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Design Airports for Safety

Airport design can play an important part in reducing the severity of injuries and damage in aircraft accidents. Requirements that control airport design can be supplemented by other practical safety applications.

by
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So long as man and machine are imperfect, aircraft incidents will continue to occur. Even with major advances in modern technology, there has been little change in the number of accidents in recent years. It is, therefore, necessary that more effort be placed on preventing an incident from becoming an accident and thereby improving the survival factors for those involved. It is in this area that airport design can play a very important role.

It is necessary for airport engineers to know where, when and how the majority of aircraft accidents have occurred. Surveys taken during the last 25 years by the Air Line Pilots Association (ALPA-U.S.) indicate that only five percent of accidents occur en route. These are usually caused by structural fatigue failure, violent weather, inflight fire or by flying into mountains or other high terrain.

However, 15 percent of accidents occur in airport approach areas, usually within 15 miles of the airport. These are usually weather related, involve engine failure, midair collisions or premature descent into high surrounding terrain. These accidents are of primary concern to community emergency services. Due to the fact that structural fire equipment is not very effective on a large fuel fire, airport equipment may be requested to respond under a mutual aid agreement.

The remaining 80 percent of accidents take place on the active runway or its overrun areas and clear zones, which extend to the point where the approach surface reaches 50 feet high. A plot of accident locations shows that almost all of these accidents occur within 500 feet of the active runway centerline and 3,000 feet of the runway thresholds (Figure 1). For airport emergency crews this is called "the critical rescue and fire fighting response area." This is the area where many lives and aircraft are lost due to unnecessary obstructions and where improved airport design can be most effective. In past years there has been little effort to remove obstructions from runway approach areas other than those that violate height restrictions. These hazards can severely damage an aircraft and also impede the response of emergency services.

Airport accidents can be divided into three categories: undershoots, veer-offs and overruns.

The undershoot occurs when the aircraft contacts the ground, or some elevated obstruction, prior to its reaching the runway. Due to the relatively high speed of the approach, the aircraft frequently comes to rest on or about the first part of the runway area. High impact damage usually occurs in this type of accident. The main causes of these accidents are windshear and pilot judgment. Windshear instrumentation is installed at many major airports, but the phenomenon continues to be difficult to predict.

Pilot judgment accidents can be caused by false visual reference. For example, where there is an upslope in either the runway or the approach zone, a pilot can experience an "above glide path" illusion. In other words, he will be lower than he

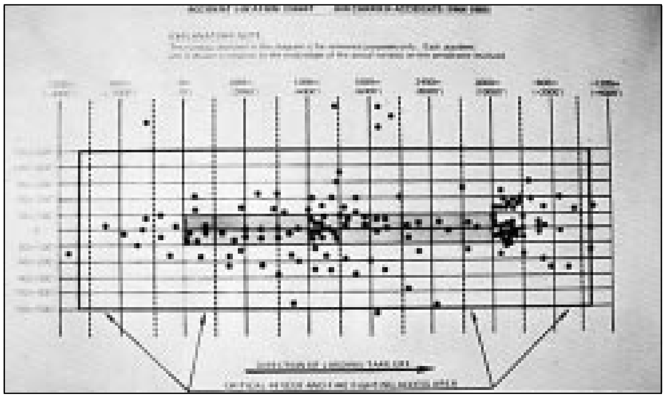


Figure 1

thinks he is. The opposite holds true for a down-sloping runway or approach zone. A similar illusion can be experienced at night with various types of lighting conditions located on high ground beyond the airport boundary.

The overrun is the most common airport accident. It occurs when the pilot loses directional control and veers off during landing or takeoff. This may be due to tire or brake failure, excess speed, skidding on an icy runway or hydroplaning on a wet runway, especially in crosswind conditions.

Most overruns occur during a rejected takeoff, usually due to a mechanical failure prior to V_1 or a blown tire. Tire failures have been responsible for many of the accidents involving fire in the last 10 years. When aircraft are certificated by the U.S. Federal Aviation Administration (FAA), takeoff runway length requirements are based on tests conducted on a clean, dry runway, new brakes and tires, and immediate pilot reaction; during normal flight operations these factors rarely exist. Overrun accidents usually involve relatively slow speeds and should be survivable.

In 1987, ALPA conducted a survey of 1,002 turboprop and turbojet aircraft accidents that occurred on airports between 1959 and 1986. The survey showed that there were 410 overruns, 326 veer offs and 216 undershoots.

Most of these accidents involved fatalities that could have been avoided if the aircraft had not come in contact with an obstruction; these accidents should have remained incidents.

