope followed by a down slope somewhat in excess of the published down slope this can increase overrun risk. Such a hump is at a relatively critical point from the perspective of landing long. In the event that an aircraft lands slightly long, beyond the high point of the hump where there is a down slope, the pilot will be attempting to touch down in an area where the runway is falling away. The down slope in this critical area will tend to increase the extent to which an aircraft lands long and hence increase the extent of any overrun beyond the expected or anticipated stopping point.
Operation: 3 Landing - touchdown		
Aircraft Malfunction		
Failure of brakes or reverse thrust	Potential over-run or veer off	Redundancy system inbuilt

Causes	Consequences	Comments
Control failure	As above	Asymmetric braking could affect overall braking ability
Burst tire	As above	Runway swept to prevent tire damage on landing
Operation: 3 Landing - touchdown		
Pilot Error		
Landing long	Not leaving enough runway to stop	It is usual for more than one of these five factors (see below) to contribute and combine in the landing. This will be compounded by runway critical aircraft movements. Training/experience/awareness Performance factorization built in to compensate for routine pilot variances and local conditions
Landing fast	Requires longer stopping distance (may not be available)	As above
Landing low	May lead to overcompensation - see above long/fast	
Landing short	Damage to aircraft	As above If airport has an arrester bed and aircraft lands on it serious damage may result.
Landing heavily	May result in aircraft damage giving control problems and loss of stopping facilities	As above
Fatigue	Increased risk of error	
Runway dimensions	Pilot observes a false perspective	Non-standard dimensions, may give appearance that runway is further away or closer – pilot awareness and experience may mitigate this risk.

Attachment 3 to Appendix B: Summary of Most Important Factors Leading to Overrun and Undershoot Accidents

The following summary the factors leading to overrun and undershoot accidents was identified based on FHA studies and on a literature review conducted. Most of the factors listed were identified in the previously referenced studies by Eddowes et al., but some were added based on available reports from other sources.

Table B3 - 1 – Summary of factors causing or contributing to aircraft overrun and undershoot occurrences

Event	Category	Factor [1]
Landing Overrun	Weather	Tail Wind
		Cross Wind
		Wind variations (gusts, shear)
		Visibility
		Ceiling
		Temperature
	Airfield	Surface contaminants and friction (water, snow, ice, rubber deposits)
		Landing Distance Available (LDA)
		Slopes (longitudinal and transverse)
		Altitude
		Runway profile
		System faults
	Pilot	Landing long
		Unstabilized approach
		Landing fast
		High threshold crossing height
		“Press-on-it is”
		Incorrect (delay) application of thrust reverse (if available) and spoilers
		Incorrect (delay) application of brakes
		Delayed nose-wheel lowering
		‘Over-consideration’ for comfort

Event	Category	Factor [1]
		Incorrect interpretation of reported operation conditions
		Landing on the wrong runway
	Aircraft	Landing Distance Required (LDR)
		Weight
		System faults (e.g. brake systems failure)
Takeoff Overrun	Weather	Tail Wind
		Wind variations (gusts, shear
		Cross wind
		Temperature
	Airfield	Accelerate-Stop Distance Available (ASDA)
		Surface contaminants and friction (water, snow, ice, rubber deposits) in case of aborted takeoff
		Slopes (longitudinal and transverse) in case of aborted takeoff
		Altitude
	Pilot	Delay to abort takeoff when required
		Incorrect (delay) application of thrust reverse (if available) and spoilers, in case takeoff is aborted
		Incorrect (delay) application of brakes, in case takeoff is aborted
		Incorrect interpretation of reported operation conditions
		Selection of wrong runway
	Aircraft	System or component malfunction require to abort takeoff
		Accelerate-Stop Distance Required (ASDR)

Event	Category	Factor [1]
Landing Undershoot	Weather	Visibility
		Ceiling
		Wind variations (gusts, shear)
		Temperature
		Crosswind
	Airfield	System faults
		Availability of navigational aids
		Altitude
	Pilot	Approach too low
		Attempt to land too close to arrival end of the runway
		Misinterpretation of approach procedures
		Visual illusion resulting incorrect pilot response
	Aircraft	System faults
		Stall speed
		Approach speed

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Appendix C – Key Accident/Incident Database Sources

A comprehensive database of aircraft overrun and undershoot accidents and incidents was created in support of risk models developed. The information was gathered from a number of agencies and organizations, in the United States and abroad. These events occurred since 1979 and the information has been organized in Microsoft Access format to facilitate the use.

This appendix summarizes the information for the most important sources of accident and incident data used for this project.

Table C - 1 - National Transportation Safety Board

	NTSB – National Transportation Safety Board
Country	USA/National Transportation Safety Board (NTSB)
Type	Mandatory
Events	Accidents and Incidents
Objective	NTSB is a Federal Agency charged by Congress with investigating transportation accidents in the United States, including every civil aviation accident. The accident reports normally describe the probable cause and NTSB issues safety recommendations for prevention of future accidents.
Description	The database is the official repository of US aviation accident data and causal factors. Each event is classified as an accident or incident. Accidents are defined as occurrences in which any person suffers death or serious injury, or which the aircraft receives substantial damage. It also defines incidents as occurrences other than an accident, which could affect the safety of operations. To date, approximately 131,000 occurrences were available.
Source of Data	Data is based on pilot accident reports (Form 6120.1) and on investigation reports that are entered in a computer-based system. A final report describing the probable cause is completed, in some cases several months after the accident. In addition, an accident investigation docket is maintained for each accident and is used to establish the permanent record of an accident. The dockets for very recent accidents may be available in the internet but in most cases the information is only available at the NTSB Records Management Division in the Public Reference Room, or from a NTSB contractor (General Microfilm Inc. (GMI)). Due to size and performance limitations, only selected Factual Reports and attachments are available online. Preliminary reports contain only a few data elements (date, location, aircraft operator, type of aircraft, etc.). Basic data may be queried and retrieved from the NTSB website. NTSB Public Dockets contain: preliminary report, hearing documents, IIC factual reports, group chair factual reports, studies by board staff, board reports, supporting material. The latter one includes pilot/operator aircraft reports, witness statements or records of

	NTSB – National Transportation Safety Board
	interviews, maps/charts, excerpts from manuals, weather reports, transcripts of radio communications, statements of party representatives, reports from other federal agencies, reports from state or local agencies, submissions or correspondence from parties to the investigations, Flight Data Recorder (FDR) data, Cockpit Voice Recorder (CVR) transcript, release of wreckage form, toxicology reports, transcripts from earings/depositions, petitions for reconsideration, related safety recommendations and/or safety studies drawings (e.g., engineering sketches), photographs pertinent to the accident, data files, other materials (flight plans, fueling records, load manifests, etc.).

Table C - 2 - Accident/Incident Data System

AIDS – Accident/Incident Data System	
Country/Org.	USA – Federal Aviation Administration (FAA)
Type	Mandatory
Events	Accidents and Incidents
Objective	The Accident/Incident Data System (AIDS) database contains accident and incident data for all categories of civil aviation. The difference between AIDS and NTSB databases is that the information available is to support FAA's responsibilities, including promulgation and enforcement of Federal Aviation Regulations for certifying aircraft airworthiness, airmen and air carriers for competency, and airports.
Description	FAA issues a separate report for each aircraft involved in an aviation accident or incident. The AIDS database contains data records for general aviation and commercial air carrier incidents since 1978. AIDS is integrated in FAA's Aviation Safety Information Analysis and Sharing (ASIAS) system.
Source of Data	The information contained in AIDS is gathered from several sources including incident reports on FAA Form 8020-5. It includes accident investigations of civil aircraft in accordance with Title 49 United States Code.

Table C - 3 - Aviation Safety Reporting System

Aviation Safety Reporting System (ASRS)	
Country	US – Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA)
Type	Voluntary and Confidential
Events	Incidents (basically)
Objective	ASRS is a voluntary, confidential and non-punitive incident reporting system. It collects, analyzes, and issues alerts and other information about voluntarily submitted aviation safety reports. The data is used

Aviation Safety Reporting System (ASRS)	
	to identify deficiencies and discrepancies, and to support policy formulation and planning.
Description	ASRS is a cooperative program funded by the FAA and administered by NASA. Information collected by the ASRS is used to identify deficiencies and discrepancies in the National Aviation System and enhance the basis for human factors research and recommendations for future operations. The program protects the identity of the reporter and all other parties involved in an occurrence. The ASRS program was established in 1976 and its database on the ASIAS portal contains to date approximately 133,000 reports, starting in 1988.
Source of Data	Pilots, air traffic controllers, flight attendants, maintenance technicians, ground personnel, and others involved in aviation operations can submit reports to the ASRS when they are involved in, or observe, an incident or situation in which they believe aviation safety was compromised.

Table C - 4 - Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile

Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA)	
Country	France
Type	Mandatory
Events	Accidents and Incidents
Objective	Technical investigations on aviation accidents and incidents which occur on the French territory and is aimed at improving civil aviation safety. The investigations have the purpose of identifying the circumstances of the event, determining the causes and developing recommendations to prevent similar occurrences. An EU directive forbids that the investigations aim to apportion blame or liability to persons and companies involved.
Description	The database is based on the European Coordination Center for Aviation Incident Reporting Systems (ECCAIRS) system and on ADREP 2000 taxonomy to facilitate exchange of information for ICAO ADREP reports and sharing with other organizations using the same software. Accident/incident reports are available in the BEA website, from 1968 and on.
Source of Data	BEA investigators are responsible for filling the database upon reception of an aviation incident or accident notification. The preliminary record contains factual data and is complemented as the investigation is carried out. The ECCAIRS database was implemented in 2004 and contains 15000 events covering the last 30 years, most converted from the former database that included occurrences from the eighties to 2003.

Table C - 5 - Australian Transport Safety Bureau

Australian Transport Safety Bureau (ATSB)	
Country	Australia – Department of Transport and Regional Services
Type	Mandatory
Events	Accidents and Incidents
Objective	ATSB is an operationally independent body within the Australian Government Department of Transport and Regional Services and is Australia's prime agency for transport safety investigations. The bureau is entirely separate from transport regulators and service providers. Its mission is to maintain and improve transport safety and public confidence through (1) independent investigation of transport accidents and other safety occurrences, (2) safety data recording, analysis and research; and (3) raising safety awareness and knowledge. It is not the purpose of ATSB investigations to lay blame or provide a means for determining liability.
Description	The ATSB is responsible for the independent investigation of accidents and incidents involving civil aircraft in Australia. All accidents and incidents related to flight safety in Australia or by Australian registered aircraft overseas must be reported to the ATSB. While the ATSB does not investigate all of these, it still needs to be notified so that the data can be recorded for possible future safety analysis. The ATSB maintains its own database (Occurrence Analysis and Safety Information System) in which all reported occurrences are recorded. As of March 2007, a total of 868 accident and incident reports were available in the ATSB website.
Source of Data	Occurrences that are classified as Immediately Reportable Matters – IRM (accidents & serious incidents) and Routine Reportable Matters – RRM (incidents) are evaluated by ATSB. From these initial reports ATSB makes a decision on whether or not to investigate. The decision is based on factors such as safety value to be obtained from the investigation and where resources may best be targeted. IRM and RRM are reported by crew members; owner or operator of the aircraft; air traffic control personnel; airfield rescue or fire fighting service members; aircraft maintenance engineers; ground handling crew; staff of the Civil Aviation Safety Authority; and airport operators.

Table C - 6 - Canadian Transportation Safety Board

Canadian Transportation Safety Board (TSB)	
Country	Canada
Type	Mandatory
Events	Accidents and Incidents
Objective	The Transportation Safety Board of Canada (TSB) is an independent agency created to improve transportation safety through the investigation of occurrences in the marine, pipeline, rail and air modes of transportation. Investigations are conducted by TSB staff located in various regional and field offices across Canada.
Description	The Transportation Safety Board (TSB) of Canada is similar to NTSB in the United States. TSB is a federal agency that operates independently of Transport Canada Civil Aviation. Its mandate is to advance safety by conducting independent investigations; identifying safety deficiencies; making recommendations; and reporting publicly on their investigations and findings. Under its mandate to conduct investigations, TSB conducts safety-issue-related investigations and studies. It also maintains a mandatory incident-reporting system for all modes of transportation. TSB and Transport Canada Civil Aviation use the statistics derived from this information to track potential safety concerns in Canada's transportation system. Canada legislation requires mandatory reporting for all aviation accidents and for many incidents involving aircraft with a weight greater than 5700 kg. Safety information is also collected for non-reportable incidents. Occurrence information is entered into the database and verified by aviation safety investigators and by other staff. The database contains more than 38000 records from 1976 to the present.
Source of Data	TSB investigation reports. In accordance with the TSB Regulations, reportable accidents or incidents must be reported to the Board as soon as possible and by the quickest means available. When a reportable aviation accident or incident takes place, the owner, operator, pilot-in-command, any crew member of the aircraft and, where the accident or incident involves a loss of separation or a risk of collision, any air traffic controller having direct knowledge of the accident or incident shall report to the Board as is available.

Table C - 7 - ICAO Accident/Incident Data Reporting

ICAO Accident/Incident Data Reporting (ADREP) system	
Country	International
Type	Mandatory
Events	Accidents and Serious Incidents
Objective	According to ICAO Annex 13 aircraft accident investigations should

ICAO Accident/Incident Data Reporting (ADREP) system	
	be conducted by the state of occurrence, though this state may delegate the investigation to the state of registry or the state of operator. ICAO recommends that serious incidents also be investigated. The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents.
Description	The ICAO offers a standard report format, which has been adopted by ICAO member states throughout the world. Member states are urged to submit information for inclusion in the ICAO Accident/Incident Reporting (ADREP) database using a standard report format. One of the problems associated with access to accident/incident investigation reports is the fact that there is no easily accessible central report repository. The ICAO office in Montreal has copies of many reports, but is unable to share this information with member states or the public. Access to reports is still limited to sending individual requests to the investigation authority that investigated the accident.
Source of Data	Final and preliminary reports, on accidents/incidents of aircraft in excess of 2500kg MTOW, submitted by member states. Information regarding the results of the investigation is usually made available by the (air) accident investigation authority of a country or any other party in charge of the investigation in the form of a preliminary and/or final report.

Table C - 8 - UK Air Accidents Investigation Branch

UK Air Accidents Investigation Branch (AAIB)	
Country	UK
Type	Mandatory
Events	Accidents and Serious Incidents
Objective	The objective of AAIB is to investigate accidents and to determine the circumstances and causes of the accident with a view to the preservation of life and the avoidance of accidents in the future; it is not intended to apportion blame or liability.
Description	The UK Air Accidents Investigation Branch (AAIB) is part of the Department for Transport and is responsible for the investigation of civil aircraft accidents and serious incidents within the UK. Approximately 3000 events with fixed wing aircraft were available in the website, from 1980 and on.
Source of Data	Investigation reports contain facts which have been determined up to the time of publication. This information is published to inform the aviation industry and the public of the general circumstances of accidents and serious incidents. Extracts can be published without specific permission providing the source is duly acknowledged.

Appendix D – Analysis of Unreported Incidents

Landing Overrun Analysis

The analysis was based on a total data set of 240 events, comprising 119 accidents and 121 incidents. In the first instance, least squares regression analysis was employed to determine a fit for the whole data set, as shown in Figure D-1.

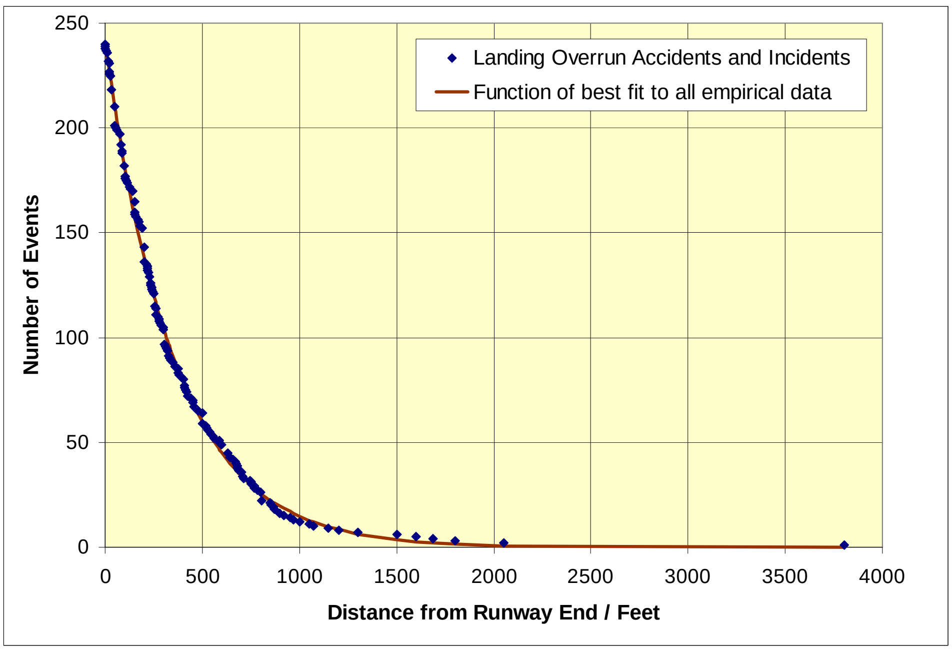


Figure D - 1: Empirical landing overrun data and fitted distribution function

This curve was then evaluated by inspection to determine if any systematic deviation from the line of best fit was exhibited by the empirical data. The line of best fit to the exponential function gave a good correlation coefficient (>0.997) and an intercept of 240.1, in good agreement with the number of events in the empirical dataset. No systematic deviation at low values of x, as would be indicative of under-reporting, was evident. The empirical data appears to be systematically above the line of best fit over the distance range of 375 to 700 ft and systematically below it over the distance range of 800 to 1200 ft. This systematic deviation would be consistent with an increased number of events being arrested early due to obstacles in the 375 to 700 ft and therefore failing to travel to the range of 800 to 1200 ft that might have occurred in the absence of obstacles.

Subsets of data starting from selected values of x greater were then analysed. Initially, data sets starting at 25 ft intervals from 100 ft to 200 ft were selected. Compared with the complete data set, each of these data sets gave intercepts greater than 240, indicative of the under-reporting phenomenon. The coefficients giving the best fit to the exponential function for each of the data sets are presented in Table D-1.

Table D - 1 - Landing overrun: coefficients for exponential functions

	a	b	n
Full data set	240.10	0.00263	1.00862
x ≥ 100 ft	249.30	0.003406	0.97195
x ≥ 125 ft	275.85	0.006066	0.89098
x ≥ 150 ft	281.30	0.006708	0.87696
x ≥ 175 ft	284.50	0.007078	0.86959
x ≥ 200 ft	252.50	0.003986	0.94833

The extent to which the intercept exceeds the value determined for the complete empirical data set increases at first with increasing starting x value. This behaviour is as expected where there is under-reporting since, with increasing x a reducing proportion of the data set will be subject to significant under-reporting. The fitted functions should therefore become less influenced by under-reporting with increasing starting x value. However, for data sets starting at higher values of x the functions are derived on the basis of a reduced amount of the data that is representative of the true overrun behaviour at low values of x. The extrapolated functions can be expected to be less reliable as smaller and smaller data sets starting at higher values of x are selected. In accordance with the expected behaviour, the intercept increases to a maximum of 284.5 for the data set with x ≥ 175 ft and then falls off significantly for the data set with x ≥ 200 ft.

On the basis of the above analysis, it would appear that the maximum value of intercept will be found for a data set starting in the range 150 to 175 ft. Data sets were selected in this interval and fitted to the exponential function. For the data set with x ≥ 170 ft an intercept of 288.5 was determined and for the data set with x ≥ 160 ft an intercept of 285 was determined. The optimum function based on this analysis is of the form a exp (- b xn) where a = 288.5, b = 0.007536, n = 0.8610. This function is shown in Figure D-2 against the empirical data set. This shows the deviation of the theoretical curve from the empirical data set at lower values of x.

According to the assumptions of the methodology, this is the function that will be least influenced by under-reporting at low values of x but derived on the basis of the sufficient data at reasonably low x values to be representative of overrun incident behavior at low values of x. The number of events expected to have occurred according to the analysis is 288.5, compared with a total of 240 events and of 121 incidents. This would correspond with 48 to 49 unreported incidents, corresponding with approximately 17% of the total events and 29% of incidents. The analysis indicates that under-reporting becomes increasingly important distances below 175 ft.

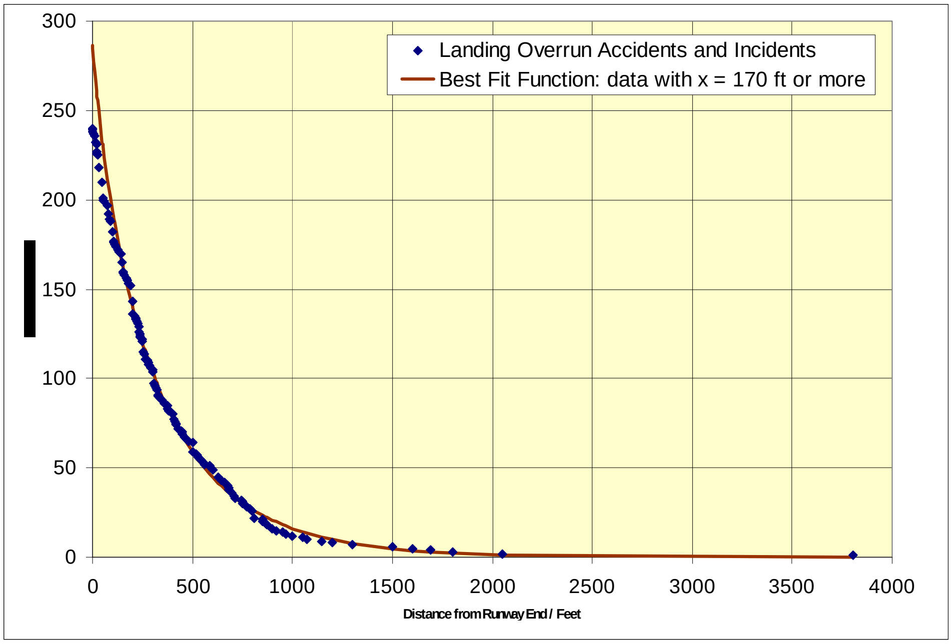


Figure D - 2 - Best fit function for selected landing overrun data set

A separate analysis has been undertaken of the US data and this gave essentially similar results. The US data set comprises 178 events. Application of the methodology as applied to the complete data set above gave the exponential coefficients presented in Table D-2. The intercept increases as the starting x value is increased from 100 ft to 150 ft and then falls.

