NASA/TM–2002-209615
AFDD/TR-00-A-010

An Analysis of U.S. Civil Rotorcraft Accidents by Cost and Injury (1990-1996)

Laura Iseler and Joe De Maio

May 2002

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at *http://www.sti.nasa.gov*

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at (301) 621-0134

- Telephone the NASA Access Help Desk at (301) 621-0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM–2002-209615
AFDD/TR-00-A-010

An Analysis of U.S. Civil Rotorcraft Accidents by Cost and Injury (1990-1996)

Laura Iseler
Ames Research Center
Moffett Field, California

Joe De Maio
Aeroflightdynamics Directorate
U.S. Army Aviation and Missile Command
Ames Research Center, Moffett Field, California

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035-1000

May 2002

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
(301) 621-0390

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

An Analysis of U.S. Civil Rotorcraft Accidents by Cost and Injury (1990 -1996)

Laura Iseler

Army/NASA Rotorcraft Division
Ames Research Center

Joe De Maio

Army/NASA Rotorcraft Division
Aeroflightdynamics Directorate
U.S. Army Aviation and Missile Command
Ames Research Center

INTRODUCTION

The present analysis is the third in a series commissioned by NASA Ames Research Center. Two other helicopter accident analyses sponsored by NASA have been completed. The largest study, performed by Harris, Iseler and Kasper (in press), looked at all civil rotorcraft accidents recorded in the past 35 years. That study gave an overview of the statistical trends. A narrow, but very thorough study was performed by the Helicopter Accident Analysis Team (HAAT, 1998). The HAAT study, conducted by a team of 20 experts from all aspects of rotorcraft aviation, reviewed the full accident reports for 34 fatal accidents. The team determined a chain of events that lead to each accident and then suggested a number of potential solutions for each accident. The theory behind these solutions was that if any event in the chain were prevented, then the accident would have been prevented. The third study, discussed in this paper, looked at seven years of rotorcraft accidents with a moderate level of resolution. This study looked solely at the first event, rather than the chain of events leading to each accident. Taken together, the three studies give some understanding of the overall problems of civil rotorcraft accidents.

The present analysis focuses on the 7-year period from 1990 to 1996. During this period the National Transportation Safety Board (NTSB) documented 1396 civil rotorcraft accidents in the United States. These accidents resulted in 491 deaths. This represents an average of 200 rotorcraft accidents and 70 fatalities per year. The purpose of the analysis was to identify potential areas of research that might produce a reduction in the helicopter accident rate.

Background for this Study

The database of accidents used in this investigation was extracted from summary data received from the NTSB. The analysis was limited to recent accidents (1990 - 1996) to ensure that the issues raised are ongoing concerns. During this period, the NTSB initiated a total of 1396 accident reports. The investigation of 1165 accidents was complete enough by January 1997 that a probable cause and a complete description of the events were available. This subset formed the basis for this study.

The focus of safety improvements should be on problems that cost the most in terms of human life, injuries and damage to the aircraft. Fatal accidents were examined in detail, and helicopters were grouped into four cost categories for a broader analysis. These categories were based on the cost of a newly equipped aircraft (in 1994 prices – see Table 1 or Appendix A for the complete list).

Table 1 Examples of helicopter models included in each cost category

Low Cost 0 - $600K	Medium Cost $600k - $1.5M	High Cost $1.5M - $4M	Very High Cost More than $4M
Aerospatiale 318 Bell 47 Enstroms Hughes Hillers McDD 369 (except D) Robinsons, Schweizers All Kits	most Aerospatiales (except 365 & 318) Bell 206 Hughes/McDD 500 - 600 McDD 369D	Augusta 109 BO 105 BK 117 Bell 204, 205, 222 UH1 Kaman 43 Sikorsky 58	Aerospatiale 365 Bell 212, 214, 230, 412 Sikorsky 19, 54, 55, 60, 64, 76

ANALYSIS BY GROUP

Rotorcraft Accident Rate Comparison

Commercial air carriers are generally considered to be the safest form of air travel. So the airline accident statistics provide a good benchmark against which to compare helicopters. Figure 1 shows a comparison of airline and helicopter accident statistics. Accident rates and fatal accident rates are shown for each mode of transport. A log scale is used because the fatal accident rate for both airlines and helicopters is about one-tenth the total accident rate. The helicopter accident rate (left scale) is about 3 accidents per 100,000 departures. The airline accident rate (right scale) is about one-tenth the helicopter rate, about 0.3 accidents per 100,000 departures. Fatal accidents show the same relationship. The airline fatal accident rate (about 0.05 fatal accidents/100K departures) is about one-tenth the helicopter rate (0.5 fatal accidents/100,000 departures).

These results suggest that helicopter accidents and airliner accidents are about equally survivable. That is the likelihood of a fatal accident, given an accident has happened, is about the same for both modes of travel. Helicopters are more likely, however, to have an accident – by a factor of ten.

This raises the question, why are helicopters more likely to have accidents. There are four general areas of difference between helicopters and airliners. These are pilot, equipment, environment, and mission. Airline pilots are highly trained and highly experienced. Helicopter pilots run the full gamut from students through weekend pilots to highly trained professionals. Similarly airline equipment is high-end state of the art. While some of the most expensive helicopters have turbine engines and sophisticated electronics, many, even most, are piston powered, VFR rated machines. The helicopter operating environment differs greatly from that of the airliner. Airliners are controlled from push back to shut down. Helicopters operate mostly in uncontrolled airspace. Finally the missions differ considerably. While airliners fly point-to-point at altitude, helicopters have a wide variety of distinctive missions, many with specific hazards.

Compared to airliners, general aviation is much like helicopters regarding pilot population, equipment and environment. It lacks many of the mission risk factors of helicopters, such as hover and external loads. Figure 2 shows a comparison of helicopter and general aviation (Arendt, 1997) accidents and fatalities. Both statistics show comparable rates for helicopters and general aviation. These results suggest that the distinctive characteristics of helicopter missions do not play a major causative role in the higher rate of accidents compared to airliners. Rather factors common to helicopters and general aviation may drive the accident rate.

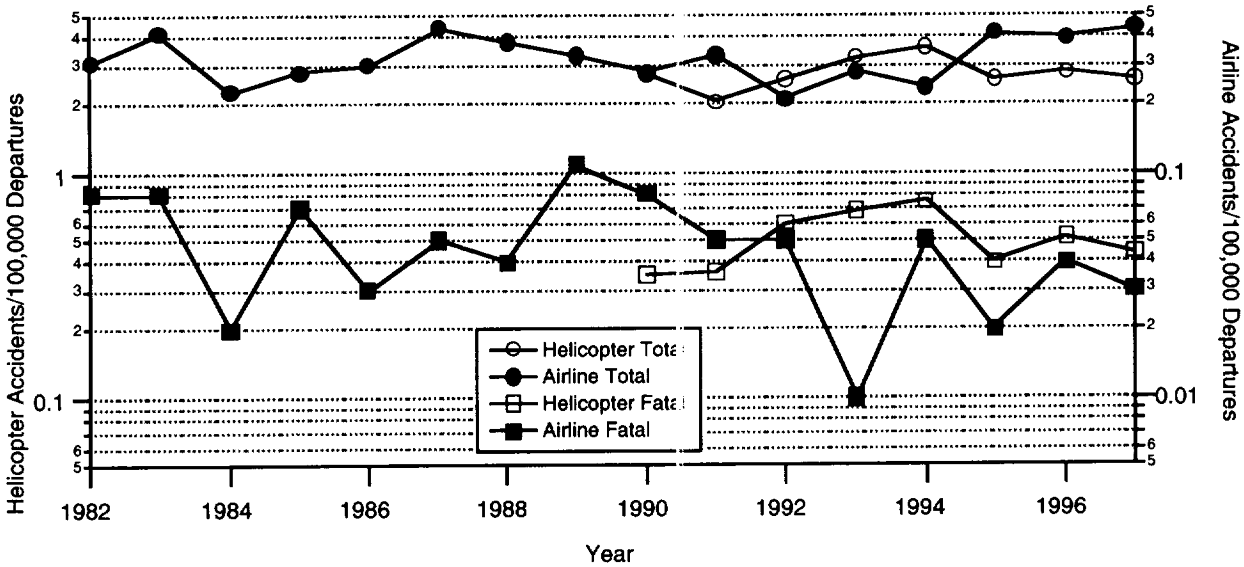

Figure 1. Total and Fatal Accident Rates for Helicopters and Airlines (per 100,000 departures)
(FAA Statistical Handbook of Aviation)

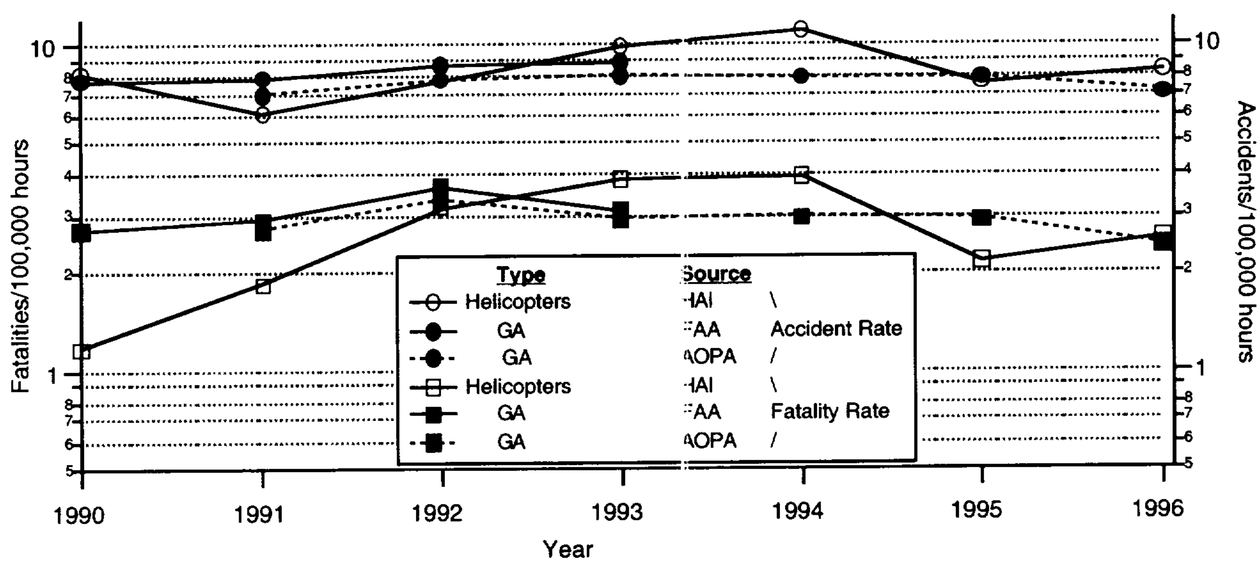

Figure 2. Accident and Fatality Rates for Helicopters and General Aviation (per 100,000 hours)
Note: Statistics for GA are shown from FAA & AOPA to cover the time range.
(FAA Statistical Handbook of Aviation, Arendt 1997, Comparative US Civil Helicopter Safety Trends)

Accident Categorization

An accident is defined by the NTSB as an occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage (Gleim, 1999).