A survey of overrun accidents conducted by the U.S. National Transportation Safety Board (NTSB) shows aircraft struck the following obstructions in overrun areas:

Lights/stanchions	10
Embankments/dikes	7
Fences	6
Ditches	6
Trees/stumps	4
Boulders/rocks	3
Hills/mounds	2
Navigation facilities	2
Other aircraft	2
Autos	2
Buildings	1
Roadways	1

Most of these accidents occurred within 500 feet of the runway centerline and within 3,000 feet of the runway ends. This is the critical response area for emergency services, and it is the area where the airport engineer can reduce or eliminate obstructions, and provide more rapid access for emergency vehicles.

National and international regulations limit the height of obstructions along the sides of runways, approach areas and clear zones. These are airspace requirements. If a tree grows into the airspace it has to be topped. If an overshooting aircraft hits the base of the tree, the result can be just as damaging. What is required is a "groundspace" regulation restricting surface hazards surrounding the runway safety areas.

International Civil Aviation Organization (ICAO) Annex 14, Chapter 3 recommends a runway end safety area extending from the runway for as great a distance as practical but not less than 90 meters (300 feet). These areas should be cleared and graded in the event of an aircraft undershooting or overrunning the runway. FAA Advisory Circular 150/5300-12 recommends a 300-meter (1,000-foot) safety area cleared of obstructions and navigable by overrunning aircraft and emergency equipment.

Neither of the above recommendations has the impact of a regulation, and accident statistics prove that both areas are inadequate in length. FAA advisory circulars only apply to new construction. Older runways are not required to meet this improved standard and many of them have little or no safety area. Also, there is no requirement for surface preparation in the clear zone despite the fact that it is in this area that most fatal accidents occur.

At present there is no requirement for a smooth negotiable transition area between the safety areas and the clear zone. Runway end safety areas often terminate in steep embankments that are impossible to negotiate by either the aircraft or the emergency vehicles. Even if there is no embankment, there is often a ditch, river, ravine, railroad, highway or other major obstruction present that even at slow speeds could cause major structural damage to an aircraft and result in severe injury to its occupants.

The following suggestions, if adopted, will reduce hazards in the overrun areas and clear zones.

Extended Runway Safety Areas And Clear Zones

Where sufficient land is available, the runway end safety area should be extended to 3,000 feet in length and 1,000 feet wide at the runway threshold extending to 2,000 feet wide at the boundary (Figure 2). This area should be cleared of all obstructions except for frangible (breakaway) navigational equipment. All large rocks, tree stumps, earth mounds and depressions, or any other object which could damage a transgressing aircraft, must be removed.

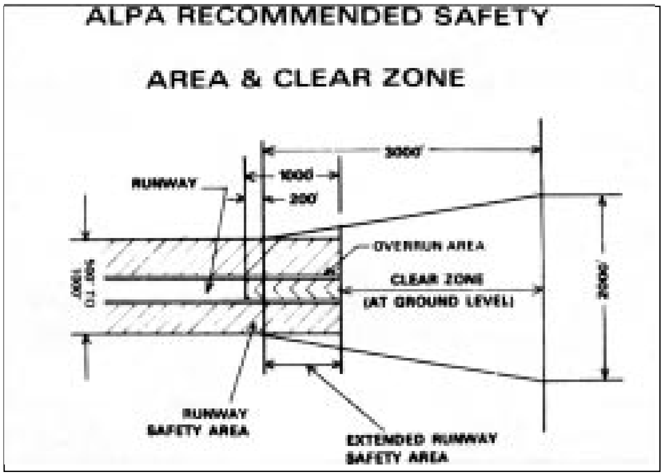


Figure 2

Regardless of its size, there must be a smooth transition area between the runway end safety area and the surrounding terrain. This should consist of a gentle slope with the elimination of sharp angles between the surfaces. If the area can be transited by emergency equipment at high speed, it is assumed that the aircraft can do likewise. (Figure 3)

Drainage Ditches Create Dangerous Traps

Ditches through the runway end safety area have been responsible for accidents ranging from tearing off the landing gear to disintegration of the fuselage. Most of these depressions can be rerouted, or replaced with pipes and then covered.

At those airports where large ditches or small streams exist that cannot be moved or rerouted, the hazard may be changed to a positive safety factor. The banks of the stream can be graded to a gentle slope and the stream bed hard-surfaced. The water depth must be reduced to a maximum of thirty inches which is the maximum wading depth of most emergency equipment. There are two advantages to this proposal: first, the decelerating effect of the water acts as an arresting device and quickly slows the aircraft; second, the emergency equipment can reach the scene without a detour.