Table D - 2 - Landing overrun us dataset: coefficients for exponential functions

	a	b	n
Full data set	181.86	0.005940	0.88856
x ≥ 100 ft	190.67	0.007935	0.84711
x ≥ 125 ft	227.75	0.017159	0.74172
x ≥ 150 ft	250.10	0.023942	0.69707
x ≥ 175 ft	213.63	0.013703	0.77148
x ≥ 200 ft	178.50	0.006388	0.87461

The best fit function for the data set with x ≥ 150 ft is shown in Figure D-3.

The under-reporting rate indicated by the analysis of the US data is higher than that indicated by the analysis of the complete data set. The analysis indicated 250 events from the best fit intercept compared with 178 events in the empirical data set, indicating an under-reporting rate of 28.8%.

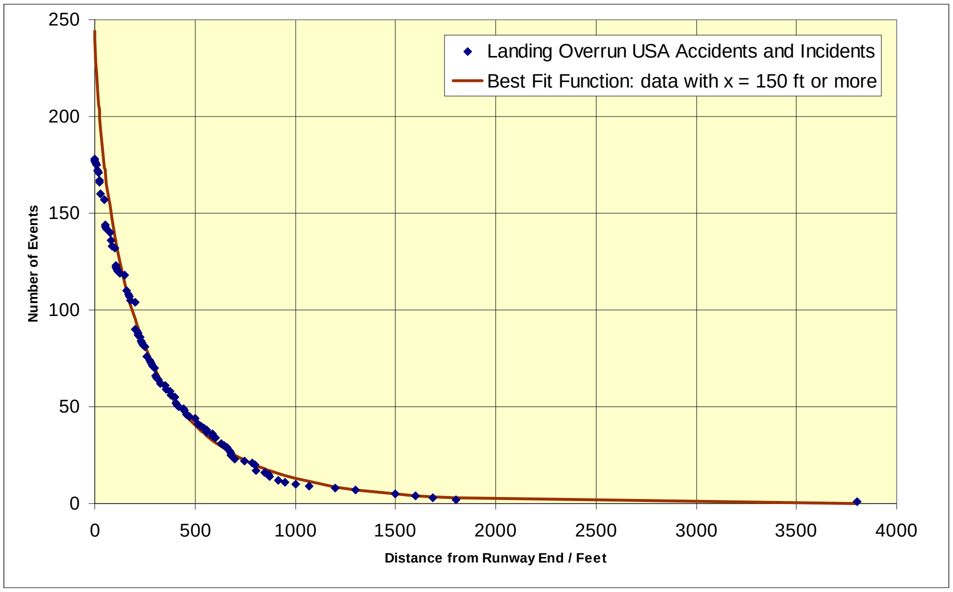


Figure D - 3 - Best fit function for US landing overrun data set, x ≥ 150 ft

There is a potential risk when using the sort of approach adopted, in particular when using a three parameter function, that the best fit function might be dominated by the empirical behavior at more extreme values of the total range that is not necessarily representative of the region of interest at relatively small distances. In order to confirm that the extrapolated function was not adversely influenced in this manner, the methodology was applied using data from a restricted range ending with a maximum value of x = 677 ft. The values for the intercept that were determined using these data sets were generally consistent with those that had been determined using the data sets out to the maximum x value. It can therefore be concluded that the extrapolated intercepts are not artifacts driven by the constraint of fitting the exponential function across a large range of distances.

Take-off Overrun Analysis

A similar type of analysis was undertaken of the take-off overrun data. The take-off overrun data from the available data set of 75 events is shown in Figure D-4. Coefficients for the exponential functions determined by application of the methodology for data sets starting at between 75 ft and 175 ft at 25 ft intervals are shown in Table D-3.

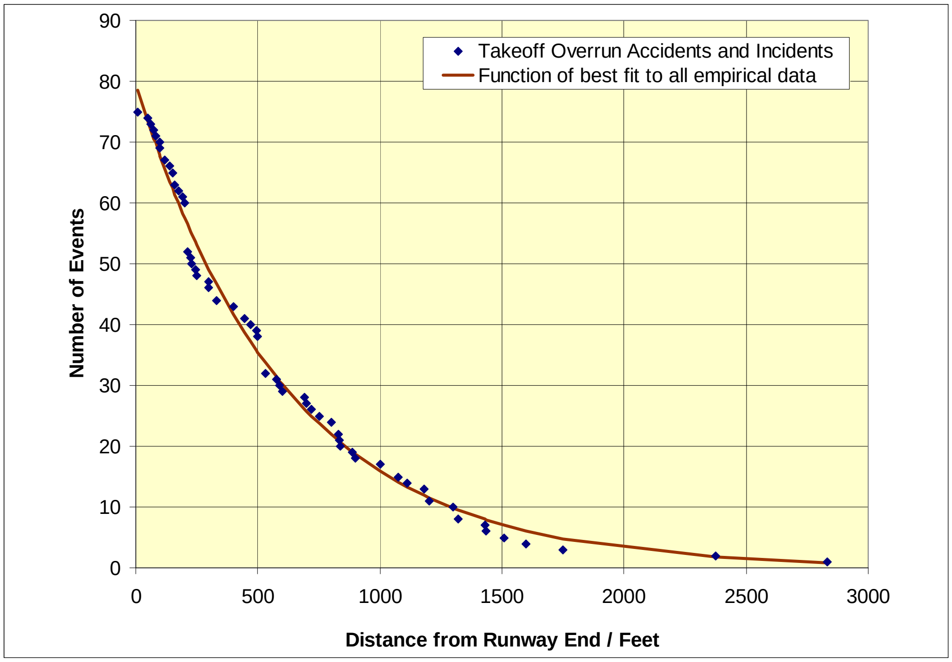


Figure D - 4 - Empirical take-off overrun data and fitted distribution function

Table D - 3 - Take-off Overrun: Coefficients for exponential functions

	a	b	n
Full data set	79.83	0.001693	0.9931
x ≥ 75 ft	82.96	0.002580	0.9348
x ≥ 100 ft	81.54	0.002223	0.9549
x ≥ 125 ft	79.00	0.001680	0.9927
x ≥ 150 ft	77.24	0.001400	1.0167
x ≥ 175 ft	71.02	0.000647	1.1208

Compared with the landing overrun data set, the take-off overrun data does not fit as well to a smooth curve and the reliability of the methodology is therefore less certain. For data sets starting between 75 ft and 150 ft, application of the methodology gives intercepts essentially consistent with that for the full data set: all intercepts are in the range 77 to 83, compared with the number of events in the data set which is 75. For data sets starting at 175 ft and 200 ft lower intercepts were determined. There is therefore some indication of under-reporting but this is relatively minor compared with that indicated for landing overrun, amounting to 9.6% based on the maximum value of the intercept of 83.

A lower rate of under-reporting of take-off overruns compared with landing overruns is perhaps not surprising, given the different contexts of the two scenarios. In the case of a landing overrun incident traveling a relatively short distance beyond the declared landing distance available, the basic objective of landing the aircraft safely may have been achieved, if not within the nominally intended distance. In the case of a takeoff overrun, the basic objective of take-off will not have been achieved and there may therefore be a greater tendency to recognize this as an incident than in the case of a landing overrun. Previous assessment has also suggested that pilot error rather than some event outside the pilot's control is a more significant contributor to the incidence of landing overrun compared to take-off overrun and this would also be consistent with a lower rate of under-reporting for take-off overruns.

Landing Undershoot Analysis

The methodology was applied to the available data set of 81 landing undershoots. An increasing intercept was determined for data sets starting at increasing values of x at 25 ft intervals from 100 ft to 150 ft, indicative of under-reporting. Coefficients for the exponential functions are shown in Table D-4 and the cumulative probability distribution is shown in Figure 4.

Table D - 4 - Undershoot: Coefficients for exponential functions

	a	**b**	**n**
Full data set	96.04	0.05079	0.54767
$x \geq 100$ ft	120.17	0.116356	0.43755
$x \geq 125$ ft	111.67	0.098412	0.45726
$x \geq 150$ ft	136.10	0.146397	0.41188

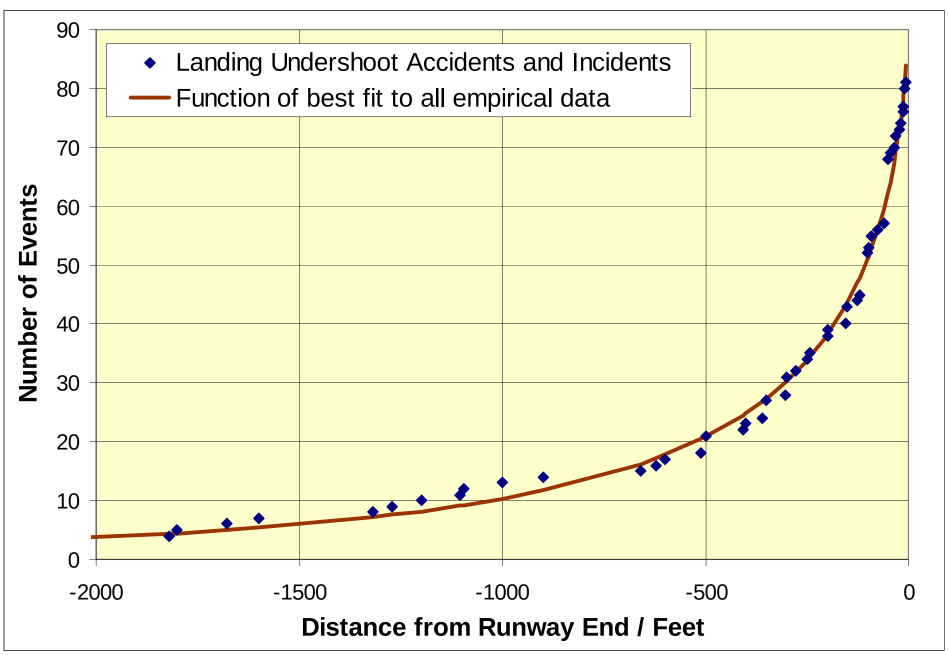


Figure D - 5 - Empirical takeoff undershoot data and fitted distribution function

Like the take-off overrun data, the undershoot data do not fit as well to a smooth curve and the reliability of the methodology is therefore less certain. For the data set starting at 175 ft a function with a very considerably greater intercept was determined that gave a reasonable r squared correlation. The best fit to the three parameter function was determined using the solver facility in excel to maximize the r squared value. However, the value to which the intercept converged was found to be dependent on the initial seeded value of the intercept and the solver did not reliably converge to a single solution and solutions with very similar r squared values were determined for functions with a fairly wide range of intercepts.

A larger and more coherent data set, such as that available for landing overrun, is evidently required in order for the methodology to give reliable results. In this case, the use of the three parameter function leads to extrapolation to unreliable and unrealistic intercepts in an attempt to fit the available data over an extended range of distances. Rather than being representative of the extrapolation of behavior in the region of primary interest at relatively low values of x, the function may be dominated by behavior over other parts of the data range.

Whereas the data would appear to be indicative of under reporting of a similar extent to that observed for landing overrun the inherent uncertainty in the methodology when applied to the available data set is such that the level of under-reporting cannot be estimated with any precision. It was therefore necessary to assume underreporting for landing undershoots is similar to that for landing overruns. The assumption causes no impact or differences to the location model for larger distances as the effect to the models is only important for the smaller undershoot distances.

Appendix E – List of Accidents for Model Development

The following table includes the accidents and incidents relevant for developing the risk models developed in this study. The events listed are those where the aircraft final wreckage location (overruns and undershoots) or the point of first impact (undershoots) are located within a 2000ft distance from the runway threshold.

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	1/19/89	USA	Baton Rouge	BTR	ASRS	INC	Medium Large Transport, Low Wing	NONE	NONE	200	0
LDOR	3/4/01	USA	Phoenix	PHX	NTSB	INC	B737	NONE	NONE	75	0
LDOR	1/30/03	UK	Norwich	NWI	UK AAIB	INC	ERJ 135ER	NONE	MNOR	427	33
LDOR	2/19/95	USA	Chicago	ORD	ASRS	INC	DC10	NONE	MNOR	10	0
LDOR	8/19/91	USA	Seattle	SEA	ASRS	INC	Light Transport	NONE	NONE	25	30
LDOR	10/1/04	USA	Panama CITY	PFN	ASRS	INC	Super King Air 200 HDC	NONE	MNOR	50	0
LDUS	5/15/91	USA	Nashville	BNA	NTSB	INC	B727	NONE	MNOR	-408	0
LDUS	9/28/87	USA	Saint louis	STL	AIDS	INC	MD80	NONE	NONE	-30	0
LDOR	9/19/95	USA	Fayetteville	FYV	ASRS	INC	Commercial Fixed Wing	NONE	UNK	52	0
LDOR	7/19/99	USA	Minneapolis	MSP	ASRS	INC	B727	NONE	MNOR	125	0
LDUS	8/28/79	USA	Saipan	GSN	AIDS	INC	B727	NONE	NONE		
LDUS	10/22/80	USA	Phoenix	PHX	AIDS	INC	DC9	NONE	NONE	-500	0
LDOR	9/13/81	USA	Boston	BOS	AIDS	INC	DC10	NONE	NONE	50	0
LDOR	9/19/93	USA	Washington	DCA	ASRS	INC	Medium Large Transport, Low Wing	NONE	NONE	50	0
LDOR	1/19/90	USA	Denver	DEN	ASRS	INC	Large Transport, Low Wing	NONE	NONE	100	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
TOOR	5/19/94	USA	Texarkana	TXK	ASRS	INC	SF340B	NONE	UNK	80	0
TOOR	5/11/00	Canada	Edmonton	YEG	Canada TSB	INC	DC9	NONE	MNOR	500	0
LDUS	12/30/00	USA	Salt Lake City	SLC	AIDS	INC	MD90	NONE	MNOR	-400	0
LDOR	8/13/96	UK	Northolt	NHT	UK AAIB	ACC	LR25	SERS	DEST	748	115
LDOR	10/19/88	USA	Columbus	LSF	ASRS	INC	Widebody	NONE	NONE	400	0
LDOR	12/19/95	USA	Los Angeles	LAX	ASRS	INC	B737	NONE	MNOR	160	100
LDUS	12/19/88	USA	Sandusky	SKY	ASRS	INC	Light Transport, High Wing	NONE	MNOR	-60	0
TOOR	1/25/07	France	Pau	PUF	ASN	ACC	F100	FATL	DEST	1598	100
LDOR	10/19/99	France	Paris	CDG	ASRS	INC	MD11	NONE	MNOR	190	50
LDOR	3/19/89	USA	Washington	DCA	ASRS	INC	Medium Large Transport	NONE	NONE	150	0
LDOR	1/1/01	USA	Glasgow	GLW	ASRS	INC	BEC90 E90	NONE	NONE		
LDOR	12/13/02	Singapore	Singapore	SIN	AAIB Singapor e	INC	DC8	NONE	DEST	968	197
LDOR	4/4/01	Canada	St. John's	YYT	Canada TSB	ACC	B737	NONE	SUBS	75	53
LDOR	7/19/04	USA	Fort Lauderdale	FXE	NTSB	ACC	LR55	NONE	SUBS	950	280
LDOR	7/18/89	USA	Chicago	ORD	NTSB	INC	DC10	NONE	NONE		
LDOR	2/19/89	USA	Covington	CVG	ASRS	INC	Large Transport	NONE	NONE	60	140
LDOR	11/19/98	USA	Atlanta	ATL	ASRS	INC	DC8	NONE	NONE	85	0
TOOR	9/11/88	USA	New Orleans	MSY	AIDS	INC	L1329	NONE	MNOR	400	0
TOOR	8/3/87	USA	Denver	DEN	NTSB	INC	A300	NONE	MNOR		
LDOR	6/20/02	Dominican Republic	Santo Domingo	SDQ	ASRS	INC	B727	NONE	NONE	200	0
LDUS	11/26/81	USA	Augusta	AGS	AIDS	INC	B727	NONE	SUBS	-300	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	1/19/99	USA	Wilmington	ILN	ASRS	INC	DC8	NONE	NONE	800	100
LDOR	2/20/03	Italy	Sigonella	NSY	ASRS	INC	B747	NONE	MNOR	800	0
LDOR	1/1/00	USA	Charlotte	CLT	ASRS	INC	DC9	NONE	NONE	225	0
LDOR	2/19/94	USA	Rifle	RIL	ASRS	INC	Bae146	NONE	NONE	630	70
TOOR	8/19/88	USA	Cleveland	CLE	ASRS	INC	Small Transport	NONE	NONE	500	300
TOOR	8/19/89	USA	New Orleans	MSY	ASRS	INC	Large Transport	NONE	NONE	800	0
LDOR	7/1/92	USA	Chicago	ORD	AIDS	INC	B757	NONE	NONE	25	0
LDOR	2/8/94	USA	Washington	DCA	AIDS	INC	MD80	NONE	NONE	50	50
LDOR	11/1/96	USA	Cleveland	CLE	ASRS	INC	MD88	NONE	NONE	285	0
LDOR	3/20/01	USA	El Paso	ELP	ASRS	INC	Medium Large Transport	NONE	NONE	150	0
TOOR	4/16/82	USA	Marana	TUS	AIDS	INC	DC8	NONE	MNOR		
LDUS	3/20/83	USA	Chicago	ORD	AIDS	INC	SABRELINER	NONE	MNOR		
LDOR	1/24/05	Germany	Düsseldorf	DUS	ASN	ACC	B747	NONE	DEST	2050	50
LDOR	11/21/79	USA	Carlsbad	CRQ	AIDS	INC	LR24	NONE	NONE	100	0
LDOR	11/22/99	Canada	Dryden	YHD	Canada TSB	ACC	SA227	NONE	SUBS	300	0
LDOR	8/10/91	USA	Charlotte	CLT	AIDS	INC	B767	NONE	NONE	50	0
LDOR	7/19/92	USA	Chicago	ORD	ASRS	INC	Large Transport	NONE	NONE	30	0
LDOR	8/19/94	USA	Savannah	SAV	ASRS	INC	-1	NONE	MNOR	2	30
TOOR	10/5/87	USA	Oakland	OAK	AIDS	INC	LR25	NONE	MNOR	50	0
LDOR	12/20/02	USA	Spokane	GEG	ASRS	INC	DHC-DASH 8	NONE	MNOR	100	0
LDOR	1/1/96	UK	Derbyshire	EMA	UK AAIB	INC	F70	NONE	NONE	377	30
LDOR	12/20/02	USA	White Plains	HPN	ASRS	INC	Hs125	NONE	NONE	200	0
LDUS	2/8/86	USA	Harlingen	HRL	AIDS	INC	B727	NONE	SUBS	-250	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	3/19/94	USA	Columbus	CMH	ASRS	INC	-1	NONE	UNK	260	0
LDOR	4/3/96	Canada	Moncton	YQM	Canada TSB	INC	B727	NONE	NONE	154	0
LDOR	9/1/00	Canada	Ottawa	YOW	ASRS	INC	B727	NONE	UNK	100	0
LDUS	6/19/95	Panama	Panama City	PTY	ASRS	INC	B747	NONE	MNOR	-350	0
LDUS	1/4/87	USA	Hudson	1B1	AIDS	INC	LR55	NONE	MNOR	-100	0
LDUS	7/19/93	USA	Nantucket	ACK	ASRS	INC	Medium Large Transport	NONE	NONE	-150	0
LDUS	10/19/97	Hong Kong	Hong Kong	HKG	ASRS	INC	B747	NONE	NONE	-150	0
LDOR	12/19/97	USA	Savannah	SAV	ASRS	INC	B727	NONE	NONE	20	0
LDOR	2/15/82	USA	Los Angeles	LAX	NTSB	INC	B737	NONE	SUBS		
LDOR	3/4/01	USA	Phoenix	PHX	AIDS	INC	B737	NONE	MNOR	100	0
TOOR	6/23/98	USA	Washington	IAD	AIDS	INC	LR60	NONE	MNOR	250	0
LDOR	2/19/95	USA	Chicago	ORD	ASRS	INC	Commercial Fixed Wing	NONE	MNOR	200	70
LDOR	8/19/91	USA	Charlotte	CLT	ASRS	INC	Widebody	NONE	NONE	80	0
LDOR	2/20/96	USA	Washington	DCA	NTSB	INC	B737	NONE	MNOR	250	0
LDOR	1/21/94	Canada	Terrace	YXT	Canada TSB	INC	BAe146	NONE	NONE	415	39
TOOR	12/3/98	Canada	Iqaluit	YFB	Canada TSB	ACC	HS748	NONE	SUBS	800	100
LDOR	2/28/96	USA	Savannah	SAV	NTSB	INC	DC9	NONE	NONE	201	0
LDOR	7/19/90	USA	Jackson	JAC	ASRS	INC	Medium Large Transport	NONE	NONE	310	0
LDUS	4/8/84	USA	Austin	AUS	AIDS	INC	LR25	NONE	MNOR	-50	0
LDOR	9/12/93	France	Faa	PPT	FRANCE BEA	ACC	B747	NONE	SUBS	230	197
LDOR	8/19/88	USA	Pensacola	PNS	ASRS	INC	Medium Large	NONE	NONE	78	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
							Transport				
LDOR	5/30/03	USA	Jamaica	JFK	NTSB	INC	MD11F	NONE	MNOR	238	0
TOOR	1/19/97	Italy	Rome	FCO	ASRS	INC	DC10	NONE	NONE		
LDOR	8/1/99	Canada	St. John's	YYT	Canada TSB	ACC	F28	MINR	SUBS	420	90
LDOR	3/19/89	USA	Daytona Beach	DAB	ASRS	INC	Medium Large Transport	NONE	NONE	50	0
LDUS	1/5/84	USA	Seattle	SEA	AIDS	INC	B727	NONE	MNOR	-200	0
LDOR	1/17/03	Spain	Melilla	MLN	CIAIAC	ACC	F50	NONE	DEST	710	90
LDOR	3/19/95	USA	Honolulu	HNL	ASRS	INC	DC10	NONE	NONE	100	70
LDOR	2/19/93	USA	Portland	PWM	ASRS	INC	Medium Large Tranport	NONE	NONE	260	0
LDUS	6/6/04	USA	San Jose	SJC	AIDS	INC	HS125	NONE	MNOR		
LDOR	11/2/02	Ireland	Strandhill	SXL	AAIU	ACC	F27	NONE	DEST	328	98
LDOR	4/22/90	Australia	Lord Howe Island	LDH	ASN	ACC	CE501	NONE	DEST	250	0
LDOR	12/18/00	Canada	Windsor	YQG	Canada TSB	INC	Antonov 124	NONE	MNOR	340	0
LDOR	2/26/82	USA	Atlanta	PDK	NTSB	INC	BE90	NONE	MNOR	600	280
LDOR	2/15/03	Italy	N/A	999	AIDS	INC	B747	NONE	MNOR	770	0
LDUS	1/27/79	USA	Agana	GUM	AIDS	INC	B727	NONE	NONE	-278	0
LDOR	5/20/04	USA	Honolulu	HNL	ASRS	INC	B767	NONE	NONE	75	0
LDOR	5/26/93	UK	Southampton	SOU	UK AAIB	ACC	CE550	NONE	DEST	630	0
LDOR	1/9/89	USA	Baton rouge	BTR	NTSB	INC	DC9	MINR	NONE	300	0
TOOR	10/15/00	USA	Anchorage	ANC	NTSB	INC	B747	NONE	MNOR	690	0
TOOR	5/9/05	USA	Brownwood	BWD	NTSB	ACC	Sabreliner 80	NONE	SUBS	1300	0
LDOR	3/12/87	USA	Des moines	DSM	AIDS	INC	DC8	NONE	NONE	50	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDUS	3/12/81	USA	Cincinnati	LUK	AIDS	INC	Sabreliner	NONE	MNOR	-50	0
LDOR	7/1/00	UK	Coventry	CVT	UK AAIB	INC	F27	NONE	SUBS	853	98
LDOR	2/19/82	USA	Harlingen	HRL	NTSB	INC	B727	NONE	NONE	299	0
LDOR	1/19/94	USA	Wilmington	ILN	ASRS	INC	-1	NONE	NONE	10	0
LDOR	8/10/94	South Korea	Jeju	CJU	ADREP	ACC	A300	NONE	DEST		
LDOR	9/19/95	USA	Charleston	CHS	ASRS	INC	MD88	NONE	MNOR	50	160
LDOR	4/19/04	Canada	Chibougamau	YMT	Canada TSB	ACC	BE100	NONE	SUBS	500	0
LDOR	6/19/99	Philippine s	Manilla	XCN	ASRS	INC	Widebody (Large Transport)	NONE	NONE		
LDOR	12/18/82	USA	Pellston	PLN	NTSB	INC	DC9	NONE	NONE	80	0
LDOR	4/19/89	USA	San Diego	SAN	ASRS	INC	Large Transport	NONE	NONE	280	50
TOOR	9/21/87	USA	Tyndall	PAM	NTSB	INC	LR36A	NONE	MNOR	230	50
LDOR	8/19/92	USA	Milwaukee	MKE	ASRS	INC	Large Transport	NONE	NONE	250	0
LDOR	8/9/99	USA	Minneapolis	MSP	AIDS	INC	DC10	NONE	MNOR	200	0
LDOR	7/19/92	Northern Mariana Islands	Rota	ROP	ASRS	INC	Large Transport	NONE	MNOR	10	0
LDUS	7/30/93	USA	Nantucket	ACK	AIDS	INC	B737	NONE	MNOR	-50	0
LDUS	11/5/92	USA	San Antonio	SAT	AIDS	INC	SA227	NONE	MNOR		
LDOR	2/19/97	USA	Chicago	ORD	ASRS	INC	B737	NONE	NONE	10	0
LDOR	5/19/98	USA	Atlanta	ATL	ASRS	INC	DC9	NONE	NONE	200	0
LDOR	2/19/94	USA	Washington	DCA	ASRS	INC	Medium Large Transport	NONE	NONE	250	50
LDOR	4/20/04	USA	New Orleans	MSY	ASRS	INC	B737	NONE	NONE	200	0
LDOR	8/19/99	USA	Minneapolis	MSP	ASRS	INC	DC10	NONE	NONE	200	30