An accident consists of a series of events that NTSB investigators attempt to identify and codify. The present analysis focuses on the first event triggering the accident and the causes of that event. Trends in first event and cause data can point to fruitful research areas. Other factors studied were the mission and associated risk factors, autorotation status (practice, emergency or none), injury, damage, and phase of flight. In general, there was little coded data regarding mission and risk factors. These data were culled from the summary descriptions. Unfortunately the NTSB codes occasionally conflict with the narrative description of the accident. Sometimes, ambiguous NTSB coding was bypassed when the description presented a reasonable explanation of what happened.

The first step in the analysis is to develop a schema for categorizing accidents. The result of an analysis depends on its level of resolution. If too few cause types were used, unrelated accidents would be lumped together. If too many types were used, spurious differences would be obtained. The present analysis uses 10 categories. Five of these categories concern pilot error, and five involve aircraft, mission and other factors. The list of causes is shown below and in Appendix B. Appendix C lists the NTSB codes that correspond to each category. The ten general causes identified for this study are listed below with brief definitions. The causes of some accidents could not be determined from the narrative description.

1. **Pilot impairment** includes both physical and psychological difficulties. Physical impairments include fatigue, nausea, food poisoning, dehydration, incapacitation due to illegal substances, a medical condition, or environmental factors directly affecting and impairing the pilot such as cold or heat. Psychological factors include depression, anxiety, and pressure by external sources or self-pressure to complete the flight.

2. **Experience** (or the lack of it) could result from inadequate training or a low number of flight hours. An associated problem is overconfidence. For this study, experience refers only to those behaviors for which a pilot can acquire skill through practice. This includes appropriate use of all flight controls, proper control of airspeed and rotor RPM, and maintaining situational awareness.

3. **Pre-flight preparation** includes everything that should be addressed before leaving the ground. This includes all required calculations (e.g., fuel, aircraft performance, envelope limits, aircraft weight and balance), all checklist items (e.g., setting instruments, securing cargo, fueling the aircraft, completing a walk-around), and finalizing choices (e.g., flight profiles, landing areas, weather evaluation, and contingency plans.)

4. **In-flight decision and judgement** includes judging distances for clearance and altitude as well as climb and descent rates. In-flight judgments regarding fuel and carburetor heat requirements and decisions to leave an aircraft running unattended also fall into this category. Weather-related decisions are not included.

5. The **interpretation** category includes all lapses of communication and miscommunication, misunderstanding, or lack of knowledge of procedures and directives.

6. The **aircraft problems** category includes all malfunctions whether they were preventable or not. This includes malfunctions due to improper maintenance, and poor design or quality control by manufacturer. In retrospect, this category would have benefited by further subdivision by either aircraft system affected or cause of failure (e.g., maintenance, design, quality control, etc.)

7. The **high risk operations** category includes accidents in which the nature of the operation or mission contributed directly to the accident. Unfortunately the NTSB does not code adequately to determine if an accident was due to the type of operation so this category may be underrepresented. The type of operations that involve inordinate risks include external load, pinnacle or confined area, low altitude, proximity to obstacles, and formation flight.

8. **Wire strikes** represent a special case. While wire strikes are an event rather than a cause, the reasons that they happen are so complex that wire strikes merit a separate cause category. Wires are hazardous because they are difficult to see and detect, thus pilots may not see them until impact is inevitable, if at all. Despite the danger, rotorcraft are routinely required to fly in a wire-rich environment. This situation is exacerbated when a pilot's attention is divided between flying and other tasks such as aerial observation or aerial application.

9. The **environment** category includes all weather-related accidents as well as those precipitated by poor lighting conditions, hazardous terrain or inadequate facilities. More specifically, this category includes VFR flight into IMC, inadequate compensation for winds, gusts or downdrafts, and inability to see due to darkness or fog. Hazardous terrain includes high altitude sites, mountains, and water. A landing area might be deficient in markings, lighting, size or clear area.

10. The '**other**' category includes foreign object damage, intentional misbehavior, instances in which the pilot or operator knowingly ignored the problem, and any known cause that is not adequately described by the preceding categories.

ANALYSIS BY COST

There are three factors that might determine the helicopter accident rate: pilot, equipment and control environment. To break these out we examine different categories of helicopters. As we move from lower cost helicopters to higher cost helicopters, the equipment becomes more sophisticated and the pilots more highly trained and experienced. Control environment, on the other hand, is relatively constant, regardless of aircraft cost. A cost by accident rate analysis was performed for the low cost and very high cost categories in Table 1. The obtained accident rates are overestimates because the usage data were incomplete. We obtained annual use data for three very high cost models and eleven low cost models (Rotorcraft Activity Survey, 1989). Using these numbers as estimates of total usage in each category, the accident rate for the low cost was more than five times that for the very high cost category. Thus the rate for very high cost helicopters is comparable to that for airliners. This difference is probably an underestimate, since the usage data for the very high cost aircraft was much less complete than that for the low cost category.

The difference in accident rate between low cost and very high cost helicopters is not attributable to environment since both groups fly mostly uncontrolled and mostly VFR. Rather the difference can be attributed to differences in pilots and equipment. The analysis that follows examines these differences, and looks at mission factors that influence accident statistics.

The most common causes merit the focus of the safety program and the rotorcraft industry. However, it is important to consider both the costs and benefits when identifying appropriate research and development areas. The most common types of accidents may not be the most costly or injurious. The value of a safety intervention is determined both by the frequency of occurrence of a type of accident and the magnitude of its consequences.

Of the 1165 accidents examined, most involved lower cost helicopters. Almost two thirds fell into the Low Cost category, one quarter into Medium, 6.5% into High, and 2.4% into Very High (see Table 2). Over the seven year period about 11% of the Low and Medium cost fleets were involved in accidents, while 7.5% of the High cost fleet and 6% of the Very High cost fleet were involved in accidents. Thus the odds of a lower priced rotorcraft having an accident are greater than are the odds for a higher priced vehicle.

Table 2. Accident Rates by Aircraft Cost

	Total	Low $0 – 0.6M		Medium $0.6 – 1.5M		High $1.5 – 4M		Very High >$4M	
	#	#	%	#	%	#	%	#	%
Fleet size (1994)	11459	7005	61.1%	2727	23.8%	1015	8.9%	473	4.1%
Accidents	1165	756	64.9%	305	26.2%	76	6.5%	28	2.4%
% of fleet of cost category*			10.8%		11.2%		7.5%		5.9%
People involved	2398	1253	52.3%	874	36.4%	137	5.7%	134	5.6%
Average # people/accident	2.06	1.66		2.87		1.80		4.79	

Note: Percentages are based on total within each row except for *

Injury

Of the nearly 2400 people involved in the 1165 accidents, most walked away. About half of the passengers and crew were injured. The degree of injury was divided about equally between minor, serious and fatal (see Fig. 3 or Table 3). The distribution of injuries shifts over the cost ranges, however. For low-cost helicopters, 20% of the accidents involve either serious injuries or fatalities. For the Very-High Cost category, on the other hand, nearly 50% of the accidents involve either serious injuries or fatalities (see definitions of injury in Appendix D). Low and medium cost helicopters experience a relatively high rate of minor and no injury accidents as compared to more expensive aircraft. These accidents occur frequently in low speed, low altitude flight under benign conditions. It

Table 3. Injuries by Cost Category

	Total		Low Cost		Medium Cost		High Cost		Very High Cost	
Type of Injury	#	%	#	%	#	%	#	%	#	%
Fatal	363	15.1%	149	11.9%	146	16.7%	39	28.5%	29	21.6%
Serious	285	11.9%	110	8.8%	122	14.0%	20	14.6%	33	24.6%
Minor	464	19.3%	249	19.9%	164	18.8%	23	16.8%	28	20.9%
None	1286	53.6%	745	59.5%	442	50.6%	55	40.1%	44	32.8%
Total # people	2398		1253		874		137		134	

Note: Percentages are calculated based on totals within cost category

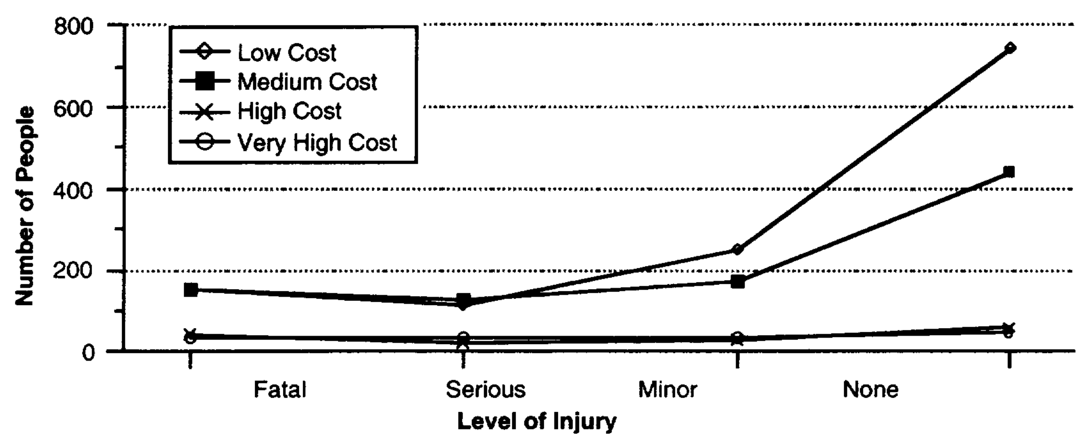

Figure 3: Injuries by Cost Category

is likely that the pilots of higher cost aircraft are simply able to avoid these minor accidents. In fact the data on accidents as a function of fleet size (see Table 2) show this reduction for higher cost aircraft.

Damage

The aircraft damage data reveals a similar difference between the cost categories (see Figure 4 and Table 4, definitions of damage categories are presented in Appendix E). Substantial damage can result from relatively benign accidents such as hard landing and practice autorotations. Since the high end helicopter pilots seem to avoid these types of accidents, there is no peak in the substantial damage category like there is for the low end helicopters. Like the injury data, the damage data suggest that pilots of more expensive aircraft can handle minor situations in a way that avoids injury and damage.

