



**GA AIRPORT
SAFETY ASSESSMENT HANDBOOK
--DRAFT--**

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1. INTRODUCTION AND SUMMARY

A Story

Rivertown has an airport dating from the late 1940's—a single 3,500 foot runway on 125 acres. Over the years, the town has grown to 80,000 population; it's now one of the outer suburbs of the expanding large city not far away.

As development intensified, a combination of neighborhood groups and developers began to agitate for closure of Rivertown Airport as being unsafe. It was argued that the airport property would be better utilized for housing than remain as a threat to the community. The advantages of 1500 new dwelling units and shops were promoted.

Using the type of analysis described here-in, supporters of Rivertown Airport were able to demonstrate and quantify:

- There is less than a 50% probability of a person living in the vicinity of Rivertown airport being fatally injured in a GA accident during the next 200 years.
- Public worries over “catastrophic” GA accidents are overblown. Over the past 40 years, there have been only 5 GA accidents in the United States in which more than 3 persons on the ground were fatally injured. And three of these accidents involved aircraft or circumstances not found at Rivertown Airport.
- The average community resident not participating in general aviation is 700 times more likely to be fatally injured from a fall in their home (or 500 times more likely to become a fatality from a fall in a public building such as the City Hall) than they are to be a fatality from a GA accident. They are even more likely to become a fatality from accidental poisoning in their own home.
- The proposed development would increase the likelihood of injury to community residents (due to increased traffic) by 2000-times compared to continued operation of the airport, and would increase the likelihood of a fatality by over 50-times.

When faced with this factual rebuttal, efforts to close the airport and redevelop the site were shelved.

(An apocryphal story, but not unrealistic.)

Introduction

Despite steady and significant improvements in General Aviation (GA) safety, concerns with possible adverse effects of GA aircraft operations continue to arise. Such concerns can be the worry of airport neighbors who see GA aircraft flying overhead daily, or they can be concerns voiced by others in the community who have a different interest in a GA airport and the land on which it sits.

General aviation is not accident-free, so some level of concern is appropriate. But one difficulty that members of the GA community typically encounter is a limited ability to provide meaningful responses to airport neighbors and community decision-makers when safety questions are raised. Too often, GA supporters have only aggregate national statistics to illustrate GA's improving safety record. Local data is often minimal, anecdotal, and fails to directly address the "yes, but what if..." worry.

Public perceptions of GA accident risks are often far from the reality. This handbook has been developed to bring these statistics and others to public attention, and to enable any community to quantify the risk of injuries and fatalities that might be expected as a result of GA airport operations. It also provides a means for comparing these risks with measures of risk associated with other daily activities and possible alternative uses of GA airport property to facilitate public understanding of their implications.

Summary

This handbook is organized as both a tutorial on GA safety information and as a "How to" manual for conducting a local assessment to quantify possible GA accident rates and the effects of such accidents.

Chapter 2 provides a description of the major sources of GA accident and activity data. As this report has been prepared at a particular point in time (summer 2005), access to these sources will enable readers to update information provided here-in so that their analyses and presentations can utilize current (and not "old") data. This chapter also provides a source of other accident measures that can be used for comparison.

Chapter 3 provides a means for quantifying GA accident probabilities. This entails several steps, including expected accident frequencies (using a mix of local activity measures and national rates) and then expected effects of these accidents (using 40 years of national accident data).

In Chapter 4, two supplemental observations related to GA accident are provided to document the very low frequency of "catastrophic" GA accidents. These can be used as needed in a local report or presentation if they appear to provide useful insights for the issue being addressed.

Finally, Chapter 5 provides a sample analysis to show how the information in Chapters 2 and 3 can be adapted to fit the circumstances of any airport or community.

Appreciation

This handbook is based in part on research funded by Santa Clara County (California) in support of the "Risk Assessment of the Reid-Hillview Airport Closure Evaluation Project" (November 1993). That research was undertaken by Drs. Brent W. Silver and P. Roger Williamson of Aircraft Safety Consultants (both since retired) and Mr. Gerald W. Bernstein, then of SRI International and now with the Stanford Transportation Group (STG) aviation consultancy (www.STGSF.com). Financial assistance enabling updates to the information and preparation of this handbook has been provided by the Alfred L. and Constance C. Wolf Aviation Fund. Details on the fund, its mission and its history can be found at www.wolf-aviation.org.