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDUS	7/25/80	USA	Tampa	TPA	AIDS	INC	B727	NONE	NONE	-50	0
LDOR	7/20/83	USA	Chicago	ORD	NTSB	INC	DC8	NONE	NONE	100	0
LDOR	2/18/99	USA	Columbus	OLU	NTSB	ACC	MU300	NONE	SUBS	150	0
LDOR	2/16/99	USA	Van Nuys	VNY	NTSB	ACC	G1159	NONE	SUBS	1072	451
LDUS	3/30/99	USA	Rogers	ROG	NTSB	ACC	LR35A	MINR	SUBS	-12	100
LDOR	4/17/99	USA	Beckley	BKW	NTSB	ACC	BE400	SERS	SUBS	216	0
LDOR	1/20/94	USA	Teterboro	TEB	NTSB	ACC	MU3	NONE	SUBS		
LDOR	2/1/94	USA	New Roads	HZR	NTSB	ACC	SA340B	MINR	SUBS	420	20
TOOR	7/13/94	USA	Atlantic City	ACY	NTSB	ACC	LR35	NONE	SUBS	446	0
TOOR	8/26/94	USA	New Orleans	NEW	NTSB	ACC	DA200	NONE	SUBS	500	0
LDUS	3/3/95	USA	Gillette	GCC	NTSB	ACC	AERO 1124A	MINR	SUBS	-50	0
TOOR	5/23/95	USA	Rogers	ROG	NTSB	ACC	LR35A	NONE	SUBS	1200	0
LDOR	7/26/95	USA	Minneapolis	FCM	NTSB	ACC	CE550	NONE	SUBS	800	0
LDUS	9/18/95	USA	Chino	CNO	NTSB	ACC	SA226	MINR	DEST	-1000	75
LDUS	10/12/95	USA	Cleveland	CLE	NTSB	ACC	G1159	NONE	SUBS		
LDOR	2/19/96	USA	Houston	IAH	NTSB	ACC	DC9	MINR	SUBS	51	140
LDOR	2/7/96	USA	Bradford	BFD	NTSB	ACC	BE1900D	MINR	SUBS	870	825
TOOR	5/1/96	USA	Albuquerque	ABQ	NTSB	ACC	NA265	NONE	SUBS	212	212
TOOR	8/14/96	USA	Pottstown	N47	NTSB	ACC	PA31	NONE	SUBS	1429	457
LDOR	9/28/96	USA	Chillicothe	RZT	NTSB	ACC	MU2B	NONE	SUBS	15	147
TOOR	10/30/96	USA	Wheeling	PWK	NTSB	ACC	Gulfstream GIV	FATL	DEST	1509	53
LDOR	1/1/97	USA	Kansas City	MKC	NTSB	ACC	LR35	NONE	SUBS	105	1000
LDOR	1/21/97	USA	Bloomington	BMG	NTSB	ACC	BE300	NONE	SUBS	600	0
TOOR	1/10/97	USA	Bangor	BGR	NTSB	ACC	BE1900D	MINR	SUBS		

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	2/27/97	USA	Greenville	GMU	NTSB	ACC	LR35	MINR	DEST	350	
LDUS	4/7/97	USA	Stebbins	WBB	NTSB	ACC	PA31	NONE	SUBS	-153	0
LDOR	5/21/97	USA	San Diego	NKX	NTSB	ACC	EMB120	NONE	SUBS	1300	0
LDOR	7/5/97	USA	Ardmore	ADM	NTSB	ACC	NA265	NONE	SUBS	60	0
LDOR	7/15/97	USA	Avon Park	AVO	NTSB	ACC	LR35A	MINR	DEST	1800	550
LDOR	8/19/97	USA	Des Moines	DSM	NTSB	ACC	SA226	MINR	SUBS	867	0
TOOR	8/7/97	USA	Miami	MIA	NTSB	ACC	DC8	FATL	DEST	575	0
LDUS	8/14/97	USA	Dalton	DNN	NTSB	ACC	BE200	FATL	SUBS	-1105	135
LDUS	8/13/97	USA	Lexington	LEX	NTSB	ACC	DA20	NONE	SUBS	-13	215
LDUS	11/13/97	USA	Wheeling	HLG	NTSB	ACC	BE65	NONE	SUBS	-90	125
LDOR	1/6/98	USA	West Mifflin	AGC	NTSB	ACC	CE500	SERS	DEST	375	75
LDOR	3/4/98	USA	Manistee	MBL	NTSB	ACC	CE650	NONE	SUBS	150	0
TOOR	3/19/98	USA	Portland	PDX	NTSB	ACC	SN601	NONE	SUBS		
LDOR	5/23/98	USA	Orlando	ORL	NTSB	ACC	LR24	NONE	SUBS	500	0
TOOR	5/12/98	USA	Monroe	TTF	NTSB	ACC	DA20	NONE	SUBS		
LDOR	6/19/98	USA	Fishers Island	0B8	NTSB	ACC	CE500	NONE	SUBS	115	0
LDOR	4/27/93	USA	Denver	DEN	NTSB	ACC	DC9	MINR	SUBS	1	30
LDOR	4/29/93	USA	Pine Bluff	PBF	NTSB	ACC	EMB120	MINR	SUBS	687	55
TOOR	4/19/93	USA	Merced	MCE	NTSB	ACC	BAE3101	SERS	DEST	200	250
LDOR	8/26/93	USA	Hailey	SUN	NTSB	ACC	DA10	NONE	SUBS	850	260
LDOR	4/23/92	USA	Ypsilanti	YIP	NTSB	ACC	DC8F	NONE	SUBS		
LDOR	6/17/92	USA	Cedar Rapids	CID	NTSB	ACC	NA265	NONE	SUBS	212	0
LDUS	6/16/92	USA	New Castle	ILG	NTSB	ACC	BE200	FATL	DEST	-1320	0
TOOR	7/30/92	USA	Jamaica	JFK	NTSB	ACC	L1011	SERS	DEST		

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDUS	8/8/92	USA	Nuiqsut	AQT	NTSB	ACC	BEC99	NONE	SUBS	-50	0
LDOR	11/22/92	USA	Cleveland	CLE	NTSB	ACC	LR25	NONE	SUBS	200	0
LDOR	11/7/92	USA	Phoenix	PHX	NTSB	ACC	N-265-60	NONE	DEST	1500	120
TOOR	12/18/92	USA	Mccall	MYL	NTSB	ACC	FALCON 10	SERS	SUBS	500	50
LDOR	2/14/91	USA	Cleveland	BKL	NTSB	ACC	G1159	NONE	SUBS	0	150
TOOR	3/12/91	USA	Jamaica	JFK	NTSB	ACC	DC8	MINR	DEST	835	550
LDOR	7/2/91	USA	Columbia	MRC	NTSB	ACC	LR23	NONE	SUBS	543	38
TOOR	7/22/91	USA	Detroit	DET	NTSB	ACC	LR23	FATL	DEST	828	0
LDUS	10/19/91	USA	Allakaket	AET	NTSB	ACC	BE99	NONE	SUBS	-100	30
LDOR	10/6/91	USA	Augusta	AUG	NTSB	ACC	SA227	MINR	SUBS	20	0
LDOR	12/23/91	USA	Carlsbad	CRQ	NTSB	ACC	LR25B	NONE	SUBS	50	75
LDOR	5/8/99	USA	Jamaica	JFK	NTSB	ACC	SA340B	SERS	SUBS	350	0
LDOR	6/1/99	USA	Little Rock	LIT	NTSB	ACC	MD82	FATL	DEST	800	0
LDOR	7/1/99	USA	Hyannis	HYA	NTSB	ACC	LR60	NONE	SUBS	745	0
LDOR	9/26/99	USA	Gainesville	GVL	NTSB	ACC	LR24	SERS	SUBS	274	100
TOOR	11/11/99	USA	Chicago	CGX	NTSB	ACC	BE200	FATL	DEST	300	100
LDOR	1/27/00	USA	Dallas	DAL	NTSB	ACC	MU300	NONE	SUBS		
LDOR	3/5/00	USA	Burbank	BUR	NTSB	ACC	B737	SERS	DEST	200	200
LDOR	3/12/00	USA	Jackson	JAC	NTSB	ACC	LR60	NONE	SUBS	160	0
LDOR	3/21/00	USA	Killeen	ILE	NTSB	ACC	SF340B	MINR	SUBS	175	3
LDOR	3/17/00	USA	Hyannis	HYA	NTSB	ACC	DA900	MINR	SUBS	667	0
TOOR	10/19/00	USA	Concord	CCR	NTSB	ACC	BE300	SERS	SUBS	496	0
TOOR	1/6/90	USA	Miami	MIA	NTSB	ACC	L1329	FATL	DEST	1180	100
LDUS	1/17/90	USA	West point	M83	NTSB	ACC	BE400	NONE	SUBS	-6	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDUS	1/19/90	USA	Little Rock	LIT	NTSB	ACC	G1159	FATL	DEST	-1600	0
LDUS	5/4/90	USA	Wilmington	ILM	NTSB	ACC	N24A	FATL	DEST	-600	0
LDOR	7/18/90	USA	Milwaukee	MWC	NTSB	ACC	MU300	NONE	SUBS		
LDUS	11/29/90	USA	Sebring	SEF	NTSB	ACC	CE550	NONE	SUBS	-100	60
TOOR	5/21/88	USA	Dallas	DFW	NTSB	ACC	DC10	SERS	SUBS	1112	0
LDUS	7/26/88	USA	Morristown	MMU	NTSB	ACC	LR35	FATL	DEST	-660	75
TOOR	8/16/88	USA	Cleveland	CLE	NTSB	ACC	SA226	MINR	SUBS	837	387
TOOR	8/31/88	USA	Dallas	DFW	NTSB	ACC	B727	FATL	DEST	2833	0
LDOR	9/22/88	USA	Fremont	3FM	NTSB	ACC	CE550	NONE	SUBS	644	150
LDOR	11/17/88	USA	Bend	BDN	NTSB	ACC	LR25B	NONE	SUBS	200	0
LDOR	2/15/89	USA	Binghamton	BGM	NTSB	ACC	FALCON D	SERS	SUBS	200	80
LDOR	2/27/89	USA	Poughkeepsie	POU	NTSB	ACC	CE550	MINR	DEST	700	100
LDOR	3/23/89	USA	Roanoke	ROA	NTSB	ACC	LR25	NONE	SUBS	200	10
LDUS	3/15/89	USA	West Lafayette	LAF	NTSB	ACC	YS11A	FATL	DEST	-510	13
LDUS	4/13/89	USA	Scottsdale	SCF	NTSB	ACC	BAE125	NONE	SUBS	-10	0
LDUS	5/6/89	USA	Mt. Pleasant	MRC	NTSB	ACC	EMB110	FATL	DEST	-2350	20
LDUS	7/19/89	USA	Sioux City	SUX	NTSB	ACC	DC10	FATL	DEST	-198	761
LDUS	8/21/89	USA	Gold Beach	4S1	NTSB	ACC	BEC90	FATL	DEST	-50	150
TOOR	9/20/89	USA	Flushing	LGA	NTSB	ACC	B737	FATL	DEST	194	
LDUS	12/26/89	USA	Pasco	PSC	NTSB	ACC	BAE3101	FATL	DEST	-1200	20
LDOR	12/30/89	USA	Tucson	TUS	NTSB	ACC	B737	MINR	SUBS	3803	175
LDUS	2/11/87	USA	Oneonta	N66	NTSB	ACC	BE99	NONE	SUBS	-10	100
TOOR	5/12/87	USA	West Mifflin	AGC	NTSB	ACC	LR35	FATL	DEST	1320	300
TOOR	5/26/87	USA	Kenner	MSY	NTSB	ACC	BAE3101	SERS	DEST	1180	20