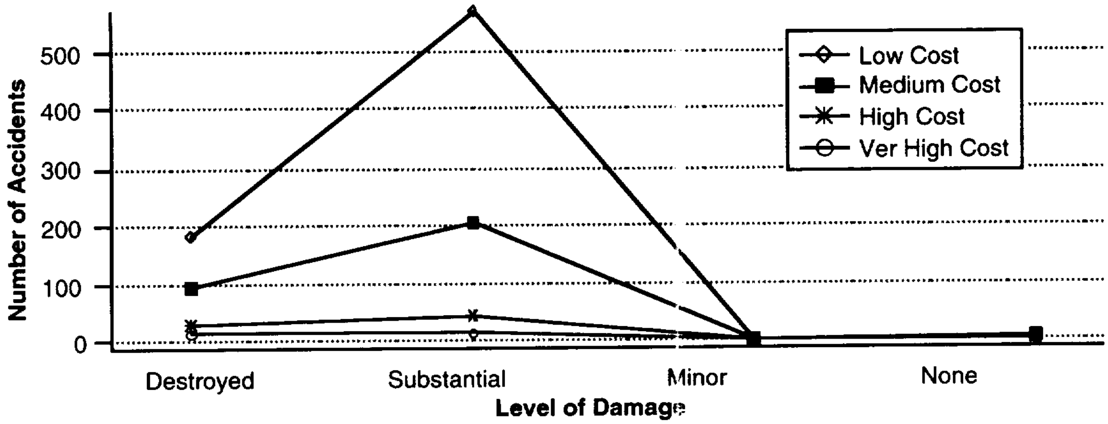

Figure 4: Damage by Cost Category

Table 4. Damage by Cost Category

Damage	Total		Low Cost		Medium Cost		High Cost		Very High Cost	
	#	%	#	%	#	%	#	%	#	%
Destroyed	318	27.3%	181	23.9%	93	30.5%	30	39.5%	14	50.0%
Substantial	835	71.7%	571	75.5%	205	67.2%	45	59.2%	14	50.0%
Minor	3	0.3%	2	0.3%	1	0.3%				
None	9	0.8%	2	0.3%	6	2.0%	1	1.3%		

Phase of Flight

Accidents were most frequent in the maneuvering, approach, landing, and cruise phases of flight except for High Cost rotorcraft (see Table 5 – largest categories are highlighted). Aircraft in the High Cost category had hover rather than approach and landing as the third most frequent phase of flight. There is no clear implication how pilot, equipment, or environment affects what phase of flight will result in an accident.

Table 5. Phase of Flight

Phase of Flight	Total		Low Cost		Medium Cost		High Cost		Very High Cost	
	#	%	#	%	#	%	#	%	#	%
Maneuvering	265	22.7%	179	[redacted]	55	[redacted]	26	[redacted]	5	17.9%
Approach & Landing	243	20.9%	176	[redacted]	51	16.7%	7	9.2%	9	[redacted]
Cruise	235	20.2%	146	19.3%	61	[redacted]	19	[redacted]	9	[redacted]
Takeoff	138	11.8%	100	13.2%	31	10.2%	7	9.2%		
Hover	132	11.3%	80	10.6%	36	11.8%	13	17.1%	3	10.7%
Climb & Descent	53	4.5%	37	4.9%	14	4.6%	2	2.6%		
Standing & Taxi	60	5.2%	30	4.0%	26	8.5%	2	2.6%	2	7.1%
Go-around (VFR)	5	0.4%	4	0.5%	1	0.3%				
Unknown	5	0.4%	2	0.3%	3	1.0%				

First Event

The first event is the first anomalous occurrence that the NTSB codes as part of the accident sequence. Appendix F contains a list of the first events found in this entire data set. Loss of engine power is the most frequent first event for all but the most expensive category (see Table 6 – largest categories are highlighted). For the more expensive rotorcraft, airframe and system failure or malfunction is most common first event. This shift of first events from loss of engine power to airframe or system failure may be due to the larger number of twin engine rotorcraft in this category, the complexity of the vehicles, or the increased level of pilot training.

Low, Medium and High cost categories had roughly the same pattern of first events: loss of engine power, loss of control, in-flight collision with object, system failure/malfunction and in-flight collision with terrain or water. However, in-flight collision with objects and loss of engine power were second and third most frequent first events for Very High Cost helicopters with few loss of control and no hard landings or rollovers. The relatively smaller number of accidents involving loss of engine power as the first event reflects the fact that many Very High Cost helicopters have two engines that rarely fail simultaneously. The low number of loss of control, hard landings and rollovers is likely due to the high skill level of pilots flying the Very High Cost aircraft.

Table 6. First Event

	Total		Low Cost		Medium Cost		High Cost		Very High Cost	
First Event	#	%	#	%	#	%	#	%	#	%
Loss of engine power	311	26.7%	204	[redacted]	77	[redacted]	25	[redacted]	5	17.9%
Loss of control	216	18.5%	154	[redacted]	47	[redacted]	13	17.1%	2	7.1%
Collision with object	150	12.9%	93	12.3%	40	13.1%	10	13.2%	6	[redacted]
Airframe/system failure/malfctn	145	12.4%	83	11.0%	37	12.1%	16	[redacted]	9	[redacted]
In-flight collision terrain/water	100	8.6%	68	9.0%	24	7.9%	4	5.3%	4	14.3%
Hard landing	74	6.4%	55	7.3%	18	5.9%	1	1.3%		
Roll over	40	3.4%	28	3.7%	12	3.9%				
In-flight encounter with weather	39	3.3%	15	2.0%	20	6.6%	3	3.9%	1	3.6%
Miscellaneous/other	90	7.7%	56	7.4%	28	9.2%	4	5.3%	1	3.6%

Cause

In interpreting the NTSB database, it is easy to confuse the First Event with the Cause of the accident. Some of the same language is used and overlap exists. Yet the first event and cause are not necessarily the same. Some examples are presented here to clarify this confusion of terms. The first event, ‘loss of engine power’ could have a number of causes. An engine malfunction would be classified as an aircraft problem. Fuel exhaustion could be classified as a pre-flight error. Foreign object damage would be coded as ‘other.’ In the extreme, flying through a sprinkler system to wash the aircraft was classified as a failure of in-flight decision making. Similarly, the first event ‘loss of control’ could be due to lack of experience, inadequate compensation for wind, loss of situational awareness, etc.

Aircraft problems are by far the most common cause of helicopter accidents, in contrast to other segments of aviation in which the most common cause is pilot error. For helicopters, the next most common causes are pilot experience, in-flight decision, environment , and inadequate pre-flight, respectively (see Figure 5 and Table 7 – largest categories are highlighted). The ‘aircraft problems’ category is very broad, encompassing design, manufacturing, and maintenance problems, as well as inadequate inspection of a deteriorated condition. This category by itself merits further investigation. This analysis reiterates the pilot versus equipment dichotomy. Aircraft problems comprise about half of the high end helicopter accidents, while pilot skill problems account for 70% of the low end accidents.

Table 7. Cause Categories

	Total		Low Cost		Medium Cost		High Cost		Very High Cost	
Cause Categories	#	%	#	%	#	%	#	%	#	%
Aircraft problems	341	29.3%	202	26.7%	91	29.8%	36	[illegible]	12	[illegible]
Experience	203	17.4%	161	21.3%	34	11.1%	6	7.9%	2	7.1%
In-flight decision	157	13.5%	104	13.8%	41	13.4%	6	7.9%	5	17.9%
Environment	134	11.5%	68	9.0%	57	18.7%	6	7.9%	2	7.1%
Pre-flight	107	9.2%	71	9.4%	25	8.2%	9	11.8%	2	7.1%
Wire strike	86	7.4%	61	8.1%	18	5.9%	6	7.9%	1	3.6%
Undetermined	75	6.4%	59	7.8%	13	4.3%	3	3.9%	0	0.0%
Other	26	2.2%	18	2.4%	7	2.3%	0	0.0%	1	3.6%
High Risk Operations	18	1.5%	4	0.5%	11	3.6%	1	1.3%	2	7.1%
Pilot Impairment	9	0.8%	6	0.8%	1	0.3%	2	2.6%	0	0.0%
Interpretation	9	0.8%	2	0.3%	6	2.0%	0	0.0%	1	3.6%

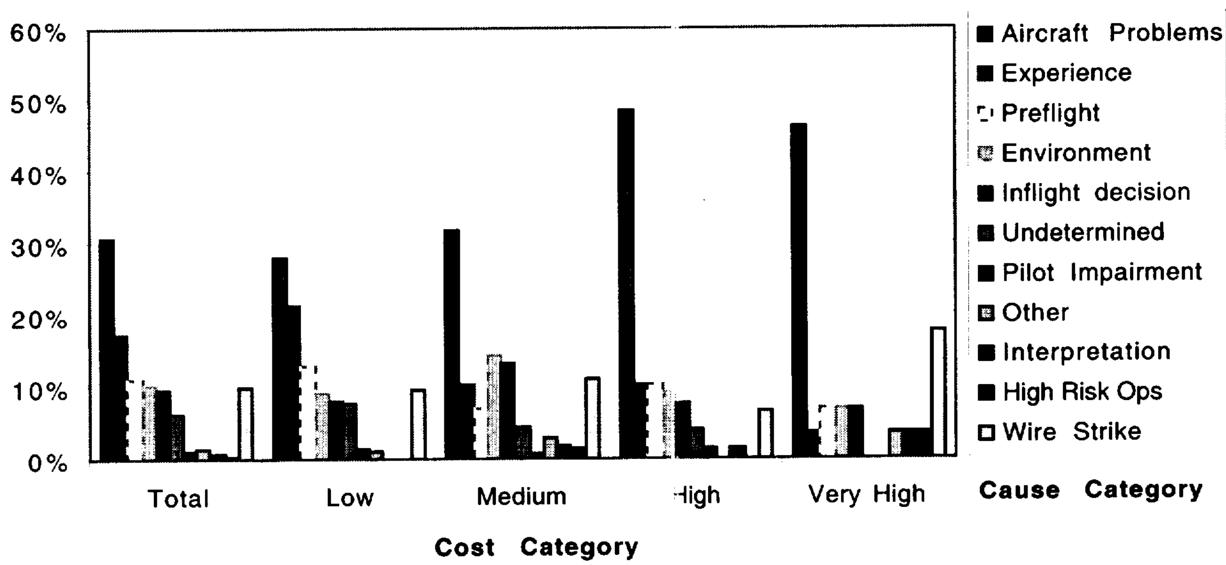

Figure 5. Causes by Cost Category

Autorotations

Practice or demonstration autorotations resulted in 100 accidents. Fortunately, these accidents resulted in only 3 fatalities and low damage levels. About 92% of these accidents happened during instruction, personal flight, or testing. The most common first event in an accident that involved an autorotation was a hard landing (43%) which resulted in rolling upon touchdown (25%) and the main rotor severing the tail boom (28%). The most common causes were lack of experience (41%) and in-flight decision-making or inadequate judgment (19%).

Emergency autorotations were performed in 241 accidents, in which there were 28 fatalities among the 499 people involved. This fatality rate is low compared to the overall fatality rate (15.1%). About 16% fewer aircraft are destroyed across the board when an emergency autorotation is performed as compared to the overall average. Abrupt maneuvers or hard landings caused the main rotor to sever the tail boom in 43 of these aircraft (17.8%). Inadequate landing site is probably the biggest environmental factor impairing the pilot's ability to land safely from an emergency autorotation without damage to the aircraft.