Sea Walls Become Unnecessary Obstructions

Many airports are located adjacent to large bodies of water, such as lakes, rivers and tidal shorelines. The runway end safety area boundary often has a concrete sea wall which can severely damage an aircraft during an overrun or undershoot. This obstruction should be eliminated and the runway end safety area graded into the water. Construction should be similar to that of a boat launching ramp. This will enable an overrunning aircraft to roll into the water with minimal structural damage and remain afloat while the occupants escape. This ramp could also minimize damage to an undershooting aircraft which could otherwise tear its landing gear off on the embankment. Where runways are adjacent to water areas subject to large tidal variations, the runway end safety area should extend at least 3,000 feet from the runway to provide for frangible approach light installations and to provide a stabilized surface for radar altimetry during low-visibility approaches.

Roadways Can Be a Menace

Roadways are one of the most common obstructions found in the runway clear zones. They may be anything from small airport service roads to four-lane interstate highways. Airport service roads and emergency vehicle access roads should be of all-weather construction but must be level with the surrounding terrain. There should be no drainage depressions or gullies that would damage the aircraft landing gear. In order to meet the FAA approach slope clearance requirements, many of these roads and highways are depressed so that transiting vehicles

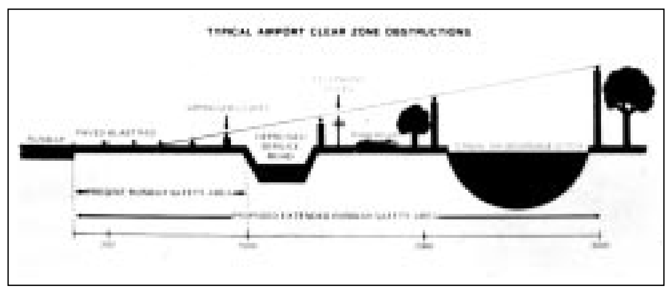


Figure 3

will not interfere with landing aircraft or navigation aids. This is done to enhance safety, but it creates a hazard because the depression forms a trap for any overrunning or undershooting aircraft.

Major roadways within the 3,000-foot extended safety area should be depressed and bridged with a structure that will support the weight of the largest aircraft using the airport. Where this is impractical, or the roadway is located at the end of the 3,000 foot clear zone, any 45-degree embankment should be replaced with a gradual slope. All surface obstructions, such as light pole signs or other objects that could damage the aircraft, should be removed. Where roadways are located outside of the airport boundary, local authorities must be persuaded to make the necessary safety improvements. A careful explanation of the hazard, and the potential for litigation in the event of an accident, should be for a part of the dialogue with them.

Railroads Were Usually Constructed First

Railroad tracks also pose a problem when they run through the extended runway safety area. The railroads were often built before the airport, therefore railway authorities are reluctant to make changes. The hazard can be reduced by grading embankments and paving between the tracks the width of the safety area to make a grade crossing similar to those crossing highways. This will allow the aircraft to traverse the tracks with minimum damage, and allow emergency equipment to follow at maximum speed. Thus, response time is reduced and the survival factor is increased.

The Runway

In order to reduce false visual references, the runway should be level throughout its length with the longitudinal gradient not exceeding one percent. Where parallel runways are constructed, the distance between the runway centerlines should be a minimum of 5,000 feet. To provide adequate drainage under adverse weather conditions, and prevent ponding, which results in hydroplaning, a runway crown of one percent to one-and-a-half-percent should be provided.

Provide Windsocks at Runway Approaches

It is very important for a pilot making a landing or takeoff to know the true wind direction and velocity. At large airports there may be a significant difference between the wind data recorded in the control tower and that experienced on the runway, especially during a thunderstorm or frontal passage. Small windsocks, frangibly mounted and lighted, should be installed near the approach end of each runway, preferably opposite the 1,000-foot mark and 150 feet off the left side of the runway.

Beware of Paving Sealer

Where runway, taxiway and ramp areas are paved with asphalt, they should not be sealed with a sealer that could provide a slick surface when wet. Lack of braking action, compounded with a tailwind, could result in the taxiing aircraft being unable to stop, thereby hitting other aircraft, sliding off the taxiway or hitting a building. If a sealer is used, the pavement should be grooved.

Landscaping Is Important

One item that is often overlooked by airport engineers is the landscaping of the area. Trees should not be planted in clear zones. Small bushes that will not damage an aircraft are acceptable; they should be of a type that will not attract birds either for cover or for food — those bearing berries that attract migrating flocks are especially dangerous. Aircraft flying through flocks of birds have experienced engine flameouts, some resulting in fatal accidents.