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
TOOR	7/16/87	USA	Jackson	JAN	NTSB	ACC	AERO 1121	NONE	SUBS		
TOOR	9/24/87	USA	Twin Falls	TWF	NTSB	ACC	SA227	SERS	DEST	245	1144
LDOR	10/28/87	USA	Bartlesville	BVO	NTSB	ACC	CV640	MINR	DEST	918	0
LDOR	10/6/87	USA	Kennewick	S98	NTSB	ACC	BAE3101	NONE	SUBS	450	0
TOOR	11/15/87	USA	Denver	Staplet on	NTSB	ACC	DC9	FATL	DEST	1300	325
LDUS	11/23/87	USA	Homer	HOM	NTSB	ACC	BE1900C	FATL	DEST		
LDUS	12/5/87	USA	Lexington	LEX	NTSB	ACC	HS125	FATL	DEST		
LDUS	2/7/86	USA	Mekoryuk	MYU	NTSB	ACC	DHC6	NONE	SUBS		
LDOR	2/21/86	USA	Erie	ERI	NTSB	ACC	DC9	MINR	SUBS	180	70
LDOR	2/8/86	USA	Carlsbad	CRQ	NTSB	ACC	MU300	NONE	SUBS	100	119
LDOR	2/27/86	USA	Coatsville	40N	NTSB	ACC	DA10	MINR	SUBS	400	250
LDOR	5/7/86	USA	Hollywood	HWO	NTSB	ACC	LR24	MINR	SUBS		
LDUS	7/1/86	USA	Lincoln	LNK	NTSB	ACC	SA227	NONE	SUBS	-243	0
LDOR	8/2/86	USA	Bedford	BFR	NTSB	ACC	HS125	FATL	DEST	677	0
TOOR	8/6/86	USA	Rutland	RUT	NTSB	ACC	LR55	MINR	DEST		
LDUS	9/29/86	USA	Liberal	LBL	NTSB	ACC	NA265	NONE	SUBS	-21	0
LDOR	10/25/86	USA	Charlotte	CLT	NTSB	ACC	B737	SERS	DEST	516	75
LDOR	1/31/85	USA	London	LOZ	NTSB	ACC	SA227	SERS	DEST	380	
LDOR	1/5/85	USA	Oklahoma City	OK15	NTSB	ACC	LR25B	NONE	SUBS		
TOOR	1/21/85	USA	Johnstown	JST	NTSB	ACC	LR25D	NONE	SUBS		
TOOR	4/3/85	USA	Grand Rapids	GRR	NTSB	ACC	DHC6-200	NONE	SUBS		
LDUS	5/12/85	USA	Lake Geneva	C02	NTSB	ACC	FALCON 50	NONE	DEST	-13	5
LDUS	6/28/85	USA	Charlotte	CLT	NTSB	ACC	PA42	FATL	DEST	-1800	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	6/11/85	USA	Van Nuys	VNY	NTSB	ACC	AERO 1121	MINR	SUBS	1300	0
LDOR	7/12/85	USA	Dallas	FTW	NTSB	ACC	LR35A	NONE	SUBS	459	100
TOOR	8/13/85	USA	Madison	MSN	NTSB	ACC	LR23	NONE	SUBS	900	
LDUS	9/25/85	USA	Unalaska	DUT	NTSB	ACC	B737	MINR	SUBS		
LDOR	9/23/85	USA	West Chicago	DPA	NTSB	ACC	Falcon10	NONE	SUBS	1200	1100
LDOR	10/19/85	USA	Bloomington	BMG	NTSB	ACC	Viscount VC-810	SERS	DEST	320	75
LDOR	11/7/85	USA	Sparta	SRB	NTSB	ACC	HS125	SERS	SUBS	359	20
LDOR	1/30/84	USA	Avalon	AVX	NTSB	ACC	LR24	FATL	DEST		
LDOR	2/28/84	USA	Jamaica	JFK	NTSB	ACC	DC10	SERS	SUBS	660	35
LDOR	4/2/84	USA	Little Rock	LIT	NTSB	ACC	CL600	NONE	SUBS	50	60
TOOR	5/31/84	USA	Denver	DEN	NTSB	ACC	B727	NONE	SUBS	1074	0
LDUS	7/12/84	USA	Mcalester	MLC	NTSB	ACC	BEC45-H	NONE	SUBS		
TOOR	7/28/84	USA	Waterville	WVL	NTSB	ACC	LR25B	SERS	SUBS	100	10
TOOR	1/11/83	USA	Detroit	DTW	NTSB	ACC	DC8	FATL	DEST	299	1200
LDOR	7/15/83	USA	Blountville	TRI	NTSB	ACC	G1159	MINR	DEST		
LDOR	9/10/83	USA	Burlington	KITR	NTSB	ACC	BE90	NONE	SUBS	225	0
LDOR	9/20/83	USA	Massena	MSS	NTSB	ACC	LR35A	MINR	SUBS	587	30
LDOR	10/25/83	USA	Norfolk	NGU	NTSB	ACC	DC8	NONE	DEST	7	129
LDUS	12/21/83	USA	Detroit	DET	NTSB	ACC	BE200	NONE	SUBS	-125	0
TOOR	12/23/83	USA	Anchorage	ANC	NTSB	ACC	DC10	SERS	DEST	1434	40
LDUS	12/12/83	USA	Coatesville	40N	NTSB	ACC	NA265	NONE	SUBS	-20	250
TOOR	1/4/01	USA	Schenectady	SCH	NTSB	ACC	LR35	NONE	SUBS	470	0
LDOR	2/4/01	USA	Ft. Pierce	FPR	NTSB	ACC	LR25	NONE	SUBS		
LDOR	2/13/01	USA	Olympia	OLM	NTSB	ACC	BE200	NONE	SUBS	442	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	3/9/01	USA	Bridgeport	BDR	NTSB	ACC	HS125	NONE	SUBS	22	0
TOOR	3/17/01	USA	Detroit	DTW	NTSB	ACC	A320	MINR	SUBS	530	73
LDUS	6/12/01	USA	Salina	SLN	NTSB	ACC	LR25	SERS	DEST	-2254	85
TOOR	8/24/01	USA	Ithaca	ITH	NTSB	ACC	LR25	FATL	DEST	1000	10
LDOR	8/28/01	USA	Detroit	DET	NTSB	ACC	Falcon	NONE	SUBS	679	120
LDUS	9/19/01	USA	Indianapolis	IND	NTSB	ACC	BE200	NONE	SUBS	-621	0
LDOR	2/10/02	USA	Cleveland	CGF	NTSB	ACC	MU300	NONE	SUBS	106	
LDOR	3/25/02	USA	Anderson	AID	NTSB	ACC	MU300	NONE	SUBS	30	50
LDOR	5/1/02	USA	Baltimore	BWI	NTSB	ACC	BE400A	NONE	SUBS	680	0
TOOR	5/20/02	USA	Bethany	PWA	NTSB	ACC	CE550	MINR	SUBS	700	0
LDUS	7/26/02	USA	Tallahassee	TLH	NTSB	ACC	B727	SERS	DEST	-1677	454
LDOR	8/13/02	USA	Big Bear City	L35	NTSB	ACC	CE550	NONE	DEST	406	30
LDOR	8/30/02	USA	Lexington	LEX	NTSB	ACC	LR25C	FATL	DEST	410	10
LDUS	1/19/82	USA	Rockport	RKP	NTSB	ACC	SA226	FATL	DEST	-1821	317
LDUS	5/16/82	USA	Hooper Bay	HPB	NTSB	ACC	DHC6-200	SERS	DEST	-1270	50
TOOR	7/9/82	USA	New Orleans	MSY	NTSB	ACC	B727	FATL	DEST	2376	564
TOOR	6/4/82	USA	Wichita	AAO	NTSB	ACC	BE65	NONE	SUBS	300	50
LDOR	11/20/82	USA	Atlanta	ATL	NTSB	ACC	Aero 680W	SERS	DEST	450	0
LDOR	1/6/03	USA	Cleveland	CLE	NTSB	ACC	ERJ145	NONE	SUBS	785	0
LDUS	4/9/03	USA	Du bois	DUJ	NTSB	ACC	SD3-30	NONE	SUBS	-500	50
LDOR	5/18/03	USA	Houston	IWS	NTSB	ACC	BE300	MINR	SUBS	20	0
LDUS	6/28/03	USA	Goodnews	GNU	NTSB	ACC	SA226	MINR	SUBS	-100	0
LDOR	9/19/03	USA	Del Rio	DRT	NTSB	ACC	LR25	FATL	DEST	1600	100
TOOR	11/11/03	USA	Wheeling	PWK	NTSB	ACC	CE560XL	NONE	SUBS	500	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDUS	11/18/03	USA	Mineral Wells	DFW	NTSB	ACC	CE550	SERS	DEST	-350	0
LDUS	8/2/85	USA	Dallas	DFW	NTSB	ACC	L1011	FATL	DEST	-6336	360
LDUS	1/7/96	USA	Nashville	BNA	NTSB	ACC	DC9	MINR	SUBS	-90	0
LDUS	10/19/96	USA	Flushing	LGA	NTSB	ACC	MD88	MINR	SUBS	-303	95
LDUS	2/9/98	USA	Chicago	ORD	NTSB	ACC	B727	MINR	SUBS	-300	500
LDOR	10/24/98	UK	Southampton	SOU		INC	F100	NONE	MNOR	262	0
LDOR	8/6/98	Canada	Kasabonika	XKS		ACC	HS748	MINR	DEST	449	0
LDOR	7/22/98	UK	Belfast City	BHD		INC	BAE146	NONE	NONE	23	0
LDOR	2/18/98	Canada	Peterborough	YPQ	TSB	INC	Falcon	NONE	MNOR	236	0
LDOR	1/7/98	UK	London City	LCY	AAIB	INC	Avro 146	NONE	MNOR	144	0
LDOR	1/5/96	UK	East Midlands	EMA	AAIB	INC	DC8	NONE	MNOR		
LDOR	1/2/96	Australia	Bankstown	BWU		INC	CEA37	NONE	UNK		
LDOR	1/1/96	UK	East Midlands	EMA	AAIB	INC	F70	NONE	UNK	115	46
LDOR	5/11/95	Canada	St Johns	YWK	TSB	INC	B727	NONE	MNOR	299	21
LDOR	3/1/95	Canada	Jasper Hinton	CEC4	TSB	INC	MU300	NONE	SUBS	256	0
LDOR	9/29/93	UK	Norwich	NWI		INC	BAC 1-11-518FG	NONE	UNK	89	0
LDOR	7/21/93	Canada	Tofino	YAZ	TSB	INC	CV580	NONE	SUBS	152	0
LDOR	5/26/93	UK	Southampton	SOU	UK AAIB	ACC	CE550	MINR	DEST	715	0
LDOR	11/27/92	UK	Southampton	SOU		ACC	L351	NONE	SUBS	246	0
LDOR	3/31/92	UK	Aberdeen	ABZ		ACC	BAe146	NONE	SUBS	479	43
LDOR	4/28/90	New Zealand	Queenstown	ZQN		INC	BAe146	MINR	MNOR	318	82
LDOR	4/22/90	Australia	Lord Howe	LDH		ACC	CE501	NONE	SUBS	300	230
LDOR	4/1/89	UK	Leeds Bradford	LBA		INC	SD360	NONE	UNK		

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	10/21/88	Canada	Happy Lake	999		INC	DHC6	NONE	UNK		
LDOR	5/27/85	UK	Leeds Bradford	LBA		INC	L1011	NONE	MNOR	538	33
LDOR	12/15/84	Canada	Sioux Lookout	YXL		ACC	CE500	NONE	SUBS	502	0
LDOR	11/1/84	UK	Bristol	BRS		INC	A300	NONE	UNK		
LDOR	7/6/84	Canada	Blanc-Sablon	YBX		ACC	HS748	NONE	SUBS	30	0
LDOR	11/29/83	UK	Sumburgh	LSI		INC	HS748	NONE	MNOR	131	70
LDOR	4/19/83	Canada	Gaspe	YGP		ACC	HS125	NONE	SUBS		
LDOR	10/1/82	UK	Scatsa	SCS		INC	HS748	NONE	UNK		
LDOR	1/1/82	UK	Cambridge	CBG		INC	CE Citation	NONE	UNK		
LDOR	8/1/81	Canada	Sugluk	999		INC	DHC6	NONE	UNK		
LDOR	9/6/80	Canada	Seal River	999		INC	DHC6	NONE	UNK		
LDOR	8/7/80	UK	Leeds Bradford	999		INC	Viscount	NONE	UNK		
LDOR	4/7/80	Canada	Athabasca, Alta	CYWM		ACC	MU2B	MINR	SUBS		
TOOR	3/30/98	UK	Stansted	STN		INC	HS748	NONE	MNOR		
TOOR	2/20/98	UK	Norwich	999		INC	Jet provost	NONE	UNK		
TOOR	11/29/97	Canada	Island Lake	YIV		ACC	BE1900D	MINR	SUBS	200	0
TOOR	8/1/96	UK	Cambridge	999		INC	CE Citation	NONE	UNK		
TOOR	8/16/96	UK	Liverpool	LPL	AAIB	INC	HS748	NONE	MNOR	718	200
TOOR	10/19/95	Canada	Vancouver	YVR	TSB	INC	DC10	MINR	SUBS	400	141
TOOR	6/27/88	UK	Newcastle	NCL		INC	BAC 1-11-409	NONE	UNK	161	0
TOOR	7/20/86	Canada	Wabush	YWK		ACC	B737	SERS	SUBS	200	0
TOOR	6/27/85	Puerto Rico	San Juan	999		ACC	DC10	SERS	SUBS	63	161
TOOR	7/31/91	USA	Denver	DEN	AIDS	INC	B727	NONE	MNOR	150	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	1/2/86	USA	Detroit	DTW	NTSB	INC	DC10	NONE	NONE	100	0
LDUS	1/24/94	USA	Key Largo	07FA	NTSB	INC	LR35	NONE	NONE	-35	0
LDOR	5/19/92	USA	Bozeman	BZN	ASRS	INC	Medium Large Transport	NONE	NONE	150	0
TOOR	2/19/81	USA	Pittsburg	PTS	AIDS	INC	DC9	NONE	MNOR		
LDOR	6/23/84	USA	Chicago	ORD	NTSB	INC	B707	NONE	MNOR	600	0
LDOR	7/20/01	USA	Portland	PWM	ASRS	INC	SA340	NONE	MNOR	50	0
LDOR	8/20/04	USA	N/A	999	ASRS	INC	B737	NONE	NONE		
LDOR	9/26/98	UK	Fairoaks	FRK	UK AAIB	INC	CE560	NONE	SUBS	765	140
TOOR	9/13/89	USA	Warsaw	ASW	AIDS	INC	AERO 1124	NONE	MNOR	1000	0
LDOR	5/2/02	USA	Leakey	49R	NTSB	ACC	CE560	NONE	DEST	560	50
LDOR	12/19/97	USA	Memphis	MEM	ASRS	INC	DC10	NONE	NONE	75	0
LDOR	8/19/90	USA	Santa Ana	SNA	ASRS	INC	Widebody	NONE	NONE	75	0
LDUS	9/19/88	USA	San Diego	SAN	ASRS	INC	Medium Large Transport	NONE	NONE	-50	0
LDOR	10/20/00	USA	St Louis	STL	ASRS	INC	MD82	NONE	NONE	807	225
LDOR	2/19/96	USA	Savannah	SAV	ASRS	INC	Medium Large Transport	NONE	NONE	300	50
LDUS	1/10/79	USA	Lubbock	LBB	AIDS	INC	LR24	NONE	MNOR	-120	0
LDOR	3/13/86	USA	Charleston	CHS	NTSB	INC	DC9	NONE	MNOR	870	200
LDOR	1/1/02	USA	Miami	MIA	NTSB	INC	MD83	NONE	MNOR	590	135
LDUS	6/1/88	USA	Jamaica	JFK	NTSB	INC	B747	NONE	MNOR		
LDOR	6/19/91	USA	Kansas City	MCI	ASRS	INC	Large Transport	NONE	MNOR	500	0
LDOR	1/12/05	USA	Jacksonville	CRG	NTSB	ACC	BE350	NONE	SUBS	557	20
LDOR	1/19/98	USA	Portland	PWM	ASRS	INC	B727	NONE	NONE	215	0
LDOR	10/18/89	USA	Monte Vista	MVI	NTSB	INC	DC9	MINR	MNOR		

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
TOOR	4/1/02	USA	Cambridge	CGE	ASRS	INC	Light Transport	NONE	NONE		
TOOR	4/19/92	USA	Charlotte	CLT	ASRS	INC	Medium Large Transport	NONE	NONE	200	130
TOOR	10/14/04	Canada	Halifax	YHZ	Canada TSB	ACC	B747	FATL	DEST	1750	40
LDOR	1/19/95	USA	Atlanta	ATL	NTSB	INC	B737	NONE	MNOR	250	0
LDOR	6/17/88	USA	W. Palm Beach	PBI	NTSB	INC	LR24	NONE	MNOR	30	0
LDOR	3/20/01	USA	Shreveport	SHV	ASRS	INC	EMB 120	NONE	NONE	110	0
LDUS	10/20/01	USA	Houston	IAH	ASRS	INC	B737	NONE	NONE	-100	0
LDOR	6/22/06	UK	Aberdeen	ABZ	UK AAIB	INC	Dornier 328	NONE	MNOR	1148	40
LDUS	9/24/99	Canada	St. John's	YYT	Canada TSB	ACC	A320	NONE	NONE	-250	0
LDOR	2/20/04	USA	Ft. Lauderdale	FXE	NTSB	ACC	LR25B	SERS	DEST	1689	220
LDOR	3/20/04	USA	-1	999	ASRS	INC	BE1900	NONE	NONE	25	0
TOOR	12/16/03	USA	Teterboro	TEB	AIDS	INC	CL600	NONE	MNOR	213	0
TOOR	2/3/82	USA	Philadelphia	PHL	NTSB	ACC	DC10	SERS	MNOR	600	0
LDOR	3/19/94	USA	State college	UNV	ASRS	INC	Jetstream 32	NONE	UNK	20	0
TOOR	9/29/93	France	Besançon	QBQ	FRANCE BEA	INC	Falcon10	FATL	DEST	99	49
LDOR	11/19/96	USA	Honolulu	HNL	ASRS	INC	DC10	NONE	NONE	25	0
LDUS	2/19/98	Hong Kong	Hong Kong	HKG	ASRS	INC	B747	NONE	NONE	-900	0
LDUS	1/23/83	USA	Jamaica	JFK	AIDS	INC	DC8	NONE	MNOR	-200	0
LDOR	8/1/88	USA	Pensacola	PNS	NTSB	INC	MD88	NONE	NONE	320	90
LDOR	1/20/00	USA	Sparta	SRB	ASRS	INC	Falcon 200	NONE	NONE		
LDOR	10/19/89	USA	Dover	DOV	ASRS	INC	Heavy Transport	NONE	NONE	200	0
TOOR	12/20/04	USA	El Paso	ELP	ASRS	INC	LR25	NONE	NONE	200	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	11/11/96	USA	Cleveland	CLE	NTSB	INC	MD88	NONE	MNOR	530	35
LDOR	3/19/89	USA	Chicago	ORD	ASRS	INC	Large Transport	NONE	NONE	500	30
TOOR	7/8/96	USA	Nashville	BNA	NTSB	ACC	B737	SERS	MNOR	750	100
LDOR	2/1/95	USA	Atlanta	ATL	ASRS	INC	DC8	NONE	NONE	470	90
LDOR	12/5/04	USA	Pine Bluff	PBF	NTSB	ACC	Falcon 20	NONE	SUBS	240	0
TOOR	4/15/92	USA	Charlotte	CLT	NTSB	INC	F28	NONE	NONE	100	0
LDUS	10/20/02	USA	Ontario	ONT	ASRS	INC	B747	NONE	NONE	-45	0
LDUS	2/19/99	USA	Miami	MIA	ASRS	INC	A300	NONE	NONE	-75	0
LDOR	12/24/00	France	Faaa	PPT	France BEA	ACC	DC10	NONE	SUBS	230	82
LDOR	11/17/94	USA	Bozeman	BZN	AIDS	INC	DC9	NONE	NONE	290	0
LDUS	12/8/93	USA	Dallas	DFW	NTSB	INC	B737	NONE	MNOR	-1095	0
TOOR	3/22/01	France	Orleans	LFOZ	FRANCE BEA	ACC	PA31	NONE	MNOR	590	66
LDOR	3/8/05	USA	Teterboro	TEB	NTSB	INC	BAE125	NONE	MNOR	230	
LDOR	5/28/03	UK	Leeds	LBA	UK AAIB	INC	CE560	NONE	MNOR	525	86
LDOR	3/17/01	FRANCE	Lyon	LYS	FRANCE BEA	INC	B737	NONE	NONE	279	197
LDUS	12/21/79	USA	Burlington	BTV	AIDS	INC	One-Eleven	NONE	NONE	-100	0
LDOR	9/23/99	Thailand	Bangkok	BKK	AUSTRA LIAN TSB	ACC	B747	NONE	SUBS	1050	59
LDOR	10/10/06	Norway	Sørstokken	SRP	ASN	ACC	BAe146	FATL	DEST	500	
TOOR	9/19/93	France	Troyes	QYR	France BEA	INC	SA227	NONE	SUBS	885	98
LDUS	2/16/88	USA	Groton	GON	AIDS	INC	SF340	NONE	NONE	-150	0
LDOR	11/19/91	USA	Los Angeles	LAX	ASRS	INC	Medium Large Transport	NONE	NONE	150	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
LDOR	10/1/03	Belgium	Liège	LGG	ASN	ACC	B747	NONE	SUBS	260	0
LDOR	9/19/88	USA	Paducah	PAH	ASRS	INC	Small Transport,	NONE	NONE		
LDUS	12/20/90	USA	Mcminnville	MMV	AIDS	INC	Falcon 900	NONE	MNOR		
LDOR	5/20/03	USA	Minneapolis	MSP	ASRS	INC	B737	NONE	NONE	200	0
LDUS	5/25/01	France	Cayenne	CAY	France BEA	INC	A340	NONE	MNOR	-98	0
LDOR	8/2/05	Canada	Toronto	YYZ	Canada TSB	ACC	A340	SERS	DEST	750	280
LDOR	6/23/04	USA	Houston	KIAH	AIDS	INC	ERJ145	NONE	MNOR	50	30
TOOR	7/2/83	USA	King Salmon	AKN	AIDS	INC	DC7	NONE	MNOR		
TOOR	4/1/02	USA	Cambridge	CGE	ASRS	INC	BE400	NONE	NONE	75	0
LDOR	7/1/03	USA	N/A	999	ASRS	INC	Falcon 50	NONE	MNOR		
LDOR	12/16/04	Canada	Oshawa	YOO	Canada TSB	ACC	SD360	SERS	SUBS	600	0
LDUS	10/19/80	USA	Phoenix	PHX	AIDS	INC	B727	NONE	NONE	-500	0
LDOR	12/13/89	USA	Chicago	MDW	NTSB	INC	DC9	NONE	MNOR	304	30
LDOR	2/13/93	USA	Portland	PWM	NTSB	INC	B737	NONE	NONE	330	50
LDOR	1/24/95	USA	Milwaukee	MKE	AIDS	INC	-1	NONE	MNOR	100	0
LDOR	9/19/99	USA	Minneapolis	MSP	ASRS	INC	DC9	NONE	NONE	25	0
LDOR	2/20/96	USA	Rifle	RIL	NTSB	INC	Avro 146-R	NONE	NONE	1000	80
LDUS	12/8/93	USA	Dallas	DFW	AIDS	INC	B737	NONE	MNOR		
LDOR	7/21/93	Canada	N/A	YAZ	CANADA TSB	ACC	CV580	NONE	SUBS	150	20
TOOR	3/9/05	USA	Tupelo	TUP	NTSB	ACC	CL600	NONE	SUBS	120	30
LDOR	2/20/06	FO	N/A	999	ASRS	INC	MD11	MINR	MNOR	220	0
TOOR	12/16/03	USA	Teterboro	TEB	NTSB	INC	CL600	NONE	MNOR	188	0

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
TOOR	9/13/82	USA	Denver	DEN	NTSB	INC	SA226	NONE	MNOR	10	0
LDUS	2/19/95	USA	Portland	PDX	ASRS	INC	B727	NONE	MNOR	-350	0
LDOR	12/19/88	USA	Charleston	CHS	ASRS	INC	Medium Large Transport,	NONE	NONE	150	0
LDOR	3/19/91	USA	Raleigh	RDU	ASRS	INC	Large Transport	NONE	NONE	150	0
LDOR	6/29/00	USA	Joliet	JOT	NTSB	ACC	BE200	MINR	SUBS	170	0
LDOR	12/11/81	USA	San Juan	JSJ	AIDS	INC	DC10	NONE	NONE	300	0
LDUS	10/15/02	CANADA	Ontario	KONT	AIDS	INC	B747	NONE	MNOR	-50	0
LDUS	8/17/79	USA	Bethany	PWA	AIDS	ACC	Falcon 20	NONE	SUBS	-200	0
LDOR	7/20/04	USA	Tallahassee	TLH	ASRS	INC	DC9	NONE	MNOR	400	0
TOOR	11/15/88	USA	Minneapolis	999	NTSB	INC	DC9	NONE	UNK	330	0
LDUS	5/19/99	USA	New York	JFK	ASRS	INC	B767	NONE	NONE	-100	0
LDUS	12/22/79	USA	Denver	DEN	AIDS	INC	B727	NONE	MNOR	-50	0
LDUS	4/18/81	USA	Sand Point	SDP	AIDS	INC	YS11A	NONE	SUBS	-300	0
LDOR	12/19/97	USA	Palm Springs	PSP	ASRS	INC	MD80	NONE	NONE	25	0
LDOR	11/19/96	USA	Honolulu	HNL	ASRS	INC	Large Transport	NONE	NONE	175	0
LDOR	9/19/99	Ireland	Shannon	SNN	ASRS	INC	MD11	NONE	NONE		
LDOR	7/30/97	Italy	Florence	FLR	ADREP	ACC	ATR42	FATL	SUBS	394	0
LDOR	9/10/02	Canada	Gander	YQX	Canada TSB	ACC	DC8	NONE	NONE	900	0
LDOR	9/15/00	Canada	Ottawa	YOW	Canada TSB	INC	B727	NONE	NONE	234	0
TOOR	6/27/85	USA	San Juan	SJU	NTSB	ACC	DC10	SERS	SUBS	140	0
LDUS	8/31/96	USA	Lubbock	LBB	AIDS	INC	B727	NONE	MNOR	-10	0
LDUS	1/5/84	USA	Seattle	SEA	NTSB	INC	B727	NONE	MNOR	-360	0
LDOR	1/19/98	USA	Mekoryuk	MYU	ASRS	INC	Commercial	NONE	MNOR	355	40