The interpretation and analysis described here-in are fully presented so that our sources and logic can be understood and verified. Any misunderstandings or mistakes are the responsibility of the authors.

2. INFORMATION SOURCES: ACCIDENT AND RELATED DATA

This chapter provides definitions to assure key terms are used in a consistent manner. We then identify sources of information subsequently used here-in. Persons wishing to pursue safety questions in more details may further explore other information available from these same sources.

2.1 Definitions

Common usage and professional usage of terms are not always synonymous. We provide two definitions using greater detail than required by some readers, but with the intent of making the concepts clearer to a broader public not familiar with aviation acronyms.

General aviation. The term “general aviation” describes a wide variety of activity. General aviation is defined as flying activity other than military or commercial activity. “Commercial” includes large airline service (termed Part 121—referring to Part 121 of the Federal Aviation Regulations that define requirements for such service), commuter airline service (termed Part 135), and charter or air taxi services (also termed Part 135). General aviation includes recreational and personal business flying, corporate aircraft with professional crews, instructional and selected commercial uses of aviation, such as agricultural applications (“crop dusting”) and aerial photography.

General aviation flying typically occurs in single- and twin-engine piston-powered aircraft; turbojet, turbofan, or turboprop-powered aircraft; helicopters; and gliders, balloons, and dirigibles. In addition, some commercial-type aircraft owned by corporations and individuals are considered to be general aviation.

Not all airports support or allow all types of general aviation activity. Airports may exclude certain types of general aviation aircraft (such as jets) due to weight, runway or noise limitations.

Aircraft accident. An “aircraft accident” is defined by the National Transportation Safety Board (NTSB) for reporting purposes as “an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury or in which the aircraft receives substantial damage.” NTSB definitions continue with “serious injury” defined as any injury that (1) requires hospitalization for more than 48 hours; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle or tendon damage; (4) involves any internal organ; or (5) involves second or third degree burns, or any burns affecting more than 5% of the body surface. “Substantial damage” is defined as damage or failure adversely affecting the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component. Examples of damages that are *not* considered substantial include ground damage to propeller blades and damage to

landing gear, wheel, and tires. Therefore, an aircraft that landed safely off-airport for emergency purposes would not be considered an accident if none of the injury or damage criteria were met.

2.2 National Transportation Safety Board (NTSB)

As the NTSB is the federal agency charged with accident investigation and reporting, it is the starting point for any analysis of accident information. As regards general aviation, the NTSB provides two types of information that we have found useful; these include local (airport-specific) accident data and national accident data.

Individual Accident Reports

The NTSB on-line system provides a way to obtain a history of accident records for any airport in the United States. This service can be found at: <http://www.nts.gov/ntsb/query.asp> . Information is available from January 1, 1962 and later about civil aviation *accidents* and selected *incidents* within the United States, its territories and possessions, and in international waters. Generally, a *preliminary* report is available online within a few days of an accident. *Factual* information is added when available, and when the investigation is completed, the preliminary report is replaced with a *final* description of the accident and its probable cause.

Most of the fields on the interactive query form are self-explanatory. The “Category” and “Operation” fields can be designated with “all” unless there is significant non-GA activity at the airport for which the query is generated.

Depending on an airport’s location, it may well be worth reading the detailed reports that are linked to the query response. It is possible that an en-route accident has been associated with a particular airport as that was the closest airport to the accident site. In fact, the accident may have had no relationship to the airport.

Summary Information

In addition to individual accident reports, NTSB provides annual summary information on aviation accidents, including those occurring in general aviation. An example of information from the NTSB website (<http://www.nts.gov/aviation/Stats.htm>) is provided in Table 1. As illustrated in the table, both the absolute number and rate (per 100,000 aircraft-hours) of general aviation accidents and fatalities has declined nationwide over the past 30 years.