Seconds are Precious in Aircraft Fires

More than 650 people lost their lives in the 21 major aircraft crash fires that occurred between 1979 and 1989.

Survival time in an aircraft crash fire is very limited. Even if the fuselage is intact, fire can burn through its aluminum skin in 30 to 50 seconds; it can penetrate the insulation and inner fuselage wall in an additional two to three minutes even under optimum conditions. If there is any break in the fuselage, these times are greatly reduced. This makes a rapid response to the accident site one of the prime requirements of an airport crash rescue service. Because most of the survivable aircraft accidents occur on the runway or in the overrun areas, the location of the fire station becomes a matter of major importance.

Response time in the United States is now a matter of regulation. Federal Aviation Regulation (FAR) Part 139 requires response to the mid-part of the most distant runway in three minutes or less. The ICAO recommendation calls for a response to any part of the movement area in three minutes, preferably two minutes, or less. The National Fire Protection Association's (NFPA) Standard 403 calls for a response to any part of the operational runway in two minutes or less, and the overrun area in two-and-a-half-minutes.

Airport crash trucks are designed and built to very exacting standards which include acceleration rates and top speeds. NFPA 414 requires an acceleration rate of 0-50 mph in 45 seconds for large vehicles and in 25 seconds for smaller vehicles. Such rapid acceleration is wasted if the airport engineer sites the fire station in the wrong location.

There have been very few fires occurring on the ramp areas during the jet age. There are very few recorded cases of a major refueling fire to a large jet. When such a fire does occur, the occupants can rapidly evacuate an aircraft in the demonstration time of 90 seconds. Because they have not been subjected to the trauma of an accident, they are mobile and they usually can leave through the jetway they used to board the aircraft. The aircraft will likely be evacuated prior to the arrival of the emergency equipment.

This is not the case when the occupants are involved in an accident. They are disoriented, injured or trapped and often cannot escape without assistance by emergency services. Fire must often be first extinguished; this is another reason that response time to a crash site is so critical.

Fire Station Locations Make Difference

It has already been noted that 80 percent of all accidents occur on the operational runway within 500 feet of the centerline and within 3,000 feet of the threshold. In order to obtain the most rapid response, the fire station should be located adjacent to the mid-point of the runway. Where more than one runway exists, consideration must be given to providing multiple fire stations to meet the response-time criteria.

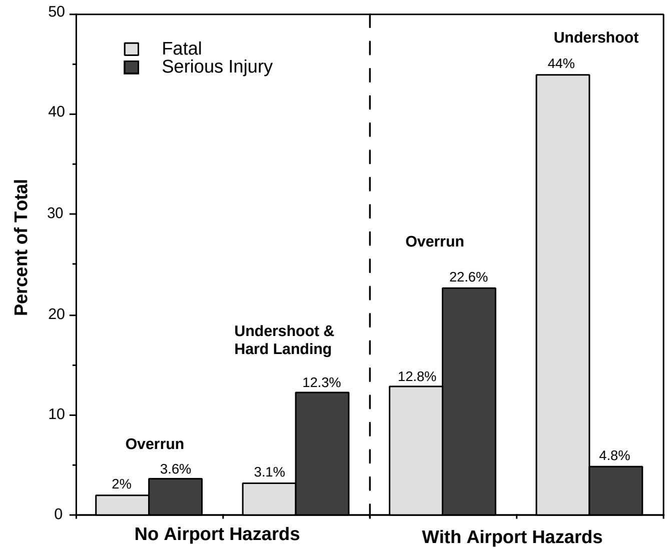
When locating these fire stations, care must be taken to ensure that rapid egress cannot be blocked by taxiing aircraft. Direct access to the runway is necessary with straight access roads that lead from the vehicle bay to the runway. The high center of gravity of most emergency vehicles makes high speed turns very hazardous.

Fire stations should be constructed according to government and local regulations. Special attention should be given to providing a visual electronic alarm system and an elevated watch office on top of the building. This is a vital part of the rapid response capability. Several valuable seconds can be saved if the firefighters know exactly where to respond without waiting for directions from the tower. Fire station doors activated by the alarm system should be capable of rapid opening even in the event of a power outage. Doors should be located at both ends of the vehicle bays to provide a drive-through capability for rapid chemical and water recharging of the vehicles. An elevated reserve foam tank should be built into the ceiling of the vehicle bay to provide this capability. Extra height should be allowed during the construction of fire station vehicle doors. Many new-generation crash trucks are being fitted with elevated platforms or booms which increase the height of the vehicle by as much as six feet. An extra bay should be provided for a mobile disaster van in order to provide power to maintain refrigeration for the preservation of emergency drug supplies.