Class	Date	Country	Location	Airport	Source	Type	Aircraft Model	H. INJ	Damage	Loc. X	Loc. Y
							Fixed Wing				
TOOR	1/27/78	USA	Nashville	BNA	AIDS	INC	B727	NONE	NONE	150	0
LDOR	11/23/87	USA	Nashville	BNA	AIDS	INC	B727	NONE	MNOR	50	0
LDOR	11/28/00	Canada	Fredericton	YFC	Canada TSB	INC	F28	NONE	NONE	320	0
LDUS	4/3/78	USA	Detroit	DTW	AIDS	INC	DC10	NONE	NONE	-50	0
TOOR	11/2/93	USA	Houston	HOU	AIDS	INC	CL600	NONE	NONE	200	0
LDOR	12/1/01	USA	Philadelphia	PHL	ASRS	INC	CE550	NONE	UNK	250	0
LDOR	7/14/04	Canada	Ottawa	YOW	Canada TSB	INC	ERJ145	NONE	MNOR	300	0
LDOR	7/23/00	Canada	Dorval	YUL	Canada TSB	ACC	B747	NONE	MNOR	700	0
TOOR	9/21/95	USA	Houston	HOU	AIDS	INC	LR25	NONE	MNOR	225	0
LDUS	8/25/04	USA	Venice	VNC	NTSB	ACC	CE550	NONE	SUBS	-30	0
LDOR	2/16/00	Japan	Sapporo	OKD	ADREP	ACC	YS11A	NONE	DEST		
TOOR	3/2/94	USA	Flushing	LGA	NTSB	ACC	MD 82	MINR	MNOR	500	0
TOOR	7/19/98	USA	Raleigh	RDU	ASRS	INC	B727	NONE	NONE	200	0

Appendix F – Database Rules

Detailed Event Info

ALL FIELDS	-2 Not Applicable (e.g. abort speed when a/c not aborted)
Approach Category Required	Assume VMC when a visual approach was required. Otherwise IMC and determine the category required according to decision height and visibility. If conditions above ILS Cat I, II and III, assume non-precision instrument approach required.
Approach Minimums Violated	Criteria based on Decision Height, Visibility (see an ILS categories table), aircraft fitment and pilot license Sometimes NTSB recorded Ceiling may be above minimums the accident report indicates another ceiling height, which is below minimums. In this case, if the accident report mentions that minimums have been violated, the violation is recorded in the database without changing the official NTSB ceiling height. Other minimum violations flagged and detailed in notes section.
Instrument Approach Type	For information only, data come directly from official reports, when available
Active/Passive Aircraft	In collision accidents, the active aircraft is that actively performing landing/take-off operations
Air Crash Controllability	Worse state during accident/incident sequence This is considered from a mechanical perspective. Therefore, in cases of hydroplaning, the aircraft is still considered "fully controllable" because it's the environmental factor (runway braking = none) which causes the braking effectiveness. A stall, however, is a physics issue and should be reflected in this field.
Stabilized Approach Achieved	This applies to ILS as well as non-ILS flights. Judgment should be used to determine if the approach is vertically and horizontally stabilized. Assume stabilized unless specific stabilization issues mentioned. Quantify deviance if possible in the notes section (e.g. height at threshold).
Late Runway Change/Decision	ATC directed runway change OR crew made late decision to use particular runway
Go-around	Related to accident airport/site only, not at previous airport from which the aircraft diverted Prior to event only, i.e. excludes touch & go cases
Notes	Take note of other minimums violated

Airport

Control Tower	Operating rather than physical existence
Runway Condition	Ice, standing water, snow, slush, rubber deposits = contaminated
Runway Slope (+ / - ,% or degree)	For the relevant runway and direction of operation If not given in the airport diagram use difference between the 2 thresholds. Source: http://avn.faa.gov/ap_diagrams.asp, www.airnav.com, www.worldaerodata.com
Temporary airfield works	Runway, taxiway works etc.
Runway threshold elevation (ft)	For the relevant end of the runway (i.e. take-off overrun and landing overrun = departure end) Source: http://avn.faa.gov/ap_diagrams.asp, www.airnav.com, www.worldaerodata.com
Runway Distance Available	For the relevant runway and operation, taking into account stopways and clearways; i.e. official take-off distance available or landing distance available.
Runway Braking Condition	5 standard semantic categories. Assume braking condition good unless otherwise mentioned Hydroplane: braking condition = none

Flight

Passenger load factor	Take into account passenger load factor only % -2 = Not Applicable (e.g. cargo flights) -1 = Unknown
Departure/Destination Country	Excludes fuelling/technical stops
Flight duration	Not recorded if fuel at time of crash known
Foreign O/D	Excludes fuelling/technical stops
Delay	No unless stated in the report
Diversion	Excludes aircraft that return to their origin airport after take-off
Maximum Certified Weight for Current Operation	Maximum Allowable Weight Calculated based on runway used (even if it is the wrong runway)
Was Actual Weight at Time of Crash Estimated	Estimated by ourselves (not NTSB)
Notes to make	Reasons for weight limitation (i.e. difference between max certified weight and max. allowable weight) e.g. short runway, hot & high Reason for diversion when applicable

Weather

The NTSB database figures are used for Ceiling Height, Wind Direction & Velocity, Gust (except when it is 0) and Visibility (except when it is 0) but NOT for RVR. However, in cases where meteorological conditions are cited as a factor in the accident report and the NTSB given observations are different from the most relevant observation as given in the accident report, the latter is used. Weather as reported in the pilot/operator report is considered generally more relevant than other NTSB or accident report sources.

Weather is often observed at the intended/ incident airport rather than where emergency was declared or failure occurred. It is acknowledged that even the NTSB data is taken from the nearest weather station and could be substantially different from the actual weather at the airport. This is taken into account by the local weather variations flag.

Always use actual data and not forecast data.

If runway aimed for was unknown, assume from wreckage site, wind direction and ATC instructions

All fields	If a range is given, take the maximum (or worse) condition e.g. gusts 4 – 6 knots, take 6 knots
Dew Point	-1 = unknown
Temperature	-1 = unknown
Gusts	If wind velocity is low, put Gust = 0 rather than Unknown or Not Applicable. -1 = unknown
Wind Direction	777 = variable -1 = unknown /not applicable
Wind Shear	Wind shear detected at time of accident or wind shear alert was effective
Wind Velocity	Calm set 0 knots -1 = unknown
Actual Weather Different to Pilot Expectations	Notes cases where there is significant discrepancy between expected and actual weather
Localized Weather Variations	Notes cases where there is significant discrepancy between weather on approach/climb and at the incident airport.
Ceiling Height	-3 = no ceiling -4 = indefinite ceiling/obscured -1 = unknown
RVR	If only available for another runway at the same airport at the same time, it is considered a good enough approximate. -1 = unknown
Visibility	-3 = unrestricted
Fog	Includes haze
Frozen precipitation	Excludes snow, icing conditions, which are separate flags
Icing conditions	As mentioned in accident report

Wreckage Info

All fields	For Landing accidents, measured from the landing threshold of intended runway For Take-off accidents, measured from the start of roll threshold X distance short of runway threshold –ve X distance beyond runway threshold (runway side) +ve Y distance +ve (right), -ve (left) -1 = Unknown /Not Applicable (e.g. undershoots that never reached the runway do not have runway exit location) Unless otherwise stated, assume distance given in report is measured from the airport reference point, then use available information to deduce X and Y distances to the runway threshold Source: http://www.fcc.gov/mb/audio/bickel/distance.html to help find the distance between 2 sets of co-ordinates Source: http://www.airnav.com for runway threshold co-ordinates Source: http://www.landings.com/_landings/pages/search/search_ap-ident.html for airport maps
Wreckage X distance	In case of displaced thresholds, X distance measured from displaced threshold
Wreckage Y distance	0 if it is reasonable to expect little lateral deviance from report/docket -1 (unknown) if lateral significant deviation confirmed but extent unknown
Wreckage Z distance (ft MSL)	Elevation difference between rwy threshold and wreckage site Above threshold +ve; below threshold –ve Source: http://www.airnav.com for runway threshold elevation
Point of First Impact	Defined as the location where aircraft first hit anything it should not have hit, including trees, fences etc. Overruns: runway exit point. Take-off & crash: Could be runway if touched down on rwy after lift-off X distance measured from landing threshold (landings) or start of roll threshold (take-off) In case of displaced thresholds, X distance measured from displaced threshold Z: Elevation difference between rwy threshold and POFI (if POFI is an obstacle then measure from impact point)
Angle of First Impact	Not applicable to overruns
Speed of First Impact	Overruns: same as runway exit speed
Number of Obstacles Hit	Accounted for in consecutive groups; e.g. tree, fence, tree = 3
Wreckage path slope	777=+ve slope/elevation; -777=-ve slope/elevation
Wreckage Path Surface Distance	Measured from POFI if obstacle hit/undershoot/take-off & crash Overruns: measured from runway exit point

Hit Terrain

Hit Terrain	This page focuses on vertical terrain rather than the horizontal terrain type, which is recorded in the wreckage path section in the Wreckage Info page. Includes terrain on which struck obstacles are situated Overruns: only relevant when significant terrain is hit (in most cases none)
ALL Fields	-1 = Unknown/ Not Applicable For Landing accidents, measured from the landing threshold of intended runway For Take-off accidents, measured from the start of roll threshold X distance short of runway threshold –ve X distance beyond runway threshold (runway side) +ve Y distance always +ve Z distanced: elevation difference with relevant runway threshold elevation Depth = Longest distance along rwy centerline Height= Largest elevation difference with rwy threshold Width = Longest distance perpendicular to rwy centerline 777=+ve slope/elevation; -777=-ve slope/elevation

Hit Obstacles

Obstacles	Obstacles defined as anything substantial enough to change aircraft's course (e.g. road embankment) as well as free-standing objects (e.g. tree) In cases of an overrunning aircraft falling off/hitting an embankment, depending if the aircraft's course is affected significantly, the embankment could be either an obstacle or just part of the wreckage path (a degree of subjectivity accepted). This is consistent with the definition of obstacle above.
ALL Fields	-1 = Unknown/Not Applicable For Landing accidents, measured from the landing threshold of intended runway For Take-off accidents, measured from the start of roll threshold X distance short of runway threshold –ve X distance beyond runway threshold (runway side) +ve Y distance always +ve Z = Elevation difference between rwy threshold and obstacle impact point Depth = Longest distance along rwy centerline Height= Largest elevation difference with rwy threshold Width = Longest distance perpendicular to rwy centerline 777=+ve slope/elevation; -777=-ve slope/elevation

Consequences

All fields	-1 = Unknown/Not Applicable
Consequence Area (m2)	Length measured from POFI/rwy exit point to final wreckage site / furthest debris scatter. Overruns: measured from runway exit point. Width measured between furthest debris scatter either side of wreckage path or the aircraft wingspan, whichever is greater Stretches to include where trees and other obstructions are hit, i.e. not only ground impact area In cases of undershoots then overrun, add consequence areas before runway and after runway exit.
Change of Terrain in Consequence Area	E.g. steep embankment (also recorded as obstacle) etc.

Injuries

ALL Fields	-1 = Not Applicable (e.g. when there are no cabin crew)
Total Injuries	Includes fatal injuries
Ground Injuries	Ground crew & traveling public injuries
Public Injuries	Third parties (non-aviation related)

Appendix G - Normal Operations Data

Many attempts to incorporate NOD in risk assessment fail because the available risk exposure data does not allow subdivision in movements based on risk factors of interest (Piers 1994, 1998a). Kirkland et al (2003a) pioneered the use of disaggregate NOD for assessing aircraft overrun risk using a limited sample of NOD.

One notable gap in previous research is the quantification and modeling of the criticality of meteorological risk factors to accident occurrence. The lack of data on flights' exposure to meteorological conditions meant traditional risk assessment had to rely on qualitative judgments (Eddowes et al. 2001) or simply ignore meteorological conditions as risk factors, as do most RSA policies. Although Enders acknowledged that adverse weather conditions is one of the most regularly cited factors in accident reports, he was unable to include the terms in his analysis (Enders et al. 1996). Kirkland also cited the lack of meteorological NOD as a major shortcoming of his work (Kirkland 2001a).

For this project exposure data on a range of meteorological parameters was used in the accident frequency modeling, including: ceiling height, visibility, crosswind, temperature, fog, precipitation, electric storm, snow, frozen precipitation and icing conditions. Other factors were also included when the statistical analysis demonstrated the significance of these additional parameters (e.g. aircraft weight, engine type, operation type). The objective was to provide a far more comprehensive analysis of risk factors relevant to airport risk assessment.

The Normal Operations Database

A number of alternatives were evaluated to gather appropriate NOD for this project. Unavailability, incompleteness and difficult access were only some of the hurdles that had to be overcome. A number of sources of NOD were considered for use in the current study including the ones in Table G-1.

Table G - 1 – Possible Sources of Normal Operations Data

System	Source	Major Problem
Flight data recorders	Aircraft operators FOQA program FAA Aircraft manufacturers NASA	Safety sensitivities and pilot union concerns, not capable of delivering the desired parameters
Airport operators	Landing fee information based on aircraft landing weight	Actual weight of the aircraft at landing is seldom recorded

A satisfactory solution was found in the data provided by FAA's Aviation Policy and Plans Office (APO). The APO hosts a number of online databases that record flight activity and associated information. Two of these were found to be useful sources of NOD. The first is the Aviation System Performance Metrics (ASPM), which provides take-off and landing counts at specific airports in fifteen-minute or hourly segments, including information on aircraft and operation type, runway orientation as well as certain meteorological parameters such as ceiling height and visibility. However, the database only covers fifty-five large and medium hub airports and using only this data this data would misrepresent actual traffic characteristics of normal flights and fail to match the accident database covering other types of airports.

The related Enhance Traffic Management System Counts (ETMSC) was therefore used instead. ETMSC provides hourly traffic counts for over 450 airports as well as the relevant traffic characteristics for individual flights, including aircraft, engine and operation type.

One of the key advantages of the ETMSC database is that, unlike specific airport or airline FOQA data, it encompasses a wide variety of airport sizes and includes commercial, air taxi, freight as well as general aviation flights. Therefore it was not necessary to collate multiple sources with potential compatibility issues to ensure that the flight population concerned was correctly represented.

However there is one limitation; ETMSC does not provide the associated weather and runway orientation information as does ASPM. Therefore a few supplementary sources were used to cover these data gaps.

While the accident database contains all relevant occurrences within the period of study, a sampling strategy was developed for collecting the appropriate sample of NOD. The prime concern was to gather a representative sample of the risk exposure for the overall normal flight population of interest.

Initially those airports for which crosswind calculation could not be carried out were filtered out. Because ETMSC does not provide meteorological information, supplementary sources of NOD must be used, as with visibility, ceiling height etc. However, unlike the latter factors, crosswind strength is dependent on the orientation of the flight path and must be calculated using runway orientation information. The solution was found by using airports with single or parallel runways and those with multiple non-parallel runways that only operate them in parallel or single configurations.

Random sampling of the ETMSC database was not considered appropriate due to the possibility of bias against airports of certain risk profiles, which could misrepresent the true risk exposure of normal flights. A stratified sampling strategy was hence developed, as shown in Appendix J, to select airports from which normal flights were sampled. Three stratification factors were used: airport size (hub and non-hub), FAA region and the presence or not of significant terrain near the airport. An airport is considered to be situated near significant terrain if the area within the planview exceeds

4,000 feet above the airport elevation, or if the terrain within a 6.0 nautical mile radius of the Airport Reference Point rises to at least 2,000 feet above the airport elevation.

The two airport classes, nine regions and two terrain categories theoretically lead to 36 strata from which the NOD sample should be drawn. However some of these were not available in any FAA Terminal Area Forecasts (TAF) from 2000 to 2005. These forecasts comprehensively includes FAA towered airports, federally contracted towered airports, non-federal towered airports as well as non-towered airports. It is therefore reasonable to assume that no airport exists under these strata. An example is a large hub in the central region in significant terrain. Eliminating these non-existent hypothetical strata resulted in 29 strata with actual airport traffic.

The 125 ETMSC airports suitable for NOD sampling were therefore split according to 29 strata. However, no airport fell under seven of these 29 strata. The limiting factor for five of them was significant terrain. For instance, none of the eligible ETMSC airports is an Alaskan non-hub airfield in significant terrain. Earlier elimination due to runway number or layout was responsible for the remaining two strata without sampling candidates. For example, all hubs in New England in normal terrain have multiple runways in non-parallel layouts.

The impact of the empty strata was considered before the described sampling strategy was accepted. From TAFs, it was calculated that all airports nationwide belonging to the seven empty strata collectively account for only 4.2 percent of the total relevant traffic from 2000 to 2005. This figure is considered sufficiently small on the overall representation of risk exposure of the great majority of relevant normal operations. Appendix K provides a list of airports sampled to obtain NOD for this study.

Clearly, it is impractical and unnecessary to use all operations from these sampled airports for analysis. Therefore only flights on the first day of February, May, August and November of 2002, 2003 and 2004 were sampled to constitute the final NOD sample for risk assessment. The selection of the four months allows seasonal variations in weather exposure to be accounted for.

The final procedure to obtain the NOD sample was to remove non-relevant data, including helicopters, piston engine aircraft, military and general aviation flights of aircraft under 12,500 lbs. Finally, some flights with incomplete data were also removed and the final NOD sample consisted of 242,420 flights. A sample of the NOD and the codes utilized for the information gathered for this study is shown in Tables G-2 and G-3. The full database for NOD is available on a CD that incorporates the accident database for ACRP 4-01.

Table G - 2 – Example Normal Operations Data

LOCID	YYYYMMDD	HOUR	FLT_TYPE	TERRAIN	HUB	USER_CLASS	ETMSARR	NEQPT_CLASS	NEQPT_TYPE	Wx Stratum	CEILING Ft	VIS Sm	TEMP	Fog	Icing	Elec. Storm	Frozen Precip	Snow	PRECIP FINAL	Light	XWIND Knts	Light2	PRECIP FINAL2	CEILING100FT	TEMP10C	DawnDusk
ADS	20040501	23	0	0	2	4	1	4	2	NHASWF	3000	10.00	11	0	0	0	0	0	0	2	0.57	1	0	30	1.1	0
ADS	20040501	23	1	0	2	4	1	4	2	NHASWF	3000	10.00	11	0	0	0	0	0	0	2	0.57	1	0	30	1.1	0
ADS	20020201	17	0	0	2	4	1	4	2	NHASWF	3000	10.00	9	0	0	0	0	0	0	2	0.48	1	0	30	0.9	0
ADS	20020201	17	0	0	2	1	1	4	2	NHASWF	3000	10.00	9	0	0	0	0	0	0	2	0.48	1	0	30	0.9	0
ADS	20020201	17	0	0	2	1	1	4	2	NHASWF	3000	10.00	9	0	0	0	0	0	0	2	0.48	1	0	30	0.9	0
ADS	20040501	22	0	0	2	1	1	4	2	NHASWF	3000	10.00	12	0	0	0	0	0	0	2	0.24	1	0	30	1.2	0
ADS	20020201	11	0	0	2	1	1	5	1	NHASWF	3000	10.00	7	0	0	0	0	0	0	1	0.53	0	0	30	0.7	0
ADS	20020201	11	0	0	2	4	1	4	2	NHASWF	3000	10.00	7	0	0	0	0	0	0	1	0.53	0	0	30	0.7	0
ADS	20020201	11	0	0	2	1	1	4	2	NHASWF	3000	10.00	7	0	0	0	0	0	0	1	0.53	0	0	30	0.7	0
ADS	20021101	9	0	0	2	4	1	4	1	NHASWF	1083	4.000	9	0	0	0	0	0	0	1	0.24	0	0	10.8	0.9	0
ADS	20021101	9	0	0	2	4	1	4	2	NHASWF	1083	4.000	9	0	0	0	0	0	0	1	0.24	0	0	10.8	0.9	0
ADS	20021101	8	0	0	2	4	1	4	2	NHASWF	1083	4.000	9	0	0	0	0	0	2	1	0.38	0	1	10.8	0.9	0
ADS	20021101	7	0	0	2	3	1	5	1	NHASWF	1280	5.000	9	0	0	0	0	0	0	1	0.38	0	0	12.8	0.9	0
ADS	20021101	7	0	0	2	4	1	4	2	NHASWF	1280	5.000	9	0	0	0	0	0	0	1	0.38	0	0	12.8	0.9	0
ADS	20030501	23	0	0	2	4	1	4	2	NHASWF	3000	10.00	23	0	0	0	0	0	0	2	0	1	0	30	2.3	0
ADS	20030501	23	0	0	2	4	1	4	2	NHASWF	3000	10.00	23	0	0	0	0	0	0	2	0	1	0	30	2.3	0
ADS	20040501	19	0	0	2	4	1	4	1	NHASWF	3000	10.00	15	0	0	0	0	0	0	4	0	1	0	30	1.5	1
ADS	20040501	19	0	0	2	1	1	4	2	NHASWF	3000	10.00	15	0	0	0	0	0	0	4	0	1	0	30	1.5	1
ADS	20040501	18	1	0	2	4	1	4	2	NHASWF	3000	10.00	16	0	0	0	0	0	0	1	0	0	0	30	1.6	0
ADS	20040501	18	0	0	2	4	1	4	2	NHASWF	3000	10.00	16	0	0	0	0	0	0	1	0	0	0	30	1.6	0
ADS	20040501	15	0	0	2	4	1	5	1	NHASWF	1575	10.00	14	0	0	0	0	0	0	1	0	0	0	15.7	1.4	0
ADS	20040501	15	0	0	2	1	1	4	2	NHASWF	1575	10.00	14	0	0	0	0	0	0	1	0	0	0	15.7	1.4	0
ADS	20040501	15	0	0	2	1	1	4	2	NHASWF	1575	10.00	14	0	0	0	0	0	0	1	0	0	0	15.7	1.4	0
ADS	20020201	13	0	0	2	1	1	4	2	NHASWF	3000	10.00	9	0	0	0	0	0	0	1	0	0	0	30	0.9	0