Table 1
ACCIDENTS, FATALITIES AND RATES, 1975 THROUGH 2004,
U.S. GENERAL AVIATION

Year	Accidents		Fatalities		Flight Hours	Accidents per 100,000 Flight Hours	
	All	Fatal	Total	Aboard		All	Fatal
1975	3,995	633	1,252	1,231	28,799,000	13.87	2.19
1976	4,018	658	1,216	1,203	30,476,000	13.17	2.16
1977	4,079	661	1,276	1,265	31,578,000	12.91	2.09
1978	4,216	719	1,556	1,398	34,887,000	12.08	2.06
1979	3,818	631	1,221	1,203	38,641,000	9.88	1.63
1980	3,590	618	1,239	1,230	36,402,000	9.86	1.69
1981	3,500	654	1,282	1,261	36,803,000	9.51	1.78
1982	3,233	591	1,187	1,171	29,640,000	10.82	1.96
1983	3,075	555	1,068	1,061	28,673,000	10.67	1.92
1984	3,017	545	1,042	1,021	29,099,000	10.28	1.84
1985	2,739	498	956	945	28,322,000	9.63	1.74
1986	2,581	474	967	879	27,073,000	9.49	1.73
1987	2,495	446	837	822	26,972,000	9.18	1.63
1988	2,388	460	797	792	27,446,000	8.65	1.66
1989	2,242	432	769	766	27,920,000	7.97	1.52
1990	2,242	444	770	765	28,510,000	7.85	1.55
1991	2,197	439	800	786	27,678,000	7.91	1.57
1992	2,111	451	867	865	24,780,000	8.51	1.82
1993	2,064	401	744	740	22,796,000	9.03	1.74
1994	2,022	404	730	723	22,235,000	9.08	1.81
1995	2,056	413	735	728	24,906,000	8.21	1.63
1996	1,908	361	636	619	24,881,000	7.65	1.45
1997	1,844	350	631	625	25,591,000	7.19	1.36
1998	1,905	365	625	619	25,518,000	7.44	1.41
1999	1,905	340	619	615	29,246,000	6.50	1.16
2000	1,837	345	596	585	27,838,000	6.57	1.21
2001	1,727	325	562	558	25,431,000	6.78	1.27
2002	1,715	345	581	575	25,545,000	6.69	1.33
2003	1,741	352	632	629	25,705,000	6.77	1.37
2004	1,614	312	556	556	25,900,000	6.22	1.20

Notes: 2004 data is preliminary; flight hours from FAA;
rate data excludes suicides and sabotage

Source: NTSB, <http://www.nts.gov/aviation/Stats.htm>, downloaded May 4, 2005. Data from 1975 – 1984 is on the same site, but not displayed in the html version.

2.3 Federal Aviation Administration (FAA)

Form 5010

Form 5010 are airport Master Plan Records. These contain useful information on airport size, facilities and use (including number of based aircraft and operations). This information is provided (unedited) by the firm *g.c.r. & associates, Inc.* using data derived from the National Flight Data Center (FAA). These Form 5010 reports can be found on the internet at: www.gcr1.com/5010web/

To access the data for a specific airport, a user can enter any known criteria, for example the airport's location identifier. If the location identifier is not known, the user can enter the city and state; in reply, the system will provide a list of all airports in that city from which the user can select the one of interest.

National Aviation Safety Data Analysis Center (NASDAC)

The NASDAC was established by the FAA to provide a facility for the integration and analysis of aviation safety data. Through NASDAC, users can view NTSB safety recommendations and accident reports, access reports submitted to the NASA Aviation Safety Reporting System and access FAA accident/incident reports. The NASDAC system enables users to perform integrated queries across multiple databases, searching diverse warehoused data, and displaying pertinent elements in an array of useful formats. A "query tool" on the website allows searching by specific keywords in the report narratives. The NASDAC web site can be found at www.nasdac.faa.gov.

NASDAC staff is helpful in addressing unusual requests. They can be reached through the website.

National GA Activity Statistics

The FAA compiles a variety of statistical and operational data that assist in understanding GA usage patterns at a national level. The primary summary of such information is found in the FAA's annual *General Aviation and Air Taxi Activity Survey*. The basis for this document is an annual survey the FAA conducts of GA aircraft owners to determine how their aircraft were operated during the preceding year. Survey results are published with a 2-year lag; thus the Calendar Year 2002 results were published in May 2004. (This is the most recent Survey available at the time this assessment description was prepared.) Recent editions of this survey can be found at <http://api.hq.faa.gov/pubs.asp>.

Later in this report, we utilize information obtained from Tables 2.1 and 2.4 from these annual surveys. The information used is summarized in Table 2, below for piston-engine aircraft and for fixed-wing aircraft powered by piston, turboprop or turbojet engines. (Other exclusions are noted in the footnote to Table 2.)

In Table 2, we develop a national average conversion of flight hours and operations. In so doing, it needs to be noted that the Survey only reports landings. As an "operation" is defined as a take-off or a landing, we have doubled the number of reported landings to obtain the estimates of annual operations.