ANALYSIS BY INJURY

Fatal Accidents

A fatal accident is one in which one or more of the occupants die as a result of the injuries that are sustained. Fifteen percent of all the people involved in the 1165 accidents were killed. Seventeen percent of all accidents were fatal. Yet two thirds of the people involved in the fatal accidents survived. Survivability is an important issue in the case of fatal accidents. If one person survives the accident, it is conceivable that other occupants could have survived as well, had one or more factors been different. If only one person were involved, it could not be determined whether additional occupants might have survived. Between 34% and 68% of all fatal accidents for the past seven years were survivable and the severity of the injuries might have been mitigated to reduce the fatality rate. The HAAT study addresses this survivability issue in more depth. (op cit)

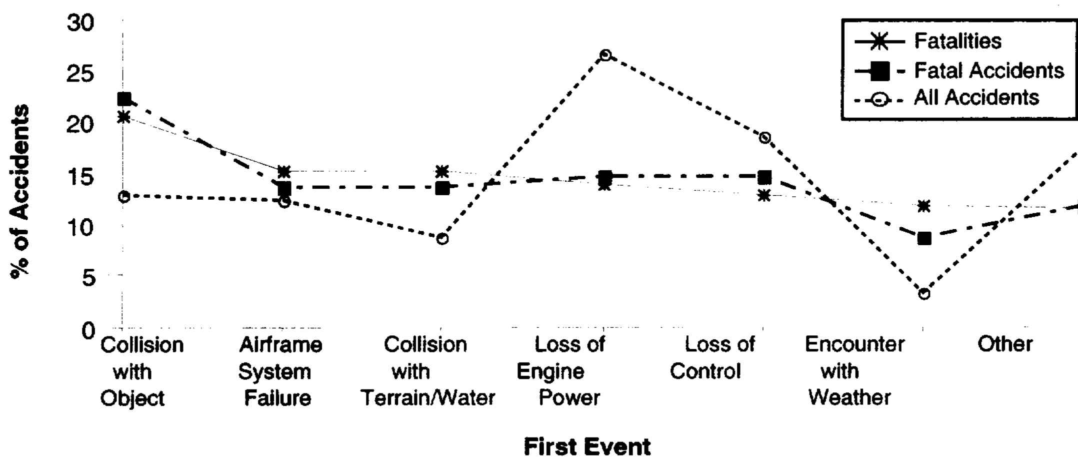

Figure 6. First Event for Fatal Accidents versus All Accidents

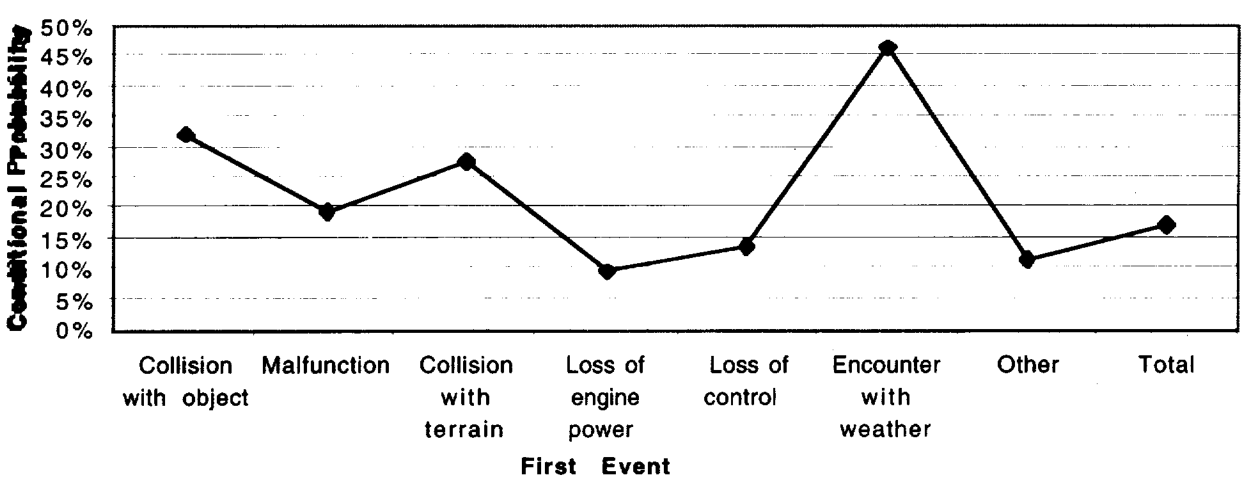

Figure 7. Conditional Probability of Fatality by First Event

The pattern of first events for fatal accidents is slightly different than for accidents in general (see Fig.6). Collisions are the biggest single cause of fatalities. Collisions with either objects or the ground account for 35% of fatalities even though these types of accidents account for only 22% of all helicopter accidents. Figure 7 depicts the conditional probability of a fatal accident given that an accident has occurred with a particular first event. In-flight encounters with weather accidents are most likely to be fatal, but since these accidents are relatively rare, their contribution to the accident rate is small. Fatalities are relatively unlikely in loss of engine power accidents. Loss of engine power is the most common first event, but has the lowest probability of fatalities.

The breakdown of generalized causes of all fatal accidents examined in this study is shown in Table 8. While aircraft problems are the predominant single cause of fatalities, the conditional probability of fatality is low. Several factors that might be grouped under the heading of "judgement" caused a third of fatal accidents. The conditional probability of fatality for this group is high. Accidents attributed to aircraft problems and pilot experience tend to be more benign, having low fatality rates. On the other hand, accidents attributed to pilot impairment, interpretation, VFR into IMC, and wire strike are more perilous.

Table 8. Causes of Fatal Accidents versus All Accidents

	Fatal accidents				All accidents		Conditional
Causes	#	fatalities	#	accidents	#	accidents	Probability
Pilot Impairment*	10	2.8%	7	3.4%	9	0.8%	77.8%
Interpretation*	5	1.4%	5	2.4%	9	0.8%	55.6%
Environment - VFR into IMC*	43	11.8%	14	6.8%	26	2.2%	53.8%
Wire strike*	57	15.7%	35	17.1%	86	7.4%	40.7%
Environment - other than IMC	45	12.4%	27	13.2%	108	9.3%	25.0%
High Risk Operations	8	2.2%	3	1.5%	18	1.5%	16.7%
In-flight Judgement/Decision*	44	12.1%	21	10.2%	157	13.5%	13.4%
Aircraft Problems	83	22.9%	44	21.5%	341	29.3%	12.9%
Pre-flight	15	4.1%	12	5.9%	107	9.2%	11.2%
Experience	20	5.5%	16	7.8%	203	17.4%	7.9%
Unknown	24	6.6%	14	6.8%	75	6.4%	18.7%
Other	9	2.5%	7	3.4%	26	2.2%	26.9%
Totals	**363**		**205**		**1165**		**17.6%**

* Judgement related causes

ANALYSIS BY FIRST EVENT

Loss of Engine Power Accidents

Loss of engine power is the most common first event for all accidents, occurring in 311 accidents that involved 616 people. There were 50 fatalities (8%), 80 serious injuries (13%), 112 minor injuries (18.2%) following a loss of engine power. This fatality rate is roughly half of the rate across all types of accidents. Autorotations were performed in 162 of the loss of engine power accidents, 52 aircraft rolled upon touchdown, and 49 severed the tail boom with the main rotor. Although destructive to the aircraft, these events tend to result in relatively few fatalities and serious injuries.

The cause of Loss of Engine Power events could not be determined for reports containing no further specification. For those containing this information, the most common system failures involved in Loss of Engine Power accidents were engine assembly (96 accidents, 31%) and fuel system (58 accidents, 19%). The most common human errors involved in Loss of Engine Power were fuel exhaustion or improper fuel (50 accidents, 16%), and maintenance (44 accidents, 14%). For more details on causes of loss of engine power, see Harris, Iseler, and Kasper (in press).

Collision with Object

Collision with object is the most catastrophic first event. Although an encounter with weather accident has a higher probability of being fatal, collision with object accidents have resulted in more deaths because they are more common. A total of 74 people were killed of the 305 people involved. Fatalities resulted in 48 of the 150 collision with object accidents. About 60% of the objects hit were wires. Environment, primarily poor visibility, was implicated in 19% of the wirestrikes. No reason, other than failure to see and avoid, was given for 60% of the wirestrikes. Over half of the remaining collision with object accidents resulted from poor clearance judgement.

Loss of Control accidents

Loss of control is the second most common initiating event for all accidents. There are 216 accidents (18.5% of all accidents) which listed 'loss of control' as a first event. These accidents involved 415 people and led to 48 fatalities. The character of these accidents differs from the Loss of Power accidents. There were few cases of autorotation (7) or severed tail boom (7). Almost one third of these accidents, 66, resulted in the aircraft rolling upon touchdown.

The most common causes of loss of control accidents are lack of experience (34%) and environment (25%). Pilots are most likely to lose control during hover, maneuvering, or takeoff, during personal or instructional flights (see Table 9). These phases of flight tend to be the most workload intensive and personal and instructional flights involve less experienced pilots.

Table 9: Statistics for Loss of Control Accidents

Cause	#	%
Experience	74	34.3%
Environment	54	25.0%
Pre-flight	24	11.1%
Aircraft Problems	23	10.6%
In flight decision	16	7.4%
Undetermined	10	4.6%
Other	6	2.8%
High Risk	5	2.3%
Pilot impairment	4	1.9%

Phase of flight	#	%
Hover	41	25.8%
Maneuvering	30	18.9%
Takeoff	26	16.4%
Approach	18	11.3%
Cruise	13	8.2%
Landing	13	8.2%
Taxi	7	4.4%
Manvr - aerial appl	7	4.4%
Standing - eng opg	2	1.3%

Type Operation	#	%
91 Personal	42	26.4%
91 Instruction	20	12.6%
137 Aerial applctn	14	8.8%
135 Air Taxi	13	8.2%
133 Other work	12	7.5%
91 Aerial observtn	8	5.0%
91 Position	7	4.4%
91 Public use	7	4.4%
91 Other work	6	3.8%

Airframe, Component, System Failure or Malfunction

Aircraft system malfunctions were identified as the first event in 145 accidents. In 46 of these accidents, autorotations were performed as a precautionary measure. Those 46 produced a 13.6% fatality rate versus 21.5% when an autorotation was not performed. Thus precautionary autorotations would seem to increase the chances of surviving this type of accident. The systems that failed or malfunctioned most often were rotor drive systems (34.5%), rotor systems (20.7%), and flight control cases (15.2%). These systems are areas for potential design improvement. Perhaps more helpful would be to review these cases more thoroughly to determine specifically what caused the problems. The particular parts of the systems that failed or malfunctioned, as determined by the NTSB, are listed in Appendix G. Frequently, the system that failed is listed but the reason it failed is not. Of those causes listed, the most common was maintenance (24.8%). Manufacturer's quality control (5.5%) and pre-flight (4.1%) were a distant second and third.

VFR Flight into Instrument Meteorological Conditions

Only 26 accidents of the total 1165 in the database were listed as having a first event of 'VFR flight into IMC'. This is only 2.2% of all accidents. However these 26 accidents account for 6.4% of fatal accidents and 11.8% of fatalities. IMC accidents have a fatality rate of 58%. Although IMC accidents are rare, they should be a concern for the safety program. Visibility is directly implicated in an additional 29 accidents and contributed in part to 30 more.

Collision with Terrain or Water

Collision with terrain or water is the third most common first event for fatal accidents (15%). Inadequate in-flight judgment or decision and lack of experience account for nearly three fourths of these collisions. As expected, many of the in-flight judgments involve estimating altitude or clearance poorly and inadequate situational awareness.

ANALYSIS BY MISSION

Fleet Activity

The FAA conducted a rotorcraft activity survey in 1989 (Rotorcraft Activity Survey 1989). This survey was limited by a poor response rate and so offers only a rough estimate. It revealed the following information. The registered fleet in 1989 consisted of 10,400 rotorcraft. Of these, 72% or 7488 were active (meaning the aircraft flew one or more hours during the year). On average, each aircraft flew about 390 hours for a total of 280 million hours for the fleet. Aircraft used primarily for air taxi and business comprised 34% of the fleet, aerial observation 17%, and personal use about 14% (Figure 8). The personal use rotorcraft had a very low total number of flight hours although they comprised a significant portion of the fleet. On the other hand, air taxi and aerial observation flew the greatest percentage of total flight hours and made up the largest percentages of the fleet. These figures differ significantly from the accident profiles, where personal, instruction and aerial application operations accounted for the highest percentage of accidents, described below.