Table G - 3 – Codes Used for NOD

Field	Notes
LOCID	Airport IATA/FAA code
YYYYMMDD	Date
HOUR	Local Time
FLT_TYPE	Foreign Origin/destination = 1; Domestic = 0
TERRAIN	Significant terrain (code 1) if the terrain within the plan view exceeds 4,000 feet above the airport elevation, or if the terrain within a 6.0 nautical mile radius of the Airport Reference Point rises to at least 2,000 feet above the airport elevation.
HUB	1 Hub; 2 Non-hub
USER_CLASS	1 Commercial; 2 Air Taxi; 3 Freight; 4 GA
ETMSARR	Arrival counts
ETMSDEP	Departure counts
NEQPT_CLASS	1 A/B (255000lbs+/B757 Heavy); 2 C(41000-255000lbs Large Jet); 3 D(41000-255000lbs Large commuter); 4 E (12500-41000lbs Medium); 5 F (<12500lbs Small)
NEQPT_TYPE	1 Turboprop; 2 Jet
Wx Stratum	For stratified sampling purposes
CEILING Ft	Ceiling in feet
VIS Sm	Visibility capped Max 10SM
TEMP	Degree C
Fog	Yes = 1; No = 0
Icing	Yes = 1; No = 0
Elec. Storm	Yes = 1; No = 0
Frozen Precip	Yes = 1; No = 0
Snow	Yes = 1; No = 0
PRECIP FINAL	0 None; 1 Trace/Light; 2 Moderate; 3 Heavy
Light	1 Day; 2 Night; 3 Dawn; 4 Dusk
APP XIND Knts	In knots
DEP XWIND Knts	In knots
Light2	0 Day; 1 Night/Dawn/Dusk
PRECIP FINAL2	0 None; 1 Trace/Light/Moderate/Heavy
CEILING100FT	Ceiling capped Max 3000ft
TEMP10C	
DawnDusk	0 Day/Night; 1 Dawn/Dusk

Appendix H - Sampled Airports

Airport Code	Sampling Stratum	Runway Layout	Runway Operative Configuration
ADS	NASWF	Single	
ADW	NAEAF	2 Parallel	
ASE	NANMT	Single	
ASG	NASWF	Single	
ASH	NANEF	Single	
ATL	HASOF		Parallel
AUS	HASWF	2 Parallel	
AVL	NASOT	Single	
BCT	NASOF	Single	
BET	NAALF	Single	
BFI	NANMF	2 Parallel	
BFL	NAWPT	2 Parallel	
BGR	NANEF	Single	
BKL	NAGLF	2 Parallel	
BLI	NANMF	Single	
BOI	HANMT	2 Parallel	
CGF	NAGLF	Single	
CHD	NAWPF	2 Parallel	
CKB	NAEAF	Single	
CLE	HAGLF		Parallel
CMH	HAGLF	2 Parallel	
CWF	NASWF	Single	
DTW	HAGLF		Parallel
EGE	NANMT	Single	
EMT	NAWPT	Single	
ENA	NAALF	Single	
EUG	HANMT	2 Parallel	
EWR	HAEAF		Parallel
FAI	HAALT	2 Parallel	
FAT	HAWPF	2 Parallel	
FLG	NAWPT	Single	
FYV	NASWF	Single	
GCN	HAWPF	Single	
GLH	NASOF	2 Parallel	
GSP	HASOF	Single	
GYR	NAWPF	Single	
HEF	NAEAF	2 Parallel	
IND	HAGLF		Parallel
ISO	NASOF	Single	
JNU	HAALT	Single	
LAW	NASWF	Single	
LAX	HAWPF		Parallel
LGA	HAEAF		Parallel
LVK	NAWPF	2 Parallel	

Airport Code	Sampling Stratum	Runway Layout	Runway Operative Configuration
LWB	NAEAF	Single	
MCI	HACEF		Parallel
MCO	HASOF		Parallel
MDT	HAEAF	Single	
MSP	HAGLF		Parallel
MYR	HASOF	Single	
NQA	NASOF	Single	
OJC	NACEF	Single	
ONT	HAWPT	2 Parallel	
OXC	NANEF	Single	
OXR	NAWPT	Single	
PDX	HANMT		Parallel
PHX	HAWPF		Parallel
PSP	HAWPT	2 Parallel	
RNT	NANMF	Single	
SAW	NAGLF	Single	
SCK	NAWPF	2 Parallel	
SEA	HANMF		Parallel
SFF	NANMT	2 Parallel	
SFO	HAWPF		Parallel
SJC	HAWPT		Parallel
SLC	HANMT		Parallel
SMO	NAWPT	Single	
SNA	HAWPT		Parallel
SQL	NAWPF	Single	
SUN	NANMT	Single	
SUS	NACEF	2 Parallel	
TEB	NAEAF		Single
TIW	NANMF	Single	
TTD	NANMT	Single	
TUP	NASOF	Single	
TUS	HAWPT		Parallel
TYS	HASOF	2 Parallel	
TZR	NAGLF	Single	

Appendix I – Stratified Sampling Strata & Weights

Stratum	TAF Relevant Traffic (2000-2005 incl.)	Stratum share of total TAF relevant traffic	Sampled flights	Stratum share of total sampled flights	Weight
HAALF	1,250,158	0.65%	0	0.00%	N.A.
HAALT	929,768	0.48%	1243	0.51%	0.94
HACEF	4,932,783	2.57%	5322	2.20%	1.17
HAEAF	21,567,290	11.24%	26028	10.74%	1.05
HAGLF	20,049,157	10.45%	50604	20.87%	0.50
HANEF	4,731,238	2.47%	0	0.00%	N.A.
HANMF	6,089,146	3.17%	11403	4.70%	0.67
HANMT	4,279,446	2.23%	20483	8.45%	0.26
HASOF	29,120,284	15.17%	43886	18.10%	0.84
HASWF	14,202,438	7.40%	3899	1.61%	4.60
HASWT	753,505	0.39%	0	0.00%	N.A.
HAWPF	14,584,951	7.60%	47943	19.78%	0.38
HAWPT	8,857,981	4.62%	16271	6.71%	0.69
NAALF	4,118,123	2.15%	427	0.18%	12.18
NAALT	1,093,992	0.57%	0	0.00%	N.A.
NACEF	2,423,410	1.26%	965	0.40%	3.17
NAEAF	7,420,230	3.87%	4513	1.86%	2.08
NAEAT	24,256	0.01%	0	0.00%	N.A.
NAGLF	15,294,362	7.97%	1098	0.45%	17.60
NANEF	3,306,238	1.72%	1034	0.43%	4.04
NANET	1,722	0.00%	0	0.00%	N.A.
NANMF	4,398,816	2.29%	1637	0.68%	3.39
NANMT	2,545,756	1.33%	1589	0.66%	2.02
NASOF	8,657,697	4.51%	573	0.24%	19.09
NASOT	133,284	0.07%	750	0.31%	0.22
NASWF	5,104,589	2.66%	1134	0.47%	5.69
NASWT	232,655	0.12%	0	0.00%	N.A.
NAWPF	2,890,900	1.51%	248	0.10%	14.73
NAWPT	2,908,415	1.52%	1370	0.57%	2.68
TOTAL	191,902,590	100.00%	242420	100.00%	

Stratum Key:

First letter:
H = Hub
N = Non-hub

2nd, 3rd, 4th letters:
AAL = Alaska Region
ACE = Central Region
AEA = Eastern Region
AGL = Great Lakes Region
ANE = New England Region
ANM = Northwest Mountain Region
ASO = Southern Region
ASW = Southwest Region
AWP = Western Pacific Region

Final letter:
T = Significant Terrain
F = Non-significant Terrain

Appendix J - Calculation of Relevant Terminal Area Forecast Traffic

Identifying the relevant traffic from Terminal Area Forecasts (TAFs) is important for deriving the weights to be applied to each stratum after stratified sampling because TAF's coverage goes beyond that of the population of flights of interest as defined by the accident database filtering criteria. TAF breaks down traffic into Air Carrier, Air Taxi & Commuter, General Aviation (GA) and Military flights. Whereas itinerant Air Carrier and Air Taxi & Commuter traffic is clearly relevant and Military operations not, only a portion of GA traffic is pertinent to the current study. The accident database only includes GA flights that involve aircraft of over 12,500lbs.

The 2002 FAA General Aviation and Air Taxi Activity (GAATA) survey was used to identify the portion of itinerant GA flights that is within the scope of the present research. GAATA breaks down GA traffic by aircraft type. The relevant aircraft types were first identified. These are 2 Engine Turboprops, "Other" Turboprops, 2 engine Turbojets and "Other" turbojets (i.e. not 2 engine). Other aircraft types, such as single engine turboprops and turbojets and rotorcraft, were considered irrelevant.

For each aircraft type, GAATA gives a breakdown of the fleet according to primary use (but not by FAA region). Four uses were considered relevant to the study. These are Business, Corporate, Air Tours and Sightseeing. Other uses such as Aerial Observation and External Load were deemed irrelevant. Air Taxi operations were not considered relevant because they are already explicitly identified and included in TAF. The following table shows the statistics for the relevant aircraft types and their primary use breakdown.

Table J - 1 – Aircraft use

Aircraft Type	Fleet Size	Business	Corporate	Air Tours	Sightseeing	Proportion of fleet in relevant use
TBP 2 Engine	5,703	1,241	2,386	0	0	
% of fleet		21.8%	41.8%	0.00%	0.00%	**63.6%**
Turboprop Other	30	0	0	0	0	
% of fleet		0.00%	0.00%	0.00%	0.00%	**0.00%**
Turbojet 2 Engine	7,655	948	5,368	0	0	
% of fleet		12.4%	70.1%	0.00%	0.00%	**82.5%**
Turbojet: Other	701	170	323	0	0	
% of fleet		24.2%	46.1%	0.00%	0.00%	**70.3%**

The share of each fleet in relevant use was then applied correspondingly to the number of landings performed by each aircraft type per FAA region[1]. This yielded an approximate number of relevant GA landings in each FAA region, as shown below.

Table J - 2 – Percentage of operations by FAA Region

FAA Region	**Proportion of Ops**
Alaskan	1.75%
Central	8.73%
Eastern	9.29%
Great Lakes	17.82%
New England	5.64%
Northwest	4.38%
Southern	6.92%
South Western	5.20%
Western-Pacific	3.93%
Overall	7.92%

Because the regional landings data is only broken down by aircraft type and region but not by primary use, the calculation assumes that the proportion of fleet in relevant use computed for each aircraft type (identified by their primary use) approximates the proportion of relevant landings of the respective aircraft types. Additionally, it was assumed that figures on the proportion of fleet in relevant use vary little from region to region.

The regional rates above were then applied to the TAF itinerant GA traffic statistics accordingly to deduce the number of relevant GA operations in each region and thus the total normal GA traffic that is relevant to the current study.

[1] The GAATA landing statistics includes air taxi aircraft but excludes commuter aircraft.

Appendix K - Normalization Procedures

As mentioned in the body of this report, a normalization technique was used to transform the data to a standard nominal airport. In this study corrections were applied to the wreckage location to make data under different operation conditions and aircraft performance comparable.

Normalization creates a larger pool of relevant and comparable data for the model building. Results from the models built with normalized data can then be applied to specific airports through de-normalization.

The standard airport is defined as an airport at sea level, International Standard Atmosphere (ISA), with a level, hard, infinitely long runway (Kirkland, Caves et al., 2003). In the study it was necessary to extend this definition to include the infinite runway being surrounded on all sides by a flat hard pavement surface.

Given this information it was possible to define specific procedures for normalizing different aspects of the accident data. The following normalization procedures developed for this project are described in this Appendix:

- Distance available relative to distance required
- Distances for aircraft performance
- Distances for type of terrain
- Point of First Impact (undershoots)
- Weight

Distance Available / Distance Required

Accident Parameters	Landing Threshold, Landing Distance Available, Takeoff Distance Available.
Data Requirements	Distance required and declared runway distance.
Procedure	Report the distance in terms of a percentage of the distance required.

<u>Example Calculations</u>

$$\text{Normalized Landing Distance} = \frac{\text{Landing Distance Available}}{\text{Landing Distance Required}} \times 100$$

$$\text{Normalized Takeoff Distance} = \frac{\text{Takeoff Distance Available}}{\text{Takeoff Distance Required}} \times 100$$

<u>Missing Data</u>

The most common problem with normalization of any parameter within the accident database is the lack of the required distance for that particular accident.

The best data source to obtain required distance information is the specific aircraft flight manual, normally available at the FAA and the UK CAA libraries. Most aircraft / operators registered in a particular country place a copy of the flight manual in these libraries.

In calculating the required distance from the flight manual data, the worst case scenario was used. There are a number of reasons for this; principally the fact that there is no way of knowing how the airline or the pilot actually calculated the required distance on the day of the aircraft accident since the detailed information is not available.

When using flight manuals, it is important to check for any corrections required for different runway conditions (i.e. wet / contaminated), runway slopes etc.

When the flight manual was unavailable, an alternative data source was used. The Flight International publication produces listing of aircraft data annually. This data contains required distance information at difference environmental conditions (ISA, ISA + 5000ft) etc. and was used to apply ICAO corrections for elevation, temperature and slope or alternatively using the different data points and interpolating to the accident condition.

Distances Adjusted for Aircraft Performance

Accident Parameters	Distance available, wreckage path length
Data Requirements	Wreckage distances from threshold, elevation, temperature, runway slope
Procedure	Report the distance in terms of a percentage of the distance required.

The following procedures use the ICAO calculations to correct a given required distance for differences in slope, elevation and temperature. These factors affect aircraft performance and are used in this study to normalize these distances to standard sea level conditions (15 deg C), sea level, no slope and no wind).

Local Factor	**Unit**	**Reference**	**Adjustment**
Elevation (E)	1000 ft	E = 0 ft (sea level)	$F_e = 0.07 \times E + 1$
Temperature (T)	deg C	T = 15 deg C	$F_t = 0.01 \times (T - (15 - 1.981\ E) + 1$
Slope (S)	%	S = 0 %	$F_s = 0.1 \times S + 1$

Example:

Conditions	**Parameter**	**Value**
Reference	Elevation (m)	0.00
	ISA Temperature (deg C)	15
	Slope	0.00

	Required Takeoff Distance for standard conditions (m)	1700
	Required Landing Distance (m)	2100
Accident	Elevation (m)	150
	Temperature (deg C)	24
	Runway Slope (%)	0.5

- Correction for Elevation (Takeoff)
  (1700 x 0.07 x 150/300) + 1700 = 1759.5 m

- Correction for Elevation (Landing)
  (2100 x 0.07 x 150/300) + 2100 = 2073.5 m

- Correction for Temperature and Elevation (Takeoff)
  (1759.5 x (24 – 14.025) x 0.01) + 1759.5 = 1935 m

- Correction for Temperature and Elevation (Landing)
  (2073.5 x (24 – 14.025) x 0.01) + 2073.5 = 2280 m
- Correction for Temperature, Elevation and Slope (Takeoff)
  (1935 x 0.5 x 0.1) + 1935 = 2032 m

- Correction for Temperature, Elevation and Slope (Landing)
  (2280 x 0.5 x 0.1) + 2280 = 2394 m

Distances Adjusted for Type of Terrain

Accident Parameters	Final wreckage location (x, y and z distance)
Data Requirements	o Point of first impact, impact angle, impact speed and impact heading. o Wreckage path surfaces o Obstacle data o Landing / takeoff distance required.
Procedure	o Adjust for different types of ground surface over which an aircraft may travel over between the point of first impact and final wreckage location. o Adjust for presence of obstacles that may have altered the path of the crashing aircraft or significantly slowed it down. o Correct for the effects of any change in terrain, such as a significant slope that may have had an effect on the deceleration of the aircraft. o Correct for the performance of individual aircraft (elevation, temperature and runway slope).

The terrain that an aircraft travels over during a crash, whether it is an undershoot, overrun, veer off or other crash just after takeoff, has a great effect on the final location of the wreckage.

In order to normalize the wreckage final location there are certain data that are required. These include:

- The wreckage final location, given as x (the distance along the runway centerline), y (the perpendicular distance from the runway centerline) and z (the change in elevation), measured from the runway threshold.
- The speed at which the first impact occurred (i.e. at the point of first impact)
- In the case of flight into terrain, the point of first impact, and the angle of flight relative to the runway plane.
- The line of flight heading at the point of first impact.
- The available and required distances for runway length.

The main tool used in the normalization of wreckage location is a model of aircraft deceleration over different types of terrain, which developed by Kirkland, Caves et al. in 2004. The terrain deceleration model predicts the ground distance covered by the aircraft between the point of first impact and the final wreckage location given an initial speed and the type of ground being covered. The model utilizes data from aircraft accident reports and dockets and the basic equation:

$$a = \frac{V^2 - u^2}{2s}$$

Where:

a	Is the acceleration
V	Is the final velocity
u	Is the initial velocity
s	Is the distance traveled

In the study by Kirkland, Caves et al., 2004, a regression on 74 data points was performed and this yielded the following equation:

$$a = p + q(u)$$

Where:

a	Is the acceleration (m/s^2)
p	A parameter derived from the regression (see table below)
q	Constant across all equations (q = –0.06749)
u	The initial speed (m/s)

Ground Type	Value of p
Wet Grass / Dry Grass / Pavement	-0.0185
Mud / Gravel	-2.8065
Obstacles / Water	-8.5365

When the initial speed (i.e. the ground speed at the point of first impact) and the initial direction are known, the normalized wreckage final location can be calculated using the terrain deceleration model and the value of p for pavement to get the acceleration and then the other equation to calculate the distance traveled. However, when these values are not known, but the distance traveled between the point of first impact and the final wreckage location and the ground that it traveled over, the terrain deceleration model can be used along with the equation stated earlier to calculate the initial speed and then the model can be used in the normal way to calculate the distance traveled.

This model works well for overruns but the values for p are not intuitive. It is thought that this could be for a number of reasons;

- There wasn't sufficient an amount of data used to generate the model
- The effects of aerodynamics, reverse thrust braking and other factors are greater than was first thought.

The other drawback of the model presented is the way in which it accounts for obstacles effecting the deceleration of the aircraft, i.e. the model only accounts for the existence of obstacles. However, common sense would dictate that for instance a localizer aerial would have little to no effect on aircraft deceleration where a concrete building would.

Missing Data

If the required distance is unavailable this can dealt with as described earlier using aircraft performance factors. If detailed obstacle information is unavailable, it should be possible to read the accident description and infer some information about the obstacle data.

Finally, it is clear that the most important piece of information that is required for the normalization of the wreckage final location is the point of first impact, this is especially the case for undershoots. Unfortunately it is very difficult to deal with a missing point of first impact information, except for its description.

Point of First Impact (Undershoots)

Accident Parameters	Point of First Impact x, y and z distances, impact angle and crash aircraft heading
Data Requirements	Runway directions, required distance
Procedure	The normalization of point of first impact requires the adjustment of the x and y distances to account for the z distance.

Formula for Normalizing Point of First Impact

The calculation works out the required change in the x distance and y distance to normalize the z distance. Below are shown the two calculations required.

$$\Delta x = \frac{z}{\tan\theta} \times \sin(h)$$

$$\Delta y = \frac{z}{\tan\theta} \times \cos(h)$$

Where:

Δx	Is the change in x distance
Δy	Is the change in y distance
θ	Is the angle with the ground plane
h	Is the angle with the runway centerline

Once the required changes are calculated, these can be applied to the point of first impact x and y. These two numbers are then converted in the same way as the distances in the previous section to given a normalized point of first impact.

Missing Data

The three key parameters here are the angle with the ground plane (the impact angle), the angle with the runway centerline (derived from the aircraft crash heading and the runway heading) and the z distance.

If there is no data available for these parameters then it is possible in a number of cases to derive an estimate for these values from the description of the accident itself.

Weight

Accident Parameters	Weight at time of crash
Data Requirements	Max allowable weight for operation
Procedure	The basic procedure is to put the weight at the time of the crash as a percentage of the maximum allowable weight.

Formula for Normalizing Weight

$$\text{Normalized Weight} = \frac{\text{Weight at time of crash}}{\text{Maximum allowable weight}} \times 100$$

Missing Data

Both the weight at the time of the crash, and the maximum allowable weight are often not available in the accident record.

There are alternatives for estimating the weight at the time of the crash by utilizing the takeoff weight, the takeoff fuel load and a source of fuel consumption data. The Flight International aircraft data source mentioned earlier contains payload range information that is essentially based on fuel consumption.

Appendix L – Direct Costs of Accidents

Cost of Investigation

Allocated Federal costs by type of accident investigation and entity incurring the cost are reported in Table L-1. The weighted cost is also reported because some air carrier accidents are followed by NTSB major investigations and others by field office regular investigations. It is a weighted average cost of major and field office regular air carrier investigations. Similarly, a general aviation average is presented. It is a weighted average of NTSB field office regular investigations and limited investigations where the weights are the respective number of such investigations conducted.