Table 2
GA HOURS FLOWN AND OPERATIONS, 2000 - 2002

Year	Hours Flown		Landings		Operations / Hour	
	Piston GA	All GA	Piston GA	All GA	Piston	All GA
2000	22,198,933	26,985,537	33,301,424	37,914,142	3.0	2.8
2001	20,882,650	25,453,710	31,108,181	35,011,549	3.0	2.8
2002	18,890,889	23,485,803	30,127,617	36,321,419	3.2	3.1

Note: "All GA" refers to fixed-wing piston, turboprop and turbojet aircraft. Excludes rotorcraft, gliders, lighter-than-air, experimental and homebuilt aircraft.

Source: Group from Tables 2.1 and 2.4, *General Aviation and Air Taxi Activity Survey*, FAA, various years as shown. Operations = Landings x 2.

2.4 GA Industry Trade Associations (AOPA and GAMA)

Nall Report

The Aircraft Owner and Pilot Association (AOPA) Air Safety Foundation (ASF) publishes this annual report providing an overview of the previous year's general aviation accident statistics, including trends and contributing factors. The report is based on NTSB accident reports involving fixed-wing GA aircraft weighing less than 12,500 pounds maximum take-off weight. Most, but not all, the NTSB reports are finalized for a year by the time the information is summarized in the Nall Report.

To supplement the published report, ASF provides other summary statistics and a query system for obtaining further data. These sources can be found on the web at: http://www.aopa.org/asf/accident_data/

General Aviation Statistical Databook

The General Aviation Manufacturers Association (GAMA) publishes this annual compendium of GA statistics, including safety information, drawing upon a wide variety of sources. The last charts and graphs in the book (in recent years) have provided a national summary of NTSB data. Other charts provide information on GA aircraft shipments, fleet and flight activity, pilot population and aeronautical facilities. A copy of this databook can be found on the web at: <http://www.gama.aero>. First click on Resources tab, then click on Statistics tab.

2.5 National Safety Council (NSC)

The National Safety Council is a non-government, not-for-profit public service organization chartered by Congress. Its goal is to promote practices (related to safety, health and the environment) that prevent and mitigate human suffering or economic losses. The council annually publishes *Injury Facts* which provides statistical data on unintentional injuries arising from a wide variety of activities. The report contains number and rate data on occupational, motor-vehicle, home and community injuries and fatalities by type of activity. While aviation accidents and injuries are reported, the report is equally useful for its non-aviation content.

Table 3 provides a number of comparative perspectives from *Injury Facts*. First is that transportation-related activities cause numerous fatalities; within this context, the number of GA fatalities is at the low end of the range of alternative transportation modes. Second, we identify accident rates for other types of hazards. These are based on population and will be used to compare expected GA fatalities in a locality with those expected from these other hazards in Chapter 5.

Table 3
SELECTED ACCIDENT FATALITY INFORMATION

Type Fatality (Year)	Number	Home Rate ¹	Public Places Rate ¹
Automobile, SUV's & Pick-up trucks (2002)	32,594		
Pedestrians (2003)	5,600		
Rail (Passengers and Trespassers, 2003)	858		
Pedacycles (2003)	700		
Water Transport (2003)	est 700		
General Aviation (2003)	626		
Falls (2003)		3.1	2.2
Poisoning (2003)		3.9	0.9
Drowning (2003)		0.2	0.7 ²
Fire / Burns (2003)		0.8	NR

1 Rate data is per 100,000 population

2 Excludes boating

NR—Not Reported

Source: *Injury Facts*, 2004 Edition. Itasca, IL. Pages 90, 123, 124, 128, 129, 133, 134, 136, 137.

3. ACCIDENT DATA DETAILS

The objective of the safety assessment is to compute the likelihood of injuries or fatalities arising from a GA accident and to compare these with injuries or fatalities arising from other home and community activity. Depending on community and airport specifics (population, housing density, highway traffic volumes, number of GA operations), the expected number of GA-related off-airport injuries to persons on the ground (not involved in general aviation) is likely to be far lower than those arising from other common activities. In this chapter we provide the sources of information that demonstrate these findings. In Chapter 5 we apply this information to a sample community.