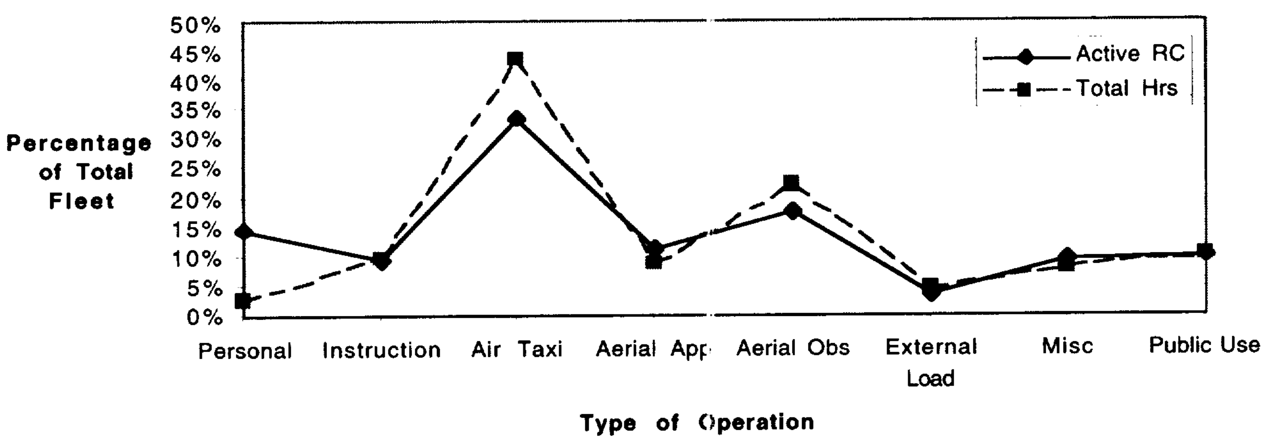

Figure 8. Type of Operation for Total Fleet - FAA Rotorcraft Activity Survey 1989

Accidents

Which operation has the highest frequency of accidents varies across the cost categories (see Figure 9 or Table 10 – largest categories are highlighted). For the least expensive group, the majority of accidents occur during personal, instruction or aerial application flights. The accidents in the next cost group are concentrated in non-scheduled air taxi. High and Very High cost rotorcraft accidents occurred primarily during positioning, external load and miscellaneous missions. These differences reflect differences in how the various cost categories of aircraft are used.

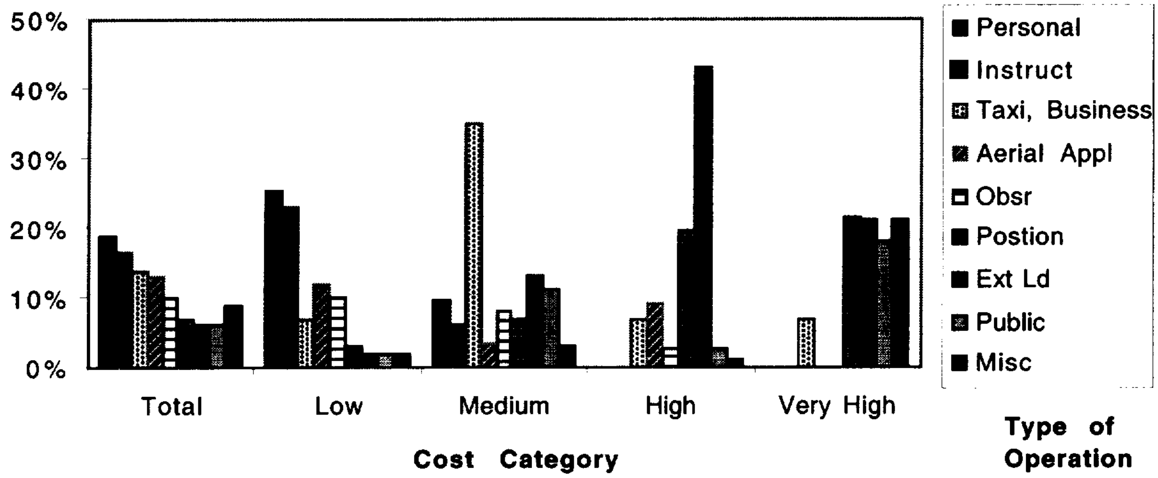

Figure 9. Type of Operation by Cost Category

Table 10. Type of Operation

Type of Operation	Total #	Total %	Low Cost #	Low Cost %	Medium Cost #	Medium Cost %	High Cost #	High Cost %	Very High Cost #	Very High Cost %
Personal	221	19.0%	192	[redacted]	29	9.5%				
Instruction	189	16.2%	172	[redacted]	18	5.9%				
Taxi, Business	169	14.5%	54	7.1%	108	[redacted]	5	6.6%	2	7.1%
Aerial Application	153	13.1%	136	18.0%	10	3.3%	7	9.2%		
Observation	110	9.4%	74	9.8%	31	10.1%	5	6.6%		
Position	80	6.9%	28	3.7%	30	10.0%	16	[redacted]	6	[redacted]
External Load	73	6.3%	16	2.1%	21	6.9%	29	[redacted]	6	[redacted]
Public	64	5.5%	33	4.4%	23	7.6%	3	3.9%	5	17.9%
Miscellaneous	106	9.1%	51	6.7%	35	11.5%	11	14.5%	9	32.1%

Since many accidents are more understandable in the context of the operation being performed, one approach is to examine the accidents within each mission. Table 11 shows the statistics for accidents grouped by mission (see Appendix H for more complete table). Note that the public use category overlaps with other categories, since it is defined by regulation not by mission. Personal and instruction flights result in the most accidents, together accounting for 35% of the database. The accident rate per 100,000 flight hours for personal flights is even more telling, five times that of any other category. Aerial application also had a relatively high accident rate.

Conditional probability gives another perspective. Conditional probability of fatality is the likelihood that an accident will be fatal given that an accident has happened. A mission group that has a high conditional probability has relatively more severe accidents. Public use, air taxi and aerial observation have a high conditional probability. None of these has an especially high accident rate.

The first event helps illuminate some of the differences in accident rate. Personal and instructional missions stand out for beginning with loss of control. For all other groups the first event is engine failure.

Personal and instruction flights are a big portion of helicopter accidents. New pilots and low end equipment contribute to the large number of accidents for these missions. The relatively high accident rate for aerial application is probably due to the nature of the agricultural task – flying close to wires and trees and maneuvering extensively. Fixed wing aerial application shows a similar pattern of accidents. (McCann, personal communication) External load accidents may also be due to the high risk nature of those operations. Air taxi has a large number of accidents, but relative to the number of hours flown, their rate is extremely low. Although mission factors may affect a small portion of the accidents, pilot skill and equipment seem to drive the overall trends.

Table 11. Statistics for Accidents by Mission

		Personal	Instruct	Taxi	Appl	Observ	Position	Ext Ld	Public	**TOTAL**
Accidents	#	220	189	167	152	110	80	73	64	**1165**
	%	19	16	14	13	10	7	6	6	**100**
Acc Rate	Acc/100k hr	44.9	9.9	2.5	9.2	2.4	Unknown	7.8	3.1	**5.3**
Fatality	%	16	8	17	6	17	21	22	20	**15**
Cond Prob	Fatal gvn acc	20	9	24	6	23	21	22	27	**18**
1st Event	Most frequent	Control	Control	Eng	Eng	Eng	Eng	Eng	Eng	**Engine**
	%	26	24	31	39	31	24	34	23	**27**

Instruction versus Personal Flight Operations

Although instructional and personal flights that are typically flown in Low Cost aircraft result in numerous accidents, these accidents tend to result in less damage and fewer injuries than do other operations (see Table 12). Only 11% of the occupants of instructional flight accidents received serious or fatal injuries. The number of destroyed aircraft was much lower as well for instructional and personal accidents (e.g., 15% versus 24%.) The number of rollovers, however, was high at 37%. Instructional flights tend to be more benign, possibly because the instructors manage to minimize the severity of accidents that do happen. In contrast, injuries and damage that occur on personal flight accidents exceed those for all types of operations flown by Low Cost aircraft.

Table 12. Statistics on Instruction versus Personal Flights versus Low Cost category

		Instruction		**Personal**		**Low Cost**	
Total accidents		191		220		756	
Injuries	Fatalities	28	8.4%	63	15.5%	149	11.9%
	Serious Injuries	9	2.7%	44	10.8%	110	8.8%
	Minor Injuries	40	12.0%	69	17.0%	249	19.9%
	No Injuries	255	76.8%	231	56.8%	745	59.5%
	People involved	332		407		1253	
Damages	Destroyed	29	15.2%	60	27.3%	181	23.9%
	Substantial	162	84.8%	160	72.7%	571	75.5%
Total # of Rollovers		71	37.2%	58	26.4%	183	24.2%

Hard landings and loss of control are the most common first events for instructional flights. (see Table 13) Students do not commonly encounter loss of engine power, in-flight collision with object or system malfunction, events that are most frequent across the database. First events for personal flights, on the other hand, parallel the pattern for the whole database.

Table 13. First Events for Instruction versus Personal Flights versus Low Cost

First Events	Instruction		Personal		Low Cost	
Hard landing	39	20.4%	15	6.8%	55	7.3%
Loss of control - in-flight	37	19.4%	56	25.5%	154	20.4%
In-flight collision with terrain/water	25	13.1%	28	12.7%	68	9.0%
Loss of engine power	22	11.5%	52	23.6%	204	27.0%
Airframe/component/system failure/malfunction	11	5.8%	18	8.2%	83	11.0%
In-flight collision with object	10	5.2%	21	9.5%	93	12.3%
Roll over	10	5.2%	9	4.1%	28	3.7%
Loss of control - on ground/water	9	4.7%				

CONCLUSIONS

Helicopters have a relatively high accident rate. They experience an accident rate ten times that of airliners. Yet helicopters, general aviation, and airliners are comparable in terms of the likelihood that an accident will be fatal. The high rate of helicopter accidents does not appear to be a product of the uncontrolled helicopter flight environment. Neither does it appear to be the product of unique helicopter missions. While there are specific hazards associated with certain helicopter missions, these factors do not significantly contribute to the high accident rate. In fact, the more expensive helicopters, which perform most of the specialized missions, show a low accident rate, comparable to that of airliners. The high accident rate derives from the lower cost end of the fleet. Lower cost helicopters have more accidents than do higher cost helicopters, despite flying fewer total hours. While lower cost helicopters have more accidents generally, they have generally less-serious accidents, which occur under fairly benign flight conditions.