Table L - 1 – Cost of Accident Investigations

Type of Investigation	NTSB	FAA	# of Accidents 1991-2002
Major	$1,931,800	$2,613,500	59
Average			
Air Carrier	$110,300	$168,100	1,551
General Aviation	$7,700	$23,900	23,172

Based on Table 3, the average investigation cost for major accident for the assessments conducted by FAA and NTSB is close to $4.5 million. Major investigations are conducted primarily for major air carrier accidents involving numerous fatalities and substantial property damage. In the accident database created for this project there are seven accidents fulfilling such criterion. For this group it was estimated that the cost of investigation represents 1.73% of the total accident cost.

The remaining accidents were divided into two additional groups; one comprising General Aviation aircraft and another including the remaining air carrier accidents. For air carriers, it was assumed the investigation represents 4.03% of the total cost; while for GA the rate is only 0.45%, based on the same approach used for major accidents and using the values shown on Table 1.

Value of Life and Injury

Guidance furnished by the Office of the Secretary of Transportation (OST) via memorandum dated January 29, 2002, provides recommendations on the treatment of the values of life and injury in economic analyses for all modes of transport. It specifies that values of life and injury be based on the “willingness to pay” (WTP) by society for reduced risks of fatalities and injuries.

WTP is the theoretically correct approach to valuing all benefits arising from public investments or regulatory actions including fatalities and injuries avoided as a result of aviation accident risk reduction. WTP values the risk of injury or loss of life because it is the maximum value of other goods and services that individuals would be willing to forgo and still be as well off after the introduction of an accident risk reduction as they were before it.

Value of Life

The latest OST guidance (2002) establishes a minimum value of $3 million per fatality averted. This $3 million value, and the injury values based on it, as presented below, are used in all FAA analyses.

Value of Injury

OST guidance established a procedure for valuing averted injuries based on the current value of life and the Abbreviated Injury Scale (AIS). AIS is a comprehensive system for rating the severity of accident-related injuries that recognizes six levels of injury severity. However, most frequently, aviation injuries are reported by the number of victims suffering "serious" and "minor" injuries as defined by ICAO.

To calculate economic values for the ICAO serious and minor injury categories, the Office of Aviation Policy and Plans (APO) analyzed aviation injury data maintained by the NTSB that contain both ICAO and complete AIS injury codes. AIS values for all injuries sustained by accident victims in each ICAO category were summed and then divided by the number of victims in each category to determine per victim WTP values as shown in Table L-2.

Table L - 2 – Average Per Victim Injury Values for Serious and Minor Injuries (2001 US Dollars)

ICAO Code	WTP Values	Emergency/Medical	Legal/Court	Total Value
Minor	$ 37,900	$ 2,300	$2,700	$42,900
Serious	$ 536,000	$ 31,300	$ 13,400	$ 580,700

Aircraft Damage Costs

The cost of damage to aircraft in aviation accidents is borne directly by operators and indirectly by users and society in the form of higher fares and costs.

For the purpose of evaluating the cost of aircraft replacement, a destroyed aircraft is assigned the value of a replacement. The assumption is consistent with the opportunity cost of the loss of the use of a typical aircraft; the value of a new aircraft would overstate the typical loss. Even though a destroyed aircraft might be replaced by a new aircraft, the new aircraft provides additional value over the one it replaces. The aircraft values provided in the report are summarized on table 5 and 7, and are based on transactions in the market for used aircraft.

Air Carriers - Replacement

Replacement values for air carriers were derived from a proprietary database developed by Aviation Specialists Group (AVSPEC). The average value was developed using an estimated value for each aircraft delivered in a given year, and then aggregating these values into the economic values aircraft categories. Table L-3 summarizes these values.

Air Carriers - Restoration

Restoration costs presented in Table L-4 were estimated for commercial air carriers by analysis of the CASE database developed by Airclaims, Inc. The database covers commercial aircraft accidents throughout the world, and includes the insured hull value of the aircraft and the value of the claim.

The NTSB classifies aircraft involved in accidents as “destroyed,” having “substantial damage,” having “minor damage,” or having “no damage.” The cost incurred as a result of “minor damage” to aircraft is generally a negligible percentage of the market value and was not evaluated in the GRA report. An aircraft with “substantial damage” is one that is damaged but repairable; industry data provide a means of estimating the relationship between the cost of damage and the total value of the aircraft.

General Aviation – Replacement

Replacement values for general aviation aircraft are shown in Table L-5 and were based on a method similar to that used for commercial air carriers. The primary source of data was the Aircraft Bluebook - Price Digest (Summer, 2003). For aircraft types not covered in this reference, the 2002-2003 Aircraft Types and Price Guidelines was utilized.

General Aviation - Restoration

Restoration values for general aviation aircraft were estimated using the data from Airclaims and AVEMCO Insurance Company, as shown in Table L-6. The values are reported by the economic values category because a further breakdown by aircraft type is not feasible.

Table L - 3 – Estimated Market Values of Air Carrier Aircraft (2003 $)

Economic Values Category	Air Carrier- Passenger			Air Carrier- Cargo		
	Number of Aircraft	Weighted Average Base Value (US$ Million)	Weighted Average Estimated Current Market Value (US$ Million)	Number of Aircraft	Weighted Average Base Value (US$ Million)	Weighted Average Estimated Current Market Value (US$ Million)
2-Engine Narrow-Body	3913	16.47	13.67	128	14.99	11.23
2-Engine Narrow-Body	554	49.24	42.26	177	26.35	23.03
3-Engine Narrow-Body	368	0.71	0.71	348	1.08	1.02
3-Engine Narrow-Body	169	7.77	6.44	163	20.22	16.90
4-Engine Narrow-Body	50	0.32	0.32	128	2.92	2.92
4-Engine Narrow-Body	133	38.42	30.02	121	27.79	19.33
Regional Jet Under 70 Seats	976	14.07	13.23	NR	NR	NR
Regional Jet 70 to 100 Seats	101	14.99	13.40	NR	NR	NR
Turboprop under 20 Seats (part 23)	1147	0.48	0.56	NR	NR	NR
Turboprop under 20 Seats (part 25)	112	0.10	0.10	NR	NR	NR
Turboprop with 20 or more Seats	1143	1.95	2.19	NR	NR	NR

Table L - 4 – Restoration Costs – Air Carrier Aircraft

Economic Values Category	Air Carrier- Passenger				Air Carrier- Cargo			
	Number of Aircraft	Average of Hull Value US$ M	Average of Gross Hull Loss US$ M	Loss/ value (%)	Number of Aircraft	Average of Hull Value US$ M	Average of Gross Hull Loss US$ M	Loss/ value (%)
2-Engine Narrow-Body	128	23.6	3.5	15%	NR	NR	NR	NR
2-Engine Narrow-Body	50	65.1	7.4	11%	2	50.5	27.2	54%
3-Engine Narrow-Body	87	21.3	3.9	18%	6	5.3	1.7	33%
3-Engine Narrow-Body	19	66.7	7.3	11%	7	63.0	5.1	8%
4-Engine Narrow-Body	4	5.3	1.8	33%	25	$7.9	1.7	22%
4-Engine Narrow-Body	48	82.7	8.5	10%	15	62.7	7.0	11%
Regional Jet Under 70 Seats	5	17.7	1.4	8%	NR	NR	NR	NR
Regional Jet 70 to 100 Seats	7	20.7	1.6	8%	1	19.7	1.3	6%
Turboprop under 20 Seats (part 23)	40	2.4	0.4	15%	17	1.0	0.5	45%
Turboprop under 20 Seats (part 25)	NR	NR	NR	NR	NR	NR	NR	NR
Turboprop with 20 or more Seats	127	5.5	1.3	24%	19	1.8	0.6	36%

Table L - 5 – Estimated Market Value for General Aviation Aircraft (2003 $)

Economic Values Category	Certification	All Years					
		Number of Aircrafts	Average Value / Aircraft US$	Minimum Value / Aircraft US$	Maximum Value / Aircraft US$	Standard Deviation of Aircraft Value US$	Average Aircraft Age
Piston engine, 1 to 3 seats (<200hp)	Part 23	33,050	24,249	4,000	135,000	4,970	40
Piston engine, 1 to 3 seats (>200hp)	Part 23	6,079	123,843	18,000	535,000	32,478	33
Piston engine, 4 to 9 seats (<200hp)	Part 23	54,352	46,095	14,500	225,000	4,530	33
Piston engine, 4 to 9 seats (>200hp)	Part 23	49,993	114,594	30,000	685,000	14,832	30
Piston engine, 4 to 9 seats, 2 engines	Part 23	16,783	152,680	33,000	900,000	21,699	30
Piston engine, 10 or more seats	Part 23	801	137,688	74,000	290,000	19,632	34
Turboprop, 1 to 9 seats, 1-engine	Part 23	1,004	803,011	143,000	2,100,000	226,704	8
Turboprop, 1 to 9 seats, 2-engine	Part 23	2,150	517,788	63,000	1,850,000	112,440	24
Turboprop, 10 to 19 seats	Part 23	3,650	1,222,412	325,000	4,650,000	243,009	19
Turboprop, 20 or more seats	Part 25	219	2,014,790	194,500	9,500,000	1,043,081	22
Turbofan/jet 2-engine, <12000 lbs	Part 23	2,029	2,568,083	370,000	6,300,000	248,989	14
Turbofan/jet 2-engine, >12000 and <65000 lbs	Part 25	4,969	5,851,422	580,000	2,3500,000	1,146,736	12
Turbofan/jet 2-engines, >65000 lbs	Part 25	1,204	17,549,160	2,800,000	32,000,000	1,639,628	13
Rotorcraft Piston <6000 lbs	Part 27	2,326	135,430	19,800	338,000	31,342	16
Rotorcraft Turbine <6000 lbs	Part 27	3,640	606,739	72,000	5,000,000	195,610	18
Rotorcraft Piston >6000 lbs	Part 29	25	NA	NA	NA	NA	NA
Rotorcraft Turbine >6000 lbs	Part 29	657	1,888,082	430,000	6,000,000	605,067	23
Other		28,313	NA	NA	NA	NA	NA
All Aircraft		211’244	361,943	4,000	32,000,000	368,204	31

Table L - 6 – General Aviation Restoration Costs (2003 $)

Economic Values Category	Certif.	Number of Aircraft	Average of Hull value US$	Average of Hull Damage US$	Damage /Value	Aircraft w/ Hull Value Data	Aircraft w/ Hull Damage Data	Source
Piston engine, 1 to 3 seats(<200hp)	Part 23	610	38,637	11,714	30%	584	554	AVEMCO
Piston engine, 1 to 3 seats(>200hp)	Part 23	76	111,164	20,516	18%	73	70	AVEMCO
Piston engine, 4 to 9 seats(<200hp)	Part 23	1200	50,326	10,981	22%	1171	1130	AVEMCO
Piston engine, 4 to 9 seats(>200hp)	Part 23	953	104,269	18,916	18%	936	902	AVEMCO
Piston engine, 4 to 9 seats, 2 engines	Part 23	327	125,382	30,010	24%	320	307	AVEMCO
Piston engine, 10 or more seats	Part 23	2	232,500	24,364	10%	2	2	AVEMCO
Turboprop, 1 to 9 seats, 1 engine	Part 23	NR	803,011	163,650	20%	NR	NR	N/A
Turboprop, 1 to 9 seats, 2 engines	Part 23	NR	517,788	105,523	20%	NR	NR	N/A
Turboprop, 10 to 19 seats	Part 23	1	900,000	6,607	1%	1	1	AVEMCO
Turboprop, 20 or more seats	Part 25	NR	2,014,790	410,605	20%	NR	NR	N/A
Turbofan/jet 2-engines, <12000 lbs	Part 23/25	NR	2,568,083	523,364	20%	NR	NR	N/A
Turbofan/jet 2-engines, >12000 and <65000 lbs	Part 25	67	4,532,030	933,119	21%	66	67	Airclaims
Turbofan/jet 2-engines, >65000 lbs	Part 25	4	12,625,000	771,250	6%	4	4	Airclaims
Rotorcraft Piston <6000 lbs	Part 27	NR	135,430	27,600	20%	NR	NR	N/A
Rotorcraft Turbine <6000 lbs	Part 27	NR	606,739	123,651	20%	NR	NR	N/A
Rotorcraft Piston >6000 lbs	Part 29	NR	NR	NR		NR	NR	N/A
Rotorcraft Turbine >6000 lbs	Part 29	NR	1,888,082	384,783	20%	NR	NR	N/A
Other		422	64,272	15,473	24%	325	294	AVEMCO
All Aircraft		3,662	172,084	35,070	20%	3,482	3,331	

Events Cost Calculation

For this study the direct cost associated with the consequences of aircraft accidents is the sum for fatalities and injuries added to the cost for property loss in terms of aircraft damage and the cost of the accident investigation as discussed in the previous section:

Total Cost = Cost of Injuries + Aircraft Damage + Investigation Cost

The values reported in the previous tables are referenced to specific years and the following inflation rates were used to adjust those numbers to obtain the present value in 2007 US dollar. The value of life was presented in 2002 US dollars; the values of minor and serious injuries were expressed in 2001 US dollars; and the market value of aircraft carrier and restoration cost analysis were presented in 2003 US dollars. Using the 2007 inflation coefficient from Table L-7, the present values were calculated and introduced in the accident database.

Table L - 7 – Annual Inflation Data

Year	Annual Inflation Rate	2007 Inflation Coefficient
2001	2.83%	1.17
2002	1.59%	1.14
2003	2.27%	1.12
2004	2.68%	1.10
2005	3.39%	1.07
2006	3.24%	1.03

Aircraft Depreciation

GRA report states that a large number of older general aviation aircraft are in use and the fact that these aircraft are still bought and sold suggests that depreciation measures that divide original acquisition costs over a fixed time period may not be appropriate. One of the reasons why general aviation aircraft retain their value for a longer period of time is that these aircraft are modernized, overhauled, and fitted with new avionics, etc. In order to estimate depreciation that allows for these factors, the geometric depreciation method was used.

This method assumes that each aircraft retains a fixed percentage of its current market value from year to year. The annual amount of depreciation is the change in this value for one year. It is based on the aircraft age and market value. GRA report suggests that aircraft retain close to 95 percent of their value from year to year. The annual depreciation factor based on this assumption is presented in Figure L-1.

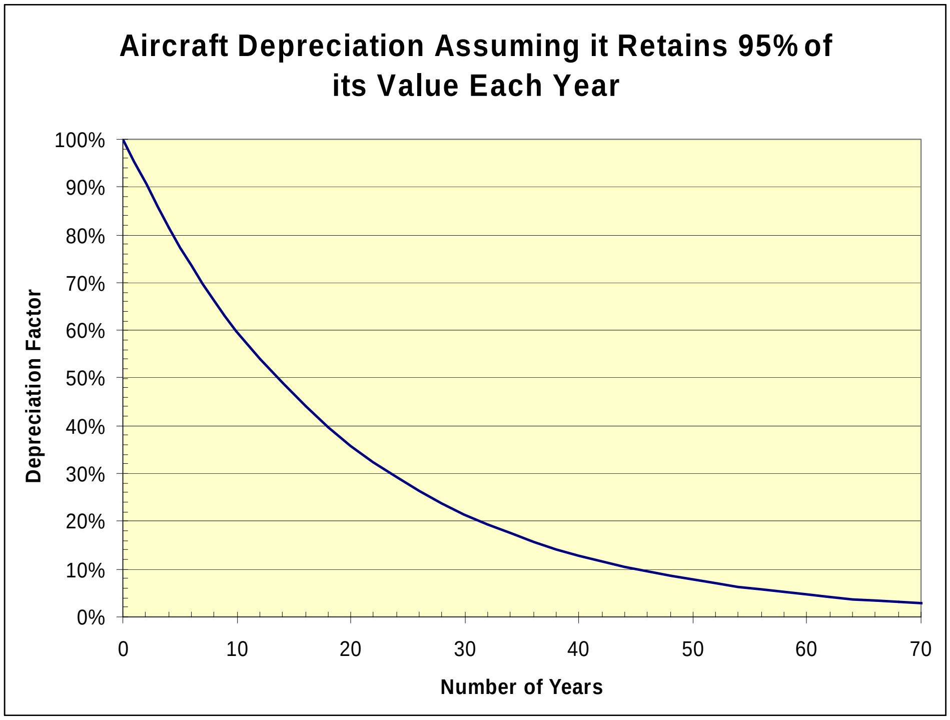


Figure L - 1 - Geometric depreciation – market value over time

Tables L-3 through Table L-6 present the replacement and restoration cost of the aircrafts based on 2003 price analysis. The database; however, contains events from 1978 through 2007. To estimate the value of an aircraft damaged in an accident, the noted price was adjusted for the event year. This is based on the fact that the aircraft depreciates over time and loses part of its value.

A simplified approach used for this study was to appreciate the value if the event occurred before 2003. At the time of the event, the aircraft had a higher value compared to the 2003 reference since the aircraft was newer. The idea was to assume an average aircraft cost at the time of the accident so that applying the 95% depreciation rule, the value would match those reported for 2003. If the event occurred after 2003 the price of the tables should were depreciated according to the number of years and the 95% rule. Therefore:

$$AV_Y = \frac{AV_{2003}}{0.95^{(2003-Y)}}$$

Where:

AV_Y is the aircraft value at event year Y

AV_{2003} is the aircraft value in 2003

As discussed before, this value was adjusted for inflation to 2007 US dollar and added to other cost items previously discussed.

Appendix M – Results for Multivariate Logistic Regression

Landing Overrun Frequency Model

Variable		B	SE	Wald	Sig.	Exp(B)	95% CI Lower	95% CI Upper
EQPT_CLASS3	Ref:C			50.191	0.000			
EQPT_CLASS3 (1)	AB	**0.551**	0.234	5.532	0.019	1.736	1.096	2.748
EQPT_CLASS3 (2)	D	**-2.113**	0.375	31.754	0.000	0.121	0.058	0.252
EQPT_CLASS3 (3)	E	**-1.064**	0.285	13.935	0.000	0.345	0.197	0.603
EQPT_CLASS3 (4)	F	**-0.876**	0.476	3.383	0.066	0.416	0.164	1.059
EQPT_TYPE (1)	T	**0.445**	0.276	2.598	0.107	1.561	0.908	2.682
FOR_OD (1)	F	**-0.857**	0.456	3.535	0.060	0.424	0.174	1.037
Ceilingband2	Ref: >2500			71.713	0.000			
Ceilingband2 (1)	<1000	**1.832**	0.253	52.481	0.000	6.247	3.806	10.255
Ceilingband2 (2)	1001-2500	**1.639**	0.210	61.014	0.000	5.150	3.413	7.770
Visband	Ref: 8-10			104.557	0.000			
Visband (1)	<2	**2.428**	0.260	87.046	0.000	11.336	6.807	18.879
Visband (2)	2-4	**1.186**	0.269	19.463	0.000	3.273	1.933	5.544
Visband (3)	4-6	**1.741**	0.233	55.708	0.000	5.702	3.610	9.006
Visband (4)	6-8	**0.322**	0.306	1.111	0.292	1.380	0.758	2.514
Xwindband2	Ref:<2			129.118	0.000			
Xwindband2 (1)	2-5	**-0.532**	0.242	4.839	0.028	0.587	0.366	0.944
Xwindband2 (2)	5-12	**1.566**	0.201	60.662	0.000	4.786	3.228	7.098
Xwindband2 (3)	>12	**1.518**	0.349	18.950	0.000	4.563	2.304	9.039
ELEC_STORM (1)		**0.986**	0.419	5.542	0.019	2.680	1.180	6.091
Icing (1)		**1.926**	0.340	32.153	0.000	6.864	3.527	13.357
Snow (1)		**1.499**	0.328	20.876	0.000	4.477	2.354	8.516
Tempband3	Ref: 15-25			25.805	0.000			
Tempband3 (1)	<5	**-1.009**	0.240	17.652	0.000	0.365	0.228	0.584
Tempband3 (2)	5-15	**-0.631**	0.199	10.103	0.001	0.532	0.360	0.785
Tempband3 (3)	>25	**0.265**	0.250	1.118	0.290	1.303	0.798	2.128
Hub (1)	NH	**1.006**	0.257	15.303	0.000	2.735	1.652	4.527
Terrain (1)	T	**0.924**	0.286	10.438	0.001	2.520	1.439	4.416
Constant		**-7.656**	0.272	792.062	0.000			
Adjusted intercept		**-15.4564**						

Landing Undershoot Frequency Model

Variable		B	SE	Wald	Sig.	Exp(B)	95% CI Lower	95% CI Upper
EQPT_CLASS3	Ref:C				54.948	0.000		
EQPT_CLASS3 (1)	AB	**0.036**	0.436	0.007	0.934	1.037	0.441	2.436
EQPT_CLASS3 (2)	D	**-1.699**	0.494	11.810	0.001	0.183	0.069	0.482
EQPT_CLASS3 (3)	E	**-0.427**	0.417	1.050	0.306	0.653	0.288	1.476
EQPT_CLASS3 (4)	F	**1.760**	0.341	26.641	0.000	5.810	2.978	11.332
USER_CLASS3	Ref:C			5.207	0.074			
USER_CLASS3 (1)	F	**0.288**	0.429	0.450	0.502	1.333	0.575	3.089
USER_CLASS3 (2)	G	**0.908**	0.403	5.068	0.024	2.480	1.125	5.469
FOR_OD (1)	F	**-1.042**	0.749	1.937	0.164	0.353	0.081	1.530
Ceilingband2	Ref: >2500			30.413	0.000			
Ceilingband2 (1)	<1000	**0.199**	0.398	0.249	0.618	1.220	0.559	2.663
Ceilingband2 (2)	1001-2500	**1.463**	0.229	25.177	0.000	4.319	2.439	7.648
Visband	Ref: 8-10			38.969	0.000			
Visband (1)	<2	**2.074**	0.446	21.635	0.000	7.958	3.321	19.071
Visband (2)	2-4	**0.069**	0.479	0.021	0.886	1.071	0.419	2.740
Visband (3)	4-6	**-0.185**	0.479	0.150	0.699	0.831	0.325	2.123
Visband (4)	6-8	**-0.295**	0.454	0.423	0.515	0.744	0.306	1.812
Fog		**1.830**	0.350	27.353	0.000	6.234	3.140	12.376
Rain2 (1)	R	**-1.705**	0.404	17.810	0.000	0.182	0.082	0.401
Tempband3	Ref: 15-25			8.801	0.032			
Tempband3 (1)	<5	**-0.505**	0.327	2.379	0.123	0.604	0.318	1.146
Tempband3 (2)	5-15	**-0.874**	0.307	8.098	0.004	0.417	0.229	0.762
Tempband3 (3)	>25	**-0.446**	0.387	1.327	0.249	0.640	0.300	1.367
Icing (1)		**2.815**	0.618	20.758	0.000	16.698	4.974	56.059
Snow (1)		**2.412**	0.454	28.223	0.000	11.155	4.582	27.158
Constant		**-7.158**	0.278	664.822	0.000	0.001		
Adjusted intercept		**-14.9642**						