3.1 Accident and Injury Data

As Table 1 illustrates, both the absolute number and rate (per 100,000 aircraft-hours) of general aviation accidents and fatalities has declined nationwide for at least 30 years. We believe this trend reflects the combined efforts of all parties concerned with general aviation to enhance safety. Efforts include:

- Improved pilot training, coupled with stricter regulations (for example, the requirement for biennial flight reviews); AOPA air safety education programs; and an increasingly experienced pilot population, as indicated by the growth of instrument ratings (*2003 Statistical Databook*, GAMA, page 23)
- Increased regulation of airspace by the FAA, coupled with pilot licensing and aircraft equipment requirements (e.g., transponders and collision avoidance systems) for using controlled airspace
- Structural and avionics improvements introduced in successive generations of GA aircraft by the manufacturers
- Strengthened zoning and land use regulations in the vicinity of GA airports by local communities.

In this study, we take a conservative approach to accident rates and use historical information, rather than forecasting continued improvements.

Table 4 summarizes 40 years of GA accident data, showing level of severity of the accident by location (on-airport or off-airport). Table 4 (c) provides the 40-year summary. This is divided into two time periods as a result of using previous research (covering the years 1964 – 1988—see table footnote) with an update obtained from NASDAC. As the NASDAC data only goes back to 1982, we utilized the combined findings to provide broader coverage. Indeed, the results reported in Tables 4, 5 and 6 reflect events arising from over 131,000 accidents.

Table 4
NATIONAL GA ACCIDENT SUMMARY

	(a) Number of Accidents, 1964 - 1988			
	NTSB Total¹	Row Total¹	On-Airport	Off-Airport
Fatal	15,413	15,248	1,624	13,624
Nonfatal (injuries and/or damage)	87,355	88,218	49,677	38,541
Total Accidents	102,768	103,466	51,301	52,165

	(b) Number of Accidents, 1989 - 2004			
	NTSB Total¹	Row Total¹	On-Airport	Off-Airport
Fatal	5,873	5,407	805	4,602
Nonfatal (injuries and/or damage)	23,042	22,297	12,113	10,184
Total Accidents	28,915	27,704	12,918	14,786

	(c) Number of Accidents, 1964 - 2004			
	NTSB Total¹	Row Total¹	On-Airport	Off-Airport
Fatal	21,286	20,655	2,429	18,226
Nonfatal (injuries and/or damage)	110,397	110,515	61,790	48,725
Total Accidents	131,683	131,170	64,219	66,951

¹ Row totals may exceed NTSB record totals due to multiple counting of accidents (with multiple aircraft) or may be less due to lack of adequate accident classification data (“unknown” or “not reported”).

Sources: Part (a) from Table 6 (a), “Risk Assessment of the Reid-Hillview Airport Closure Evaluation Project,” SRI International for Santa Clara County, November 1993.

Part (b) STG from NASDAC correspondence May 16, 2004.

Part (c) STG

From 1964 through 1981, the data format of these records was essentially the same. In 1982, however, NTSB completely revised the format and content of its computer records, which it then modified slightly in 1983. Since 1983, the format has remained fairly stable. Our prior work combined data sets with the different formats. The change in formats is why most sources (such as NASDAC and ASF) only provide results from 1982.

As indicated in Table 4 (c), the number of accidents is approximately split on an equal basis between those which occur on-airport (that is, within the airport boundary) and those which occur off-airport (outside the airport boundary). Also noted is that off-airport accidents are more likely to result in fatalities than on-airport accidents.

While Table 4 presents the distribution of accidents, Table 5 presents the distribution of injuries and fatalities that arose from these accidents. Again, due to the combination of prior research and a current update, Table 5 is presented in three parts. Part 5 (c) provides the 40-year total. As indicated, On-Board (that is, aircraft occupant) injuries and fatalities far outnumber those that occur to persons on the ground—either on or off the airport.

3.2 GA Accident Probabilities

Table 6 is derived by dividing Table 5's injury and fatality results by the Table 4 total number of accidents (131,683) reported by the NTSB. As indicated, when an accident occurs, the expected result is 0.710 injuries based on 40 years of computerized accident data. (Note this value is less than 1.0, reflecting the large number of accidents that do result in no personal injury.) The distribution of these 0.710 injuries by severity and location (on- or off-airport, on-board or on-ground) are presented. As indicated, the greatest risks are to aircraft occupants.