While breaking down accident statistics by cost shows the lower cost helicopter have the higher accident rate, the underlying cause is more likely due to the type of pilot instead of due to the cost of the aircraft. Indeed the most dramatic dichotomy in the accident data is the division between accidents involving personal pilots and those involving professional pilots. Personal pilots tend to fly low cost aircraft in benign environments. They have accidents that are often a direct result of their own errors. Even when pilot error is not the primary cause, it is often a major factor leading to or exacerbating the accident. Professional pilots are highly trained and have ample flight experience. They fly larger, more expensive aircraft carrying passengers or valuable cargo. They may fly in hazardous environments and perform difficult tasks, such as external load, and maneuvers near objects. Yet their accidents are usually a result of mission or equipment factors rather than pilot error.

In order to determine other issues associated with the increased number of accidents occurring in the low end fleet, it is helpful to examine the major missions: personal, instructional and aerial application. Pilot experience and proficiency are concerns for the first two areas. The specific problems are primarily inadequate pilot training and experience, and poor judgement. Maintenance quality is a concern for all three missions. All three are usually small operations and lack company controls on both pilot and maintenance.

Of the categories used in this study, aircraft problems are the most common cause of all accidents and most dominant for the high-end fleet. Unfortunately "aircraft problems" is a very broad category that contains a variety of loosely related causes. No single system failure stands out for targeted improvement in either design, manufacturing or maintenance aspects.

Finally, fatal accidents are an important target for improving safety. Collision with objects or terrain is the most common first event in fatal accidents. While the cause of a collision is not always clear, two causes stand out. Inadvertent flight into weather is an infrequent cause of accidents, but it is the most lethal. Wire strikes are a problem for one segment of the low-end fleet. The agricultural application mission presents a continual wire strike hazard, and most wire strikes occur during this mission. The causes that are most likely to result in fatal accidents are all related to pilot error. This is true for all cost segments of the fleet. While fatal accidents are relatively more common in the high-end fleet, the absolute number is greater for the low-end fleet. Judgement, interpretation, inadvertent IMC, and pilot impairment are much more likely to cause fatal accidents than are other causes.

RECOMMENDATIONS

A safety awareness/training system could help reduce the accident rate of personal pilots. It should begin by identifying target populations and determining their unique characteristics and needs. It could then develop programs tailored to each population. Awareness of safety issues and risks would emphasize the importance of safety to pilots. This might motivate them to be more thorough and deliberate in their actions, potentially breaking the chain of events leading to an accident.

Training aids aimed at students could improve the effectiveness of ground school and use the instructors' time more efficiently. Development of such aids could best be accomplished through a cooperative effort with schools.

Similarly, a program addressing mission and equipment should look at characteristics of target missions to determine equipment deficiencies. The present analysis has identified no missions that stand out for a high accident rate, excepting aerial application. Wire strikes are a significant hazard in this mission.

An immediate benefit might be derived by improving the dissemination of safety related information to the general flying community. Safety related brochures, available at airports, could enhance awareness of safety issues. A helicopter safety web site could facilitate rapid dissemination of up-to-date safety information.

Certainly the rotorcraft accident rate could synergistically benefit from programs aimed at reducing the fixed-wing accident rate. This may be especially true for the high-end rotorcraft fleet, which may benefit from the generic improvements in the reliability of on-board systems.

ADDENDUM - Recommendations for Accident Reporting

Suggestions For NTSB Database

This researcher acknowledges the immense task set before the NTSB. Nevertheless, what follows are recommendations for improving the investigation and reporting process for the purpose of determining where to expend the resources to improve the helicopter accident rate. The reporting items refer to the brief summary reports, which are more useful for statistical manipulation than are the full multi-page reports.

Data requirements vary depending on the question being investigated. The safety program needs data on missions, costs, risks, problems and demographics. For comparison to other transportation modes, rotorcraft activity should be reported by number of flights.. The 1989 FAA rotorcraft activity survey attempted to provide some data on normal rotorcraft activity, but received a poor response and the degree to which it is representative is questionable.

Investigation Process

Most rotorcraft accidents do not receive a full analysis by a NTSB investigator. The NTSB does not have the staff available to permit this level of investigation nor do they have investigators devoted solely to rotorcraft. They attend primarily to fatal accidents, first accidents of new models and suspicious accidents. Thus, local officials who may be unfamiliar with the unique design and operational capabilities of helicopters report on the majority of the accidents. Forms with standardized choices would make the report easier for such ad hoc investigators to fill out and more useful for analysts.

Reporting Process

To provide information to the rotorcraft community and insight into the problems specific to rotorcraft operations, more details regarding rotorcraft accidents are needed. Many of the details below are included in the full reports and may be in the summary reports but are not necessarily in coded form that would be most useful in analysis. This list represents a starting point and could be expanded profitably.

List specifics on

1) Mission - fire fighting, AMS, instruction
2) Risk elements - external load, confined area, low altitude, near obstacles, pinnacle
3) Weather - winds, fog, cloud, storm, IMC
4) Terrain - mountains, obstacles, water, soft ground
5) Lighting - night, dusk, dawn, day

- Pilot Experience and condition -
- Pilot's Reaction to primary event - procedure, instinct - improve or worsen problem

8) Autorotation by necessity, practice, demonstration
9) First Event Details – pilot's recognition of problem, handling
   Loss of Engine Power – cause, phase of flight
   System Failure – part, cause
   Collision with object - type of object , cause, mission, part hit, awareness of object
   Loss of Control – axis of control, cause, phase of flight, mission, pilot certification

- Roll over, severed tail boom
- Potential solutions

A simplified coding scheme would make organizing the data easier. Interested parties could then examine a particular category of accident. The current system lacks standardized coding. For example, fuel exhaustion can be listed under three categories. These are <u>17001 1131 Fluid, fuel - Exhaustion, 15100 1131 Fuel system - Exhaustion,</u> or <u>15101 1131 Fuel system, tank - Exhaustion</u>.
Using multiple categories for one situation makes it difficult to search the database and get complete answers. Simplification is required to see the bigger picture.

APPENDIX A   Aircraft Cost Categories based on 1994 Prices (source –HAI, Harris)

A = \$0 - 0.6M	Low Cost	
AdvWPtTech UltraSport 254	Scorpion 133	Texas Hel OH13E/M74L
Enstrom 280	Scorpion 133 - Cloutier	Texas Hel OH13H
Enstrom 280C	Scorpion 2 - Sharp	Townsend 47-G2
Enstrom 280FX	Scorpion 2 - Wyman	Wms Bell OH13H/Tomcat Mk5a
Enstrom F28	Revolution Mini-500	Bell OH13E
Enstrom F28-280c	Dennis L. Fetters Mini 500	Bell Transworld 47G-2
Enstrom F28A	Lampert Revolution M500	Bell TH13T
Enstrom F28C	Bell47D1 -World Hel	Bell 47G3 Soloy
Enstrom F28C2	Bell 47	Bell 47G3B1 Soloy
Enstrom F28F	Bell 47 Mark6	Bell (Soloy) 47G-3B2
Enstrom TH28	Bell 47-62	Brantley B2B
Hiller 12C	Bell 472A1	Fairchild Hiller FH1100
Hiller 12E	Bell 47B3	K Copter 47d1
Hiller 12e 1345	Bell 47D	Hughes 269
Hiller OH23C	Bell 47D1	Hughes 269A
Hiller UH12	Bell 47D1 Wasp	Hughes 269A1
Hiller UH12A	Bell 47D1G	Hughes 269B
Hiller UH12B	Bell 47G	Hughes 269C
Hiller UH12C	Bell 47G Continental Copters	McD D 269A
Hiller UH12D	Bell 47G-Super C4 -Carson	Schweizer 269B
Hiller UH12E	Bell 47G2	Schweizer 269C
Hiller UH12E4	Bell 47G2 -K-Copter	Schweizer 269D
Hiller UH12l4	Bell 47G2 -Transworld Corp	Schweizer Hughes 269C
Hiller UH12D Soloy	Bell 47G2 Huddleston	Hughes TH55
Hiller UH12D Osborn	Bell 47G2A	Hughes TH55A
Hiller UH12E, Soloy	Bell 47G2A -Moore	Hughes 369
Hiller UH12ET	Bell 47G2A1	Hughes 369A
Hiller UH12L4 Soloy	Bell 47G2M	Hughes 369B
Soloy H-23d	Bell 47G3B	Hughes 369C
Hughes 300C	Bell 47G3B1	Hughes 369E
Schweizer 300C	Bell 47G3B2	Hughes 369FF
Schweizer H300	Bell 47G3B2A	Hughes 369HE
Aerospatiale AS318C	Bell 47G4	Hughes 369HS
Robinson R22	Bell 47G4A	McD D 369E
Robinson R22A	Bell 47G5	McD D 369HS
Robinson R22B	Bell 47G5A	Hughes OH6A
Robinson R22HP	Bell 47H1	McD D H369
Robinson R22M	Bell 47J2	McD Hughes 369E
Robinson R44	Bell 47J2A	Continental Copters Tomcat Mk5a
Rotorway Exec	Bell BH47G3B1	Continental Copters Mark 5
Rotorway Exec 90	Bell BH47G3B2	Continental Copters Mk5a
Rotorway R162 - Vuncannon	Texas Helicopter M74	Continental Copters Mk6b
Rotorway RW 152	Texas Helicopter M74L	Continental Copters Tomcat Mk 6C
Bob Sandlin Bob's Executive	Texas Hel OH13E	
Executive - Townsend	Texas Hel OH13E/M74	

B = $0.6 - 1.5M	**Medium Cost**	
Aerospatiale AS350	Bell 206	Hughes 500C
Aerospatiale AS350B	Bell 206A	Hughes 500D
Aerospatiale AS350B1	Bell 206B	McD D 500
Aerospatiale AS350B2	Bell 206B2	McD D 500E
Aerospatiale AS350D	Bell 206B3	Md Hughes MD500d
Aerospatiale AS350D ASTAR	Bell B206 II	McDonnell Douglas MD600
Amer Eurocopter As350ba	Bell 206L	Aerospatiale AS315
Eurocopter AS350B	Bell 206L1	Aerospatiale AS315B
Eurocopter AS350B2	Bell 206L1	Aerospatiale AS316B
Eurocopter AS350BA	Bell 206L3	Bell L4 Experl (206)
Eurocopter AS350D	Bell 206L3+	Bell OH58A (206)
Aerospatiale AS355F	Bell 206L4	Sikorsky H-19-UH19D
Aerospatiale AS355F1	Bell B206LI	Sikorsky H-19/S55
Eurocopter AS355F1	McD D 369D	Sikorsky S55B
Aerospatiale AS341G	McDonnell Douglas 520N	Sikorsky UH19D
C = $1.5 - 4M	**High Cost**	
Agusta A109c	Bell 204B	Sikorsky HSS-1N
Agusta Spa A109a II	Bell 205A1	Sikorsky 58h
Bolkow Bo-105s	Bell 222	Sikorsky H34-G
Mbb BO105	Bell UH1B	Sikorsky S58
Mbb BO105C	Bell UH1E	Sikorsky S58D
Mbb BO105CB4	Bell UH1F	Sikorsky S58F
Mbb BO105CBS	Bell UH1H	Sikorsky S58G
Mbb BO105CBS4	Bell UH1L	Sikorsky S58J
Mbb BO105S	Bell TH1L (UH1)	Sikorsky S58BT
Mbb BK117	Hawkins & Powers UH-1B	Sikorsky S58JT
Mbb BK117A1	Kaman Hh-43b/F	Sikorsky S58T
Mbb BK117A4	Kaman Hh-43f	
Mbb BK117B1	Kaman Hh43	
D = $4M & up	**Very High Cost**	
Aerospatiale AS365N2	Sikorsky S76A	Sikorsky Ch-54A
Bell 412	Sikorsky S76B	Sikorsky MH-53E
Bell 412SP	Sikorsky UH60A	Bell 212
Bell 214B1	Sikorsky S64E	Bell 230
Bell H214	Sikorsky S64F	McDD AH64D
Undetermined		
Hillberg Eh-101	Franklin 6y-350-B	Garlick Th-11