Airport Accidents 1959-1989

	Jet	Turboprop	Total
Undershoots	186	92	278
Overshoots	353	113	466
Veeroffs	293	109	402
			1146

Major CFR vehicles are designed to carry one charge of water and a double charge of foam solution allowing a second application with only a water refill. It is therefore essential that the vehicles can be refilled with water as soon as possible after the first discharge. A water hydrant system should be installed around the CFR critical response area for this purpose.



Comparison of Percentage of Accident Fatalities and Serious Injuries With and Without Airport Hazards

When an aircraft accident occurs off the end of a runway but outside the airport perimeter, a problem of rapid access for the fire trucks exists. Even with the increased emphasis on airport security, access roads and gates must still be available at the end of each overrun area. These gates should have frangible mountings to save valuable seconds.

Disaster Exercises Required

The first Airport Disaster Exercise was held in Oakland California in 1971, a joint effort of ALPA and the California Medical Association. Since that time, the state of the art has improved dramatically. Many lives have been saved in recent accidents because the airports were ready to provide effective emergency services.

FAA regulations require that each certificated airport hold periodic disaster exercises. Each airport is required to have at least one firefighter per shift trained as an emergency medical technician (EMT). It is recommended that adequate first aid facilities and equipment be provided for the maximum number of passengers on the largest aircraft scheduled into the airport. It is, therefore, desirable to make the airport fire stations the primary first aid holding points until transportation to hospitals can be arranged. Design of the fire station should include provision of storage facilities for first aid equipment and drugs. Firefighter sleeping quarters should be capable of being turned into emergency first aid rooms and be located for easy access by stretchers and wheel chairs. At least one adjacent ambulance bay should be provided.

Practical application of safety considerations, based on recent accident experience and local and federal requirements, can contribute to a safer airport. If, however, an accident does occur, the outcome will depend to a great extent on the elimination of airport hazards and the ability of the emergency services to quickly and efficiently reach the scene. This requires the active participation of airport management and airport design engineers.♦

References

National Fire Protection Association NFPA 403, 412, 424, 402

Federal Aviation Administration FAR Part 139, Advisory Circular 150/5335-4 and 150/5300-12.

International Civil Aviation Organization Annex 14, chapters 3, 4, 9, Aerodrome Manual Part 1.

DOT/FAA/CT-82/109 Equivalency Evaluation of Firefighting Agents and Minimum Requirements at U.S. Air Force Airfields; G. Geyer.

Air line Pilots Association, Guide for Airport Standards.

Air line Pilots Association, Compilation of Accidents/Incidents involving runway overruns/undershoots/veer-offs.

Air line Pilots Association, Guide for Accident Survival Factors.

About the Author

B. Victor Hewes, a retired Delta Air Lines captain, is the author of several publications and articles on airport fire and rescue, and has presented numerous papers at Flight Safety Foundation seminars. He presently is a consultant specializing in accident investigation, airport safety and security and aircraft fire protection. Hewes is a member of the Society of Air Safety Investigators and has participated in more than 25 major accident investigations.

Hewes was born in England and in 1940 he became a pilot in the Royal Air Force (RAF), serving two combat tours flying Spitfires, Hurricanes and Mosquitoes and as a VIP squadron commander flying Dakotas (C-47). He began his air safety activities as a pilot in the RAF and continued these activities after leaving the service at the end of hostilities when he joined Delta as a line pilot. He has logged more than 33,500 hours and 12 million miles in the air. He is the Dixie Wing Leader of the Confederate Air Force and regularly flies B-24s and B-29s.

Hewes served more than 30 years as regional and national safety committee chairman for the U.S. Air Line Pilots Association (ALPA). Under his leadership, many advances were made in the field of accident survival that resulted in several U.S. and international regulations on aircraft cabin interior fireworthiness, evacuation, seat restraint standards, disaster exercises and airport certification.

Hewes has been associated with the National Fire Protection Association (NFPA), the International Federation of Air Line Pilots Associations (IFALPA) and the International Civil Aviation Organization (ICAO), serving on the latter's Fire Fighting Panel for many years, during which present worldwide standards were established for airport fire services. He has received a number of air safety awards including the Flight Safety Foundation's Admiral Luis Florez and Laura Taber Barbour Awards, the Aviation Week and Space Technology *Distinguished Service Award, the IFALPA Scroll of Merit and the National Fire Protection Association Distinguished Service Award.*

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