Table 5
NATIONAL GA INJURY SUMMARY

	(a) Number of Injuries, 1964 - 1988				
	NTSB	On-Airport		Off-Airport	
	Total	On-Board	On-Ground	On-Board	On-Ground
Fatalities	29,759	2,663	89	26,811	196
Serious injuries	15,930	3,660	135	11,958	177
Minor injuries	24,697	8,433	118	15,779	367
Total Fatalities And Injuries	70,386	14,756	342	54,548	740

	(b) Number of Injuries, 1989 - 2004				
	NTSB	On-Airport		Off-Airport	
	Total	On-Board	On-Ground	On-Board	On-Ground
Fatalities	9,587	1,237	14	8,301	35
Serious injuries	5,206	1,447	34	3,673	52
Minor injuries	8,259	3,043	34	5,024	158
Total Fatalities And Injuries	23,052	5,727	82	16,998	245

	(c) Number of Injuries, 1964 - 2004				
	NTSB	On-Airport		Off-Airport	
	Total	On-Board	On-Ground	On-Board	On-Ground
Fatalities	39,346	3,900	103	35,112	231
Serious injuries	21,136	5,107	169	15,631	229
Minor injuries	32,956	11,476	152	20,803	525
Total Fatalities And Injuries	93,438	20,483	424	71,546	985

Sources: Part (a) from Table 6(b), "Risk Assessment of the Reid-Hillview Airport Closure Evaluation Project," SRI International for Santa Clara County, November 1993.
Part (b) STG from NASDAC correspondence May 16, 2004.
Part (c) STG

Table 6
GA INJURY RATES, 1964 - 2004

	Expected Injuries Per Accident				
	Total ¹	On-Airport		Off-Airport	
		On-Board	On-Ground	On-Board	On-Ground
Fatalities	0.299	0.030	0.001	0.267	0.002
Injuries	0.411	0.126	0.002	0.277	0.006
Total¹	0.710	0.156	0.003	0.543	0.007

1 May not add due to rounding

Sources: Table 4 (c) divided by Total Accidents (NTSB Total) from Table 3 (c)

4. SUPPLEMENTAL GA ACCIDENT OBSERVATIONS

As indicated by the difference between the two “Fatality” columns of Table 1, there appear to be a combined 5 to 10 non-occupant fatalities per year on- and off-airport. While the safety record is steadily improving (last column of Table 1), there remains both opportunity and responsibility for further improvements.

Yet despite the improving safety rates and the relative low incidence of non-occupant fatalities (particularly off-airport), the public remains very concerned with the possibility of catastrophic GA accidents. Concerns expressed as “what if the aircraft hits a house (or school or shopping center)” are repeated at airport hearings.

The severity of an aircraft crash and the resultant damage to objects on the ground are related to numerous factors not explicitly identified in the NTSB data and which can not be meaningfully forecast for any specific (or hypothetical) accident. These factors include:

- Weight, speed, and size of aircraft
- Angle of incidence to ground or structure (that is, straight-in or glancing)
- Nature of structure (wood-frame, steel-reinforced, etc.)
- Occurrence of post-crash fire.

In keeping with focus of this handbook to emphasize the historic record, we review both the past occurrence of significant accidents and review selected aircraft weight, speed and size issues as they might effect the outcome of an aircraft striking a structure. This review will show that catastrophic events are unlikely with the type of aircraft found at the typical GA airport.

4.1 Accidents with A Significant Number of On-Ground Fatalities

A review of 131,000 accident reports spanning 40 years of GA activity identifies 10 accidents in which 3 or more persons off-airport who were not aircraft occupants were fatally injured. These and other accidents with fewer non-occupant fatalities are summarized in Table 7.

Two observations can be made from Table 7. First, the three accidents that were most deadly to persons on the ground outside of an airport are all related to circumstances not found at a typical GA airport. The most deadly was the result of the crash of a civil-registered jet fighter. The second two are the result of collisions between GA aircraft and commercial transports. The crash of the Hughes helicopter and the Beech twin are arguably the most deadly of the crash of a “typical” GA aircraft. Yet these are unique single events in 40 years of national records. It would appear that GA crashes occur with neither the frequency nor severity imagined by the public.