Takeoff Overrun Frequency Model

Variable		B	SE	Wald	Sig.	Exp(B)	95% CI Lower	95% CI Upper
EQPT_CLASS3	Ref:C			22.467	0.000			
EQPT_CLASS3 (1)	AB	**0.721**	0.424	2.889	0.089	2.056	0.895	4.722
EQPT_CLASS3 (2)	D	**-0.619**	0.442	1.968	0.161	0.538	0.227	1.279
EQPT_CLASS3 (3)	E	**-0.009**	0.451	0.000	0.984	0.991	0.409	2.400
EQPT_CLASS3 (4)	F	**1.669**	0.448	13.857	0.000	5.305	2.203	12.770
USER_CLASS3	Ref:C			15.811	0.000			
USER_CLASS3 (1)	F	**1.336**	0.401	11.126	0.001	3.806	1.735	8.346
USER_CLASS3 (2)	G	**1.052**	0.409	6.601	0.010	2.863	1.283	6.388
Ceilingband2	Ref: >2500			25.497	0.000			
Ceilingband2 (1)	<1000	**1.225**	0.500	5.988	0.014	3.403	1.276	9.076
Ceilingband2 (2)	1001-2500	**1.497**	0.297	25.412	0.000	4.467	2.496	7.994
Visband	Ref: 8-10			9.518	0.049			
Visband (1)	<2	**0.201**	0.569	0.125	0.723	1.223	0.401	3.728
Visband (2)	2-4	**-1.941**	0.811	5.731	0.017	0.144	0.029	0.703
Visband (3)	4-6	**-0.366**	0.502	0.530	0.466	0.694	0.259	1.856
Visband (4)	6-8	**0.317**	0.342	0.860	0.354	1.374	0.702	2.687
Fog		**1.660**	0.461	12.974	0.000	5.259	2.131	12.978
Xwindband2	Ref:<2			48.820	0.000			
Xwindband2 (1)	2-5	**-0.292**	0.413	0.502	0.479	0.746	0.332	1.677
Xwindband2 (2)	5-12	**1.598**	0.335	22.781	0.000	4.941	2.564	9.523
Xwindband2 (3)	>12	**1.781**	0.499	12.736	0.000	5.939	2.232	15.798
Tempband3	Ref: 15-25			8.929	0.030			
Tempband3 (1)	<5	**-0.536**	0.378	2.008	0.157	0.585	0.279	1.228
Tempband3 (2)	5-15	**-0.507**	0.331	2.342	0.126	0.603	0.315	1.153
Tempband3 (3)	>25	**0.502**	0.334	2.261	0.133	1.652	0.859	3.178
Icing (1)		**1.805**	0.703	6.583	0.010	6.077	1.531	24.117
Snow (1)		**2.567**	0.528	23.618	0.000	13.031	4.627	36.697
Constant		**-8.790**	0.443	392.863	0.000	0.000		
Adjusted intercept		**-16.6515**						

Appendix N – Recommended Reporting Information

Much of the information obtained from this study came from accident investigation and incident reports. In many instances data was obtained from additional sources (e.g. weather) or based on interpretations from descriptions available in those reports (e.g. wreckage location). In many cases, either of these alternatives was not possible to complement the data.

The models developed in this study could be improved if the data was available. In many cases, the accident investigator will gather data that is relevant to causal or contributing factors of the accident. This process leads to missing important data that can be used to improve the models developed in this research and, although some of these factors in fact are not related to the specific accident, they will help establishing risk factors and their respective weights when evaluating the overall risk for a specific runway.

- Airport Location
- Aircraft
    a. Model
    b. Type
    c. Actual weight during accident/incident
    d. Landing/takeoff distance required
- Airport
    a. Runway direction
    b. Landing Distance Available/Accelerate-Stop Distance Available
    c. Elevation
    d. Runway friction and condition (dry, wet or contaminated)
    e. Type of contamination (standing water, snow, slush, ice, rubber)
- Weather
    a. Temperature
    b. Wind direction
    c. Wind speed
    d. Gust speed
    e. Visibility
    f. RVR
    g. Ceiling
    h. Precipitation (rain, snow, frozen)
    i. Electric storm (yes, no)
    j. Precipitation Intensity (none, light, moderate, heavy)
    k. Fog
    l. Light (day, night, dawn, dusk)
- Operation
    a. Reference approach speed
    b. Actual approach speed
    c. Touchdown speed

    d. Touchdown location (from approach end, x and y)
    e. Type of Approach (visual, non-precision, precision)
    f. Pressonitis (yes or no)
    g. Flight rule (VFR, IFR)
    h. NAVAIDS utilized
- Accident
    a. Wreckage location (x, y and z, relative to runway end)
    b. Wreckage path, type of terrain, slope and length for each segment
    c. Obstacles hit (number, type, location and dimensions)
    d. Location where aircraft departed runway
- Consequences
    a. Aircraft
    b. Injuries (type and number of: none, minor, severe, fatal)
    c. Total on board, 3rd party
    d. Fire
    e. Explosion

Appendix O – Prototype Software for RSA Risk Assessment

As part of this effort, prototype software was developed with basic capabilities for risk analysis of runway safety areas. Although simple, the analysis can be conducted for specific conditions using historical normal operations data for the airport.

Figure O-1 depicts the initial screen where the user will input some basic information. The four initial fields are used to identify the airport and the RSA that is being evaluated.

The fields for landing distance available (LDA) and accelerate-stop distance available (ASDA) are used in the normalization process, if this option is selected. The LDA is used to normalize distances for the analysis of landing overruns, and the ASDA for takeoff overruns.

The next three fields are used to define one obstacle location and size. Length is the *x* distance from the threshold. Distances Y1 and Y2 refer to the locations relative to the extended runway centerline where the aircraft may strike the obstacle to the right or to the left. It should be noted that these distances are not the location of the obstacle edges. In reality they represent the locations where an aircraft hitting the obstacle are likely to cause severe consequences, as depicted in Figure 26, Chapter 3, of this report.

The field for terrain type is also used for normalizing the distances, when this option is selected. Finally, the target level of safety is selected as a criterion. The probability of an accident for each operation at the airport that may challenge the RSA is compared to this value. The objective is to obtain the percentage of operations under high risk.

Three additional folders in the Excel worksheets are available in the application to enter historical normal operations data for the airport: NOD-LDOR, NOD-LDUS and NOD-TOOR. In the LGA example, data for landing operations on runway 4 were entered in the NOD-LDOR worksheet. Data for flights landing on runway 22 were input in the NOD-LDUS worksheet. Finally, NOD for takeoff operations on runway 4 were entered in worksheet NOD-TOOR. The NOD data used to run the analysis is that described in Appendix E of this report.

Analysis output is provided in three separate worksheets: LDOR, LDUS and TOOR. For each worksheet two run buttons are available. The one labeled “Calculate Probabilities” runs the frequency models represented by equations (7), (8) and (9). The second button “Location Models” uses the location models for the alternative selected: raw or normalized. Pressing this button will combine the probability of the incident with the location probability for the specific obstacle selected.

The output is a histogram depicting the probabilities for each risk level. The line represents the total probability that the risk is higher than the level selected. For example, in Figure O-3, for the example, approximately 10% of the operations have a risk higher than 1.44E-7. The second type of output is the percentage of high risk operations. The value represents the percentage of movements having a risk higher than the target level of safety selected.

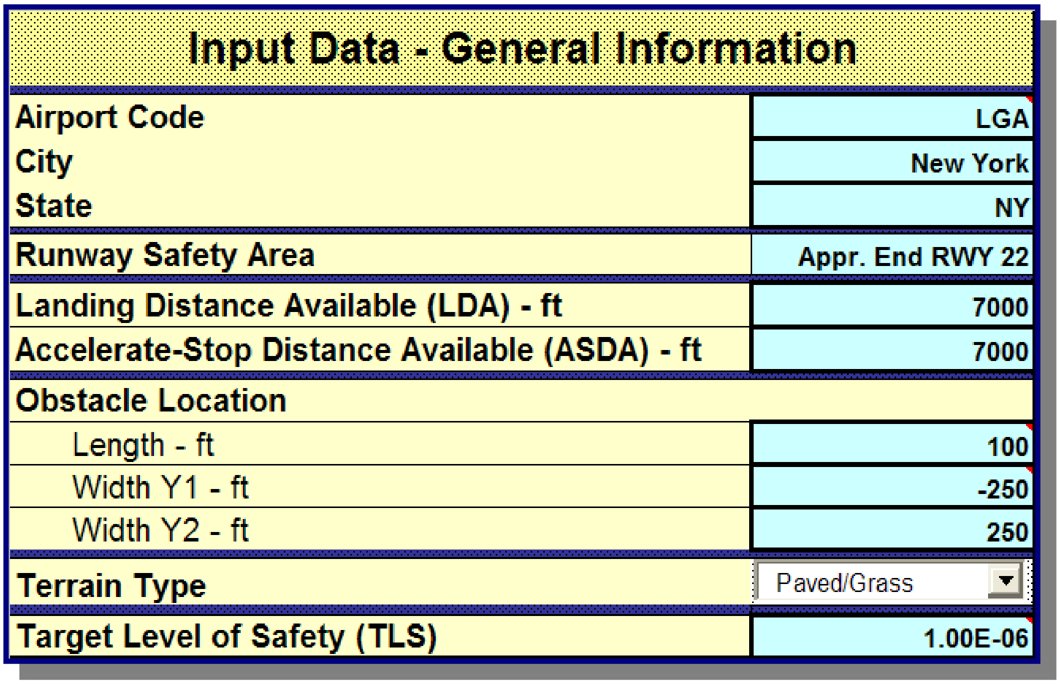


Figure O- 1 – Prototype software – initial screen

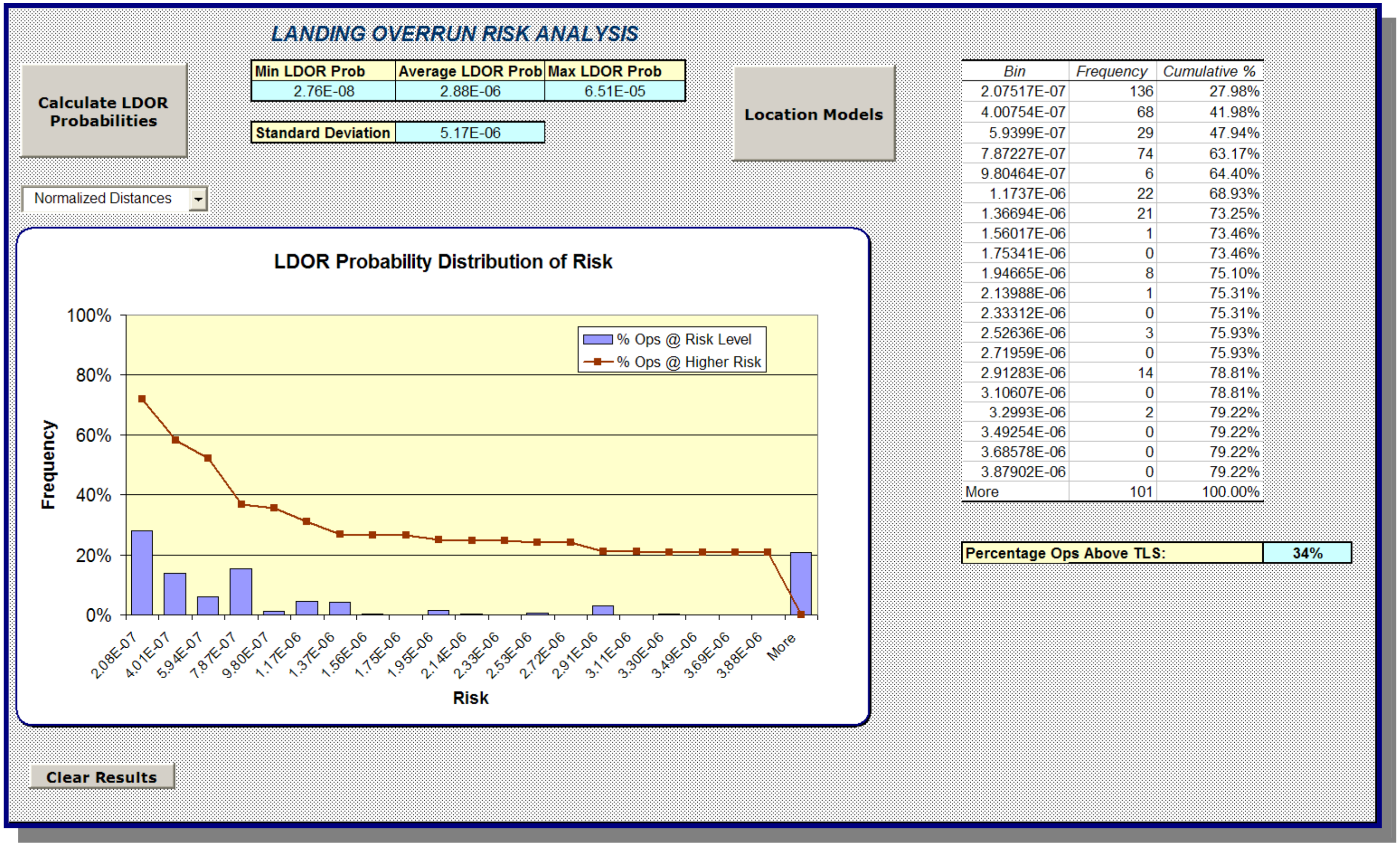


Figure O- 2 – prototype software – screen for analysis of landing overruns

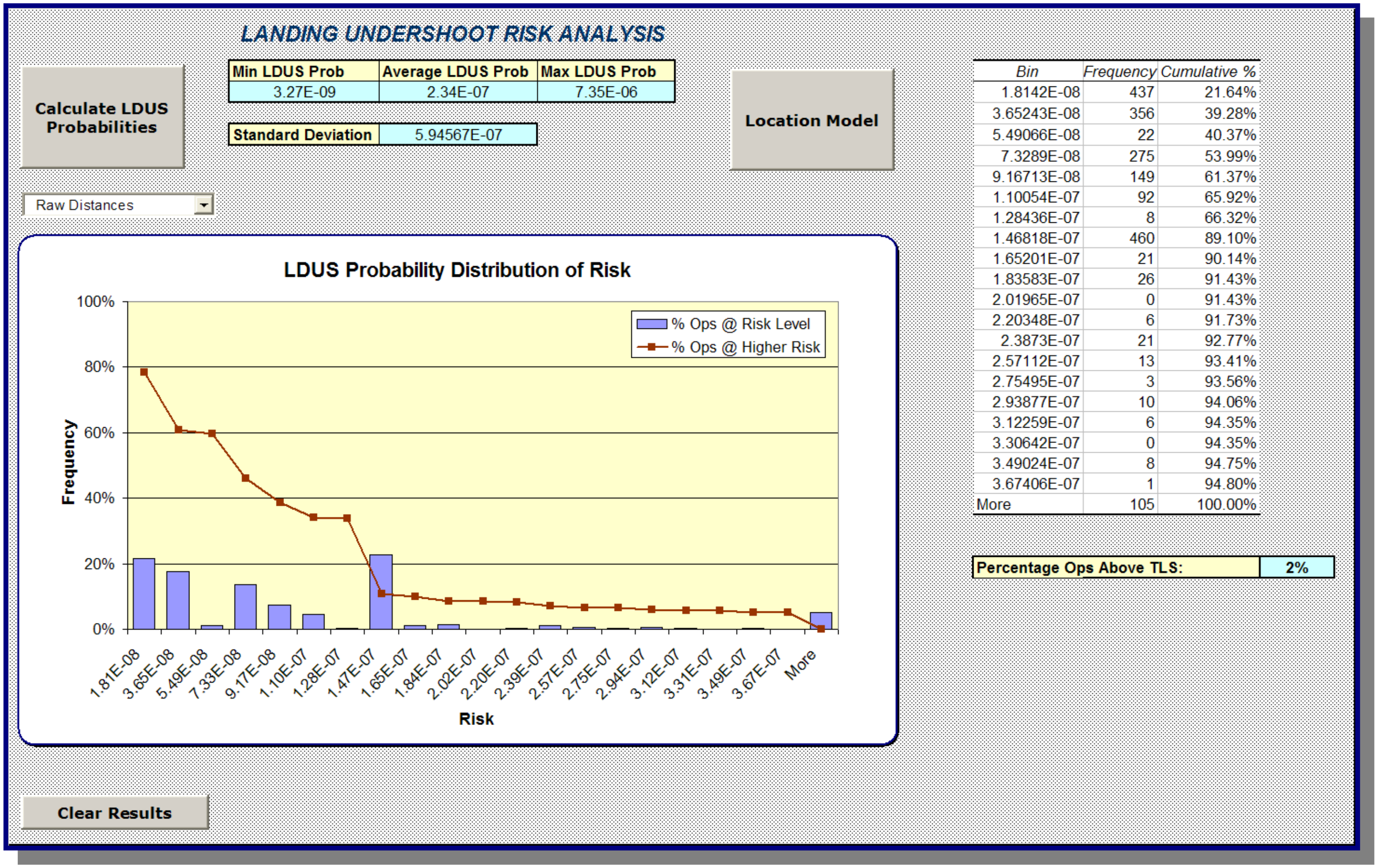


Figure O-3 – Prototype software – screen for analysis of landing undershoots

TAKEOFF OVERRUN RISK ANALYSIS

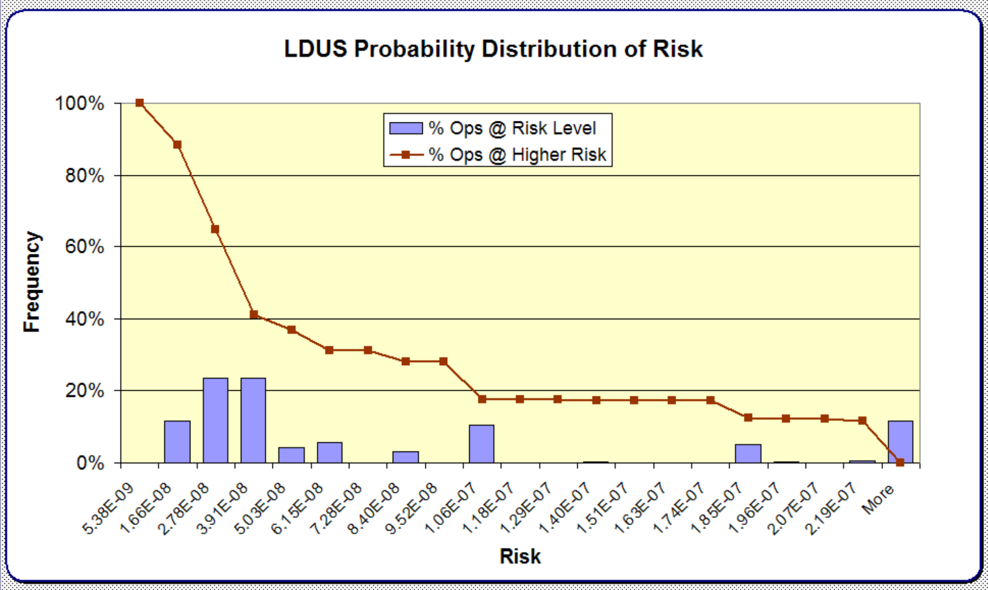
Calculate TOOR Probabilities

Min TOOR Prob	Average TOOR Prob	Max TOOR Prob
1.89493E-08	1.45511E-07	2.6406E-06

Standard Deviation	2.77048E-07

Location Models

Raw Distances



Bin	*Frequency*	*Cumulative %*
5.38043E-09	0	0.00%
1.66091E-08	70	11.57%
2.78379E-08	143	35.21%
3.90666E-08	143	58.84%
5.02953E-08	26	63.14%
6.1524E-08	35	68.93%
7.27527E-08	0	68.93%
8.39814E-08	18	71.90%
9.52101E-08	0	71.90%
1.06439E-07	64	82.48%
1.17668E-07	0	82.48%
1.28896E-07	0	82.48%
1.40125E-07	1	82.64%
1.51354E-07	0	82.64%
1.62582E-07	0	82.64%
1.73811E-07	0	82.64%
1.8504E-07	30	87.60%
1.96269E-07	2	87.93%
2.07497E-07	0	87.93%
2.18726E-07	3	88.43%
More	70	100.00%

Percentage Ops Above TLS:	1%

Clear Results

Figure O- 4 – Prototype software – screen for analysis of landing undershoots