APPENDIX B – Cause Categorization

1 Pilot Impairment -a) physical - fatigue, nausea, food poisoning, hunger, dehydration
medical - medications, pre-existing or new condition
illegal - alcohol, drugs
environmental – heat, cold, spatial disorientation
b) psychological - pressure - self or external, depression

2 Experience - a) Lack of- insufficient training, practice, or experience to handle situation
inappropriate use of flight controls, improper scan, visual lookout,
behind on airspeed, RPM (feel & scan)
b) Complacency -overconfidence, inattentive

3 Pre-flight Preparation a) Calculations - fuel requirements, aircraft performance, envelope limits, aircraft weight & balance
b) Checklist - set instruments, cargo security, fuel in aircraft, walk around
c) Choices - flight profiles, landing area, weather evaluation

4 In-flight - Decision Judgment a) Judging distances and rates - altitude, clearance, descent rate, climb
c) Judging weather regarding changes in fuel or carburetor heat requirements
d) Decisions - leave aircraft running while unattended, change of plans

5 Interpretation a) Communication - flight crew coordination, radio communications,
Air Traffic Control
b) Information - Misinformation, Lack of Information,
c) Procedures/Directives - incorrect, unclear, or non-existent

6 High Risk - Operations Nature of the operation contributed directly to the accident
a) External Load
b) Pinnacle, Confined Area
c) Low Altitude
d) Near Obstacles, Formation Flight
e) Demonstration/practice Autorotations
f) Student / Training
g) Emergency – Emergency Medical Services, Fire fighting, police

7 Aircraft - Problems 1) Aircraft - Something breaks - not known to be preventable by 2, 3 or 4
2) Manufacturer - inadequate design, manufacture quality control or procedure
3) Maintenance - problems that could have been prevented by proper maintenance
4) Operator - knowingly ignored problem, operation with known deficiencies
Note : next level of description - what system of aircraft

8 Environment 1) Weather Related - VFR to IMC, Wind Compensation, Downdrafts, Gusts,
2) Lighting/Terrain - Night, High Altitude, mountainous, water
3) Facilities - inadequate markings, lighting, size, clear area

9 Other - 1) Foreign Object Damage,
2) Intentional Misbehavior - ostentatious display, ignoring instructions

10 Wire strike - usually cited as lack of adequate clearance, improper visual lookout
or failure to see and avoid

APPENDIX C - NTSB Cause Codes Corresponding to General Cause Categories

Impairment	
31210 Visual/aural perception	
31280 Other psychological condition	
33130 Impairment (alcohol)	
33140 Impairment (drugs)	
33200 Incapacitation (medical)	
33400 Spatial disorientation	

In flight decision	Modifiers
22202 Fuel boost pump selector position	
22304 Carburetor heat	3102 Continued
24005 Aircraft unattended/engine(s) running	3107 Exceeded
24019 3124 performance data	3109 Improper
24029 Unsuitable terrain or to/landing area	3110 Improper use of
24031 Judgment	3114 Intentional
24036 Flight into adverse weather	3120 Misjudged
24518 Altitude	3122 Mot attained
24521 Buzzing	3124 Not followed
24523 Distance	3127 Not maintained
24524 Descent	3128 Not performed
24525 Proper descent rate	3135 Performed
24528 Proper climb rate	3136 Poor
24545 Emergency procedure	3139 Selected
24577 Altitude/clearance	
24580 Distance/alt	
24583 Low alt flight/maneuver	
60000 Improper decision	
31260 Ostentatious display	

Interpretation	Modifiers
24018 Flight manuals	
24032 Procedures/directives	3124 Not followed
24611 Radio communications	3106 Disregarded
24615 Safety advisory	3115 Inadequate
24624 Crew/group coordination	3111 Inaccurate
80000 Procedure inadqt	
80200 Condition/step insufficiently defined	
91000 Insufficient standards/rqmts	

Environment	Modifiers
19016 Airport facilities, obstruction marking	2205 Downdraft
19017 Airport facilities,heliport	2206 Fog
19200 Terrain condition	2207 Gusts
20000 Weather condition tailwind, turbulence	2208 Crosswind
24023 Flight into known adverse weather	2209 Haze/smoke
24024 IFR procedure	2212 High density alt
20100 Light condition	2305 Dark night
24015 VFR flight into IMC	2306 Sun glare

High Risk Operations	Modifiers
17505 External load sling/harness	3128 Not performed
17506 External load equipment	1216 Entangled
24540 Load jettison	3114 Intentional
24565 Formation Flying	

Wire Strike	Modifiers
10601 1122 Window/windshield <>	1122 Dirty(foggy)
20200 2524 Object <> Wire, transmission	
24021 3115 Visual lookout <> Inadequate	
24526 3127 Clearance <> Not maintained	

Experience	Modifiers
22100 Flight controls	3109 Improper
22301 Throttle/power control	3110 Improper use of
23200 Rotorcraft flight controls	3113 Inadvertent
23201 Cyclic	3115 Inadequate
23202 Collective	3122 Not attained
23203 Tail rotor/anti-torque control	3127 Not maintained
24500 Airplane handling	3128 Not performed
24506 Airspeed	3147 Encountered
24518 Altitude	
24520 Autorotation	
24524 Descent	
24530 Proper alignment	
24531 Proper touchdown point	
24533 Lift-off	
24535 Flare	
24539 Directional control	
24542 Remedial action	
24558 Rotor rpm	
24561 Vertical takeoff	
24566 Aircraft control	
24567 Touchdown	
24706 Relinquishing of control	
24715 Wake turbulence	
24801 Dynamic rollover	
24813 Tail rotor effectiveness	
31110 Diverted attention	
31120 Inattentive	
34330 Lack of total experience	
31160 Overconfidence-persnl ability	

Preflight preparation	Modifiers
10510 Door, inspection	
10605 Window, canopy	1122 Dirty(foggy)
16903 Engine compartment	1130 Exceeded
17001 Fluid, fuel	1131 Exhaustion
17116 Cargo/baggage	1157 Loose
17119 Misc equipment/furnishings	1212 Unlatched
17310 Aircraft hover performance	1213 Not secured
17310 Aircraft performance	3012 Not removed
17505 Equipment entangled	3107 Exceeded
22204 Fuel supply	3109 Improper
23300 Miscellaneous equipment	3113 Inadvertent
23316 Ground tie-down rope/strap	3114 Intentional
24001 Preflight planning /prep	3115 Inadequate
24005 Aircraft unattended/eng run	3120 Misjudged
24006 Aircraft weight & balance	3124 Not followed
24008 Tie down	3128 Not performed
24009 Proper assistance	3129 Not obtained
24012 Fuel consumption calculation	3136 Poor
24019 performance data	
24034 Planned approach	
24035 Security of cargo	
24401 Weather forecast	
24518 Altitude	
24626 Passenger briefing	
24803 Height/velocity curve	
10010 Fuselage, fairing	
22600 Anti-ice/deicing system	

Aircraft problems Parts, subject	
10008	Fuselage, attachment
10402	Landing gear, main gear shock abs strut
10708	Flight control system, stabilator contrl
10804	Vertical stabilizer attachment
10900	Rotorcraft flight control
10901	Rotorcraft flight control, cyclic control
10902	Rotorcraft flight control, cyclic control rod
10904	Rotorcraft flight control, collective control
10909	Rotorcraft flight control, tailrotor control
10911	Rotorcraft flight control tailrotor cable
10915	R/c flt ctrl, swashplate assembly
10916	Rotorcraft flight control
10920	Rotorcraft flight control, ctrl rod bearing
11000	Rotor drive system
11002	Rotor drive sys, m.r. mast(drive shaft)
11003	Rotor drive sys, freewheel sprag unit
11005	Rotor drive sys, clutch assembly
11006	Rotor drive sys, main gearbox/transmn
11008	Rotor drive sys intermediate gearbox (42°)
11009	Rotor drive system, tailrotor gearbox (90°)
11011	Rotor drive system, tailrotor drive shaft
11014	Rotor drive system
11018	Rotor drive system, main rotor drive belt
11021	Rotor drive sys, tailrotor drive shaft
11101	R/c flight control system, primary servo
11103	Rotorcraft flight control system
11200	Rotor system
11201	Rotor system, main rotor blade
11208	1137 Rotor system, tailrotor blade
11231	Rotor system, main rotor hub
11235	Rotor system, main rotor
11237	Rotor system, tail.rotor
11303	Miscellaneous,bolt/nut/fastener/clamp
12004	Electrical system, generator
12015	Electrical system, electric switch
12100	Hydraulic system
13000	Miscellaneous rotorcraft
13007	Miscellaneous rotorcraft, tail boom
13108	Safety system (other)
14006	Engine assembly
14017	Engine assembly, rocker arm/tappet
14104	Compressor assembly, blade

Aircraft problems Parts, subject – continued	
14107	Compressor assembly, impeller
14113	Compressor assembly
14308	Turbine assembly, turbine wheel
14311	Turbine assembly
14314	Turbine assembly, shaft bearing
14707	Accessory drive, drive gear
14801	Ignition system, magneto
14815	Ignition system
15006	Bleed air system, fittings
15124	Fuel system, electric boost pump
15128	Fuel system
15131	Fuel system, PC line
15213	Lubricating system
15413	Carburetor air temperature gage
15420	Engine instruments
15904	Turboshaft engine, gas generator
15905	Turboshaft engine, free (power) turbine
15909	Turboshaft engine
16000	Throttle/power lever
16004	Throttle/power lever, cable
16005	Throttle/power lever, linkage
16600	Fuel injection control/system
16709	Induction air filter/screen
16711	Induction air ducting
16902	Powerplant
16903	Engine compartment
16911	Misc, engine compressor stall/surge
17001	Fluid, fuel
17002	Fluid, oil
17400	Aerial application equipment
23203	Tail rotor/anti-torque control
24101	Maintenance, service of aircraft
24111	Maintenance, installation

Other Parts, subject	
22314	Throttle/power control friction lock
24009	Proper assistance
24705	Control interference
24708	Stolen aircraft/unauthorized use
24710	Sabotage

Aircraft problems Modifiers	
1108	Unapproved part
1115	Contamination
1121	Deteriorated
1125	Disconnected
1134	Failure,partial
1135	Failure, total
1136	False indication
1137	Fatigue
1138	Fire
1147	Improper
1151	Jammed
1165	Not engaged
1167	Not switched
1174	Overtorque
1180	Separation
1183	Starvation
1193	Water
1194	Worn
1205	Not installed
1209	Eroded
1215	Seized
1260	Scored
3145	Restricted

Other Modifiers	
1120	Deployed inadvertently
1144	Fumes
1145	Foreign object damage
3116	Inadvertent deactivation

APPENDIX D - NTSB Part 830 Definitions of Injury

The following definitions of terms used in this report have been extracted from NTSB Part 830 of the Federal Aviation Regulations. These regulations are included in most commercially available FAR/AIM digests and should be referenced for detailed information.