Table 7
GENERAL AVIATION ACCIDENTS: GROUND FATALITY SUMMARY
BY NUMBER OF FATALITIES, 1964-2004

Number of Ground Fatalities per Accident	Number of Accidents	Type of Aircraft Involved
22	1	CL Mark 5 ¹
15	1	DC-9 and PA-28 ²
7	2	B727 and C-172 ³ / Hughes 269C ⁴
4	1	Beech 95-A55 ⁵
3	5	Various
2	25	Various
1	225	Various

¹ Privately-owned Canadair variant of F86F jet fighter—Sacramento, CA, 9/25/72

² DC-9 collided with Piper PA-28, Cerritos, CA, 8/31/86

³ Boeing 727 collided with Cessna 172, San Diego, CA, 9/25/78

⁴ Hughes 269C helicopter accident, Derry, PA, 9/4/78

⁵ Buchanan Field, Concord, CA, 12/23/85

Sources: NTSB; SRI International/Aircraft Safety Consultants; STG using data provided by NASDAC

The second observation is that four of the five most severe accidents have occurred in California. We have no explanation for this disproportionately high incidence of severe accidents in one state.

4.2 Impact and Energy Implications

We can not analyze in advance all the factors that would influence the outcome of an accident (as referenced in the opening paragraphs in this chapter). But we can demonstrate the range of possible crash severities in general terms by examining the energy transfer that might occur as the result of an aircraft accident.

The energy with which an aircraft will strike the ground or an object (such as a house or tree) can be calculated as one-half the product of the mass of the aircraft and the square of its speed. Since neither of these can be absolutely predicted, we have demonstrated possible crash energies using maximum gross weight and alternative speeds ranging from the stall speed (the slowest at which the aircraft could remain airborne) to its maximum cruise speed. These results are provided in Table 8.

**Table 8
CRASH ENERGY**

Aircraft	Maximum Gross Weight (lb.)	Stall Speed (mph)	Maximum Cruise Speed (mph)	Minimum Energy (ft.-lb.)	Maximum Energy (ft.-lb.)	Maximum Energy Ratio
Cessna 150	1,600	48	125	123,134	835,059	1.0
Cessna 182	2,950	58	166	331,478	2,715,283	3.3
Beech Bonanza V35B	3,400	59	209	395,300	4,960,763	5.9
Piper Seneca V	4,750	70	235	780,977	8,801,935	11
Beech King Air E90	10,100	89	287	2,672,258	27,788,311	33
Boeing 737-300	124,500	110 (est)	550	50,547,947	1,263,698,673	1,510
Boeing 747-200	785,000	115 (est)	608	346,770,635	9,692,901,322	11,610

Sources: "Jane's All the World's Aircraft" (various editions); weight is converted to slugs; speed is converted to feet/second, Energy = 0.5 * Mass * V²

As indicated, the energy with which aircraft can impact an object varies by at least 11,600-to-1. This shows that the severity of impact of a fully loaded Boeing 747 jetliner striking an object would occur with over 11,000 times the energy of a Cessna 150 in the same circumstances. A typical GA aircraft would transfer orders of magnitude less energy on impact than would a commercial airliner.

5. SAMPLE ANALYSIS: PUTTING IT ALL TOGETHER

This Handbook has been developed to present the GA accident findings and to illustrate how these can be applied to assess accident risks at any airport. For this sample analysis, we utilize the following imaginary (but not unrealistic) airport and community description. The airport consists of a single runway of 3,500 foot length, 100 based aircraft, a control tower and 90,000 annual operations on a 125 acre parcel. The airport sits at the edge of a suburban community of 80,000 population.

The following sections illustrate how to compute (statistically expected) GA-related accident probabilities and their resulting effects (injuries and fatalities), and how to compute similar measures of likely non-aviation accidents as comparison. Users of this data will likely find additional ways to apply this information; we would be pleased to hear about these applications and insights. (Contact us through www.STGSF.com).

Expected non-Transportation Accidents and their Probabilities

Our example community has a population of 80,000 persons. Thus, the number of expected fatalities from non-transportation sources identified in Table 3 would be 0.8 times the fatality rate per 100,000 persons (0.8 is the ratio of the community's population to the 100,000 on which the rate is based). Results are presented in Table 9. This table presents fatalities expected in both the home and in public places as shown by the rate data in Table 3. We have used local population as the exposure measure for public activities.

For a geographically wide-spread community or for multiple communities in proximity to the airport, it may be appropriate to use the population within a 5-mile radius rather than a single-community population for estimating the home population.

Table 9
EXAMPLE COMMUNITY FATALITY ESTIMATES

Type Fatality	Home Rate	Home Number	Public Rate	Public Number
Falls	3.1	2.5	2.2	1.8
Poisoning	3.9	3.1	0.9	0.72
Drowning	0.2	0.16	0.7	0.56
Fire / Burns	0.8	0.64	NR	---

Source: Table 3 and estimated community population. Note that rate data is expressed per 100,000 population

Expected Aviation Accident Probabilities

The expected number of annual GA accidents at an airport can be estimated using the rate data in Table 1 and the conversion data in Table 2. According to Table 1, 6.2 GA accidents can be expected for each 100,000 flight hours; according to Table 2, each flight hour is equivalent (national average) to 3.2 operations. Thus, an alternative rate for GA accidents would be 6.22 GA accidents per 320,000 operations, or 1.94 accidents per 100,000 operations.

For our example airport with 90,000 annual operations, approximately 1.74 accidents would be expected annually $((90,000/100,000) \times 1.94)$.

Expected Effects of Aviation Accidents and their Probabilities

As indicated in Table 6, when an accident occurs, based on 40 years of accident history, we would expect 0.710 injuries or fatalities. In our example with 1.74 expected accidents annually, we would therefore expect a total of 1.24 (1.74×0.710) injuries or fatalities annually.

Again using the distribution information in Table 6, we expect 0.28 $(1.74 \times (0.0156 + 0.003))$ injuries or fatalities to occur annually within the airport boundary, 0.95 (1.74×0.543) to occur off-airport to aircraft occupants, and 0.012 (1.74×0.007) to occur off-airport, to persons on the ground. Of this latter measure, the expected number of off-airport, non-occupant injuries is expected to be 0.01 per year (1.74×0.006) and the expected number of fatalities is expected to be 0.0035 per year (1.74×0.002) per year at current airport operation levels. (These two expected numbers don't add to the total due to rounding.)

This fatality estimate can be interpreted in several ways. First, it can be compared with the expected fatalities from other causes displayed in Table 9. In this case, a person in our 80,000- person community has a 700-times greater likelihood $(2.5 / 0.0035)$ of being fatally injured by a fall in a home than they have in being fatally injured by a GA aircraft. A fall in public buildings (such as the City Hall) is 500-times $(1.8 / 0.0035)$ more likely to lead to a fatality than would an aircraft accident to a person not participating in general aviation.

Or, we can ask how many years are likely to pass until an off-airport, non-occupant fatality is expected due to activity at this airport. In this case, the probability of there being no off-airport, non-occupant fatality is 0.9965 $(1.0000 - 0.0035)$. Almost 200 years would have to pass before the likelihood of their being no fatality fell below 50% $(0.9965$ to the 200th power). (Or conversely, the likelihood of their being a fatality rose above 50%.)

As with all statistics, this is the expected outcome. In fact, such a fatality could occur next year, or not within the lives of our families through our great, great grandchildren.

Expected Auto-Related Injuries and Probabilities

If an alternative use for an airport site has been proposed, many of these alternatives will generate as much or more traffic than airport use. Such an increase in traffic volume

is likely to result in an increased number of automobile-related accidents, with resulting damage, injuries and fatalities. Such details may exist in an environmental impact assessment of alternative site uses.

For the purpose of example, we continue with our city of 80,000 persons. Traffic accident data is available in most cities from either police or transportation departments. Our example city's traffic records show an average of 500 automobile-related injuries and 4 fatalities per year in recent years. The proposed project is to convert the airport's 125 acres into 1500 dwelling units and shops. Expected residency is 3,900 persons (national average is about 2.6 persons per dwelling unit according to the year 2000 US Census).

Again, this approach is simplified as it ignores the particular characteristics of the city's traffic network. This approach is suggested to provide a comparative measure of risk only if a more detailed traffic-based analysis is not available. The average number of injuries and fatalities per 10,000 (or 100,000) residents can be computed.

In this case, we would expect 62 injuries ($500 / 8$) and 0.5 ($4 / 8$) fatalities per year for each 10,000 residents. The additional 3,900 residents in the proposed development would be expected to result in 24 auto-related injuries ($62 \times (3,900/10,000)$) and 0.20 fatalities ($0.5 \times (3,900/10,000)$) per year.

Thus, in our example city, the resultant development is expected to result in 2400-times more injuries ($24 / 0.01$) to persons off the airport site and 55-times more fatalities ($0.20 / 0.0035$) resulting from increased traffic than GA operations at the airport.

Such an approach is not as accurate as a detailed traffic analysis utilizing trip generation rates and intersection accident frequencies. But a population-based estimate provides a reference point if a traffic analysis or full environmental assessment has not yet been undertaken.