Aircraft Accident -- An occurrence incident to flight in which "as a result of the operation of an aircraft, any person (occupant or non-occupant) receives fatal or serious injury or any aircraft receives substantial damage."

A **fatal injury** is one that results in death within 30 days of the accident.

A **serious injury** is one that:
1.Requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received;
2.Results in a fracture of any bone (except simple fractures of the fingers, toes, or nose).
3.Involves lacerations that cause severe hemorrhages, nerve, muscle, or tendon damage.
4.Involves injury to any internal organ; or
5.Involves second- or third-degree burns, or any burns affecting more than 5% of body surface.

A **minor injury** is one that does not qualify as fatal or serious.

Destroyed means that an aircraft was demolished beyond economical repair; that is, substantially damaged to the extent that it would be impractical to rebuild it and return it to an airworthy condition.

(This may not coincide with the definition of "total loss" for insurance purposes. Because of the variability of insurance limits carried and such additional factors as time on engines and propellers and aircraft condition before the accident, an aircraft may be "totaled" even though it is not considered "destroyed" for accident investigation purposes.)

Substantial Damage:
1.Except as provided below, substantial damage means damage or structural failure that adversely affects the structural strength, performance, or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected part.
2.Engine failure, damage limited to an engine, bent fairings or cowling, dented skin, small puncture holes in the skin or fabric, ground damage to rotor or propeller blades, damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wing tips are not considered "substantial damage."

(As with "destroyed" above, the definition of "substantial" for accident investigation purposes does not necessarily correlate with "substantial" in terms of financial loss. Contrary to popular misconception, there is no dollar value that defines substantial damage. Because of the high cost of many repairs, large sums may be spent to repair damage resulting from incidents that do not meet the NTSB Part 830 definition of "substantial damage.")

Minor damage is damage that does not qualify as substantial, such as that under "substantial damage" above.

APPENDIX E - Definitions of Type of Operation

The purpose for which the aircraft is being operated at the time of the accident:

On-Demand Air Taxi -- Revenue flights conducted by commercial air carriers operating under 14 CFR 135 that are not operated in regular scheduled service, such as charter flights, and all non-revenue flights incident to such flights.

Personal -- Flying by individuals in their own or rented aircraft for pleasure or personal transportation, not in furtherance of their occupation or company business. This category includes practice flying (for the purpose of increasing or maintaining proficiency) not performed under supervision of an accredited instructor and not part of an approved flight training program.

Business -- The use of aircraft by pilots (not receiving direct salary or compensation for piloting) in connection with their occupation or in the furtherance of a private business.

Instruction -- Flying accomplished in supervised training under the direction of an accredited instructor.

Executive/Corporate -- The use of aircraft owned or leased and operated by a corporate or business firm for the transportation of personnel or cargo in furtherance of the corporation's or firm's business, and that are flown by professional pilots receiving a direct salary or compensation for piloting.

Aerial Application -- The operation of aircraft for the purpose of dispensing any substance for plant nourishment, soil treatment, propagation of plant life, pest control, or fire control, including flying to and from the application site.

Aerial Observation -- The operation of an aircraft for the purpose of pipeline/powerline patrol, land and animal surveys, etc. This does not include traffic observation (electronic news gathering) or sightseeing.

Other Work Use -- The operation of an aircraft for the purpose of aerial photography, banner/glider towing, parachuting, demonstration or test flying, racing, aerobatics, etc.

Public Use -- Any operation of an aircraft by any federal, state, or local entity.

Ferry -- A non-revenue flight for the purpose of (1) returning an aircraft to base, (2) delivering an aircraft from one location to another, or (3) moving an aircraft to and from a maintenance base. Ferry flights, under certain terms, may be conducted under terms of a special flight permit.

Positioning -- Positioning of the aircraft without the purpose of revenue.

Other -- Any flight that does not meet the criteria of any of the above.

Unknown -- A flight whose purpose is not known.

APPENDIX F NTSB First Event Codes

100 Abrupt maneuver
120 Cargo shift
130 Airframe/component/system failure/malfunction
132 Rotor failure/malfunction
150 Ditching
160 Dragged wing, rotor, pod, float or tail/skid
170 Fire/explosion
171 Fire
180 Forced landing
190 Gear collapsed
191 Main gear collapsed
200 Hard landing
220 In flight collision with object
230 In flight collision with terrain/water
240 In flight encounter with weather
250 Loss of control - in flight
260 Loss of control - on ground/water
270 Midair collision
271 Collision between aircraft (other than midair)
290 Nose down
300 Nose over
310 On ground/water collision with object
320 On ground/water encounter with terrain/water
350 Loss of engine power
351 Loss of engine power(total) - mechanical failure/malfunction
352 Loss of engine power(partial) - mechanical failure/malfunction
353 Loss of engine power(total) - non-mechanical
354 Loss of engine power(partial) - non-mechanical
370 Propeller/rotor contact to person
380 Roll over
390 Undershoot
400 Undetermined
430 Miscellaneous/other

APPENDIX G – Specifics of Airframe, component, system failure or malfunction

50/3	**11000 Rotor drive system**		30/6	**11200 Rotor system**
50/3	11001	- engine to transmission drive	30/7	11208 - tail rotor blade
50/4	11003	- freewheeling sprag unit	21/1	**10900 Rotorcraft flight control**
50/8	11005	- clutch assembly	21/3	10901 - cyclic control
50/4	11006	- main gearbox/transmission	21/3	10909 - tail rotor control
50/4	11008	- intermediate gearbox(42°)	21/3	10911 - tail rotor cable
50/4	11009	- tail rotor gearbox(90°)	3	104## Landing gear
50/8	11011	- tail rotor drive shaft	3	152## Lubricating system
50/3	11014	- tail rotor drive shaft bearing	2	151## Fuel system
50/4	11018	- main rotor drive belt		
50/3	11021	- tail rotor drive shaft coupling	**145**	**Total Accidents**

The NTSB gives each accident cause a five digit code. The first three digits determine what particular aircraft system or assembly is involved. The last two digits specify an element of the system or assembly. Thus 110## codes refer to rotor drive system problems, 112## to rotor system problems, 140## to engine assembly problems and so on. The table above gives the number of occurrences for each code that had more than three. When two numbers are given, such as 57/5 for 11003, it means that 57 accidents had a primary cause of rotor drive system problems, with 5 of those being specifically engine to transmission drive.

APPENDIX H – Accident Information by Mission

		Personal	Instruct	Taxi	Appl	Observ	Position	Ext Ld	Public	TOTAL
ACC	#	220	189	167	152	110	80	73	64	**1165**
	%	19	16	14	13	10	7	6	6	**100**
Ops	Est Fleet	14	9	33	11	17	?	4	10	**7488**
%	Est Hrs	3	9	44	8.5	22	?	5	10	**2825756**
COST	A	86	90	32	89	67	35	22	52	**65**
%	B	13	10	63	7	28	38	29	36	**26**
	C	0	0	3	5	5	20	40	5	**7**
	D	0	0	1	0	0	8	8	8	**2**
DMG	Dest	27	15	32	26	56	34	30	34	**27**
%	Subst	73	85	66	74	43	66	66	64	**72**
#	Ftl Acc	45	17	40	9	25	17	16	17	
%		20	9	24	6	23	21	22	27	0
INJR	Ftl	16	8	17	6	17	21	22	20	**15**
%	Ser	11	3	13	13	15	12	28	11	**12**
	Mnr	17	12	19	27	21	19	20	18	**19**
	No	57	77	51	55	47	48	31	51	**54**
Per	Total	407	329	570	155	262	147	102	152	**2398**
	P/Acc	1.9	1.7	3.4	1.0	2.4	1.8	1.4	2.4	**2.1**
Other	Emg Auto	18	13	25	20	25	20	34	17	**21**
%	Roll	26	40	13	15	12	15	14	13	**20**
	TB	10	13	8	8	11	5	5	10	**9**
EVNT	Most frq	Ctrl	Ctrl	Eng	Eng	Eng	Eng	Eng	Eng	**Eng**
	%	26	24	31	39	31	24	34	23	**27**
	2nd	Eng	Lndg	Ctrl	Obj	Obj	Ctrl	Malfn	Obj	**Ctrl**
	%	24	21	12	21	18	18	22	14	**17**
	3rd	Terrn	Terrn	Obj	Malfn	Malfn	Obj	Ctrl	Malfn	**Obj**
	%	13	13	11	16	15	16	21	14	**12**
	4th	Obj	Eng	Malfn	Ctrl	Ctrl	Malfn	Obj	Ctrl	**Malfn**
	%	10	12	10	11	13	14	12	13	**12**
	Sum	71	70	64	87	76	72	90	64	**68**
Phase	Most frq	Crz	Lndg	Crz	Manv	Crz	Crz	Hov	Crz	**Manv**
	%	24	41	39	62	31	41	41	33	**23**
	2nd	TO	Hov	TO	TO	Manv	TO	Manv	Manv	**Lndg**
	%	15	16	14	15	29	14	30	27	**21**
	3rd	Lndg	Manv	Manv	Crz	TO	Taxi	TO	Lndg	**Crz**
	%	14	9	14	12	11	10	7	9	**20**
Cause	Most frq	A/C	Exp	A/C	A/C	A/C	A/C	A/C	A/C	**A/C**
	%	25	40	32	48	29	28	49	28	**31**
	2nd	Exp	Decsn	Envrn	Wire	Decsn	Envrn	Hi Rsk	Decsn	**Exp**
	%	20	17	17	16	16	14	14	17	**17**
	3rd	Decsn	A/C	Preflt	Exp	Preflt	Preflt	Decsn	Envrn	**Preflt**
	%	16	12	11	9	15	14	12	16	**11**
Make	Model	R22	R22	Bell 206	Bell 47	Bell 47	Bell 206	369	Bell 206	
%		29	47	37	47	25	25	19	27	

REFERENCES

Arendt, D. (Ed) 1997 Nall Report, Accident Trends and Factors for 1996 - AOPA Air Safety Foundation, Frederick, MD (1997)

Comparative US Civil Helicopter Safety Trends. http://www.rotor.com (1998)

Harris, F.D., Kasper, E.F., Iseler, L.E. U.S. Civil Rotorcraft Accidents, 1963 through 1997, NASA TechnicalPublication 209597, Ames Research Center, Moffett Field, CA (2000)

Helicopter Accident Analysis Team. Final Report of the Helicopter Accident Analysis Team, NASA-Ames Research Center, Moffett Field, CA (1998)

Gleim, I.N. Federal Aviation Regulations and Aeronautical Information Manual, Gleim Publications, Gainsville, FL (1999)

FAA Statistical Handbook of Aviation. Office of Airline Information, http://www.bts.gov/oai/faasha.html#AA (1997)

Rotorcraft Activity Survey Summary Report 1989 Data. Washington, D. C.: Federal Aviation Administration (1989)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
May 2002

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
An Analysis of U.S. Civil Rotorcraft Accidents by Cost and Injury (1990-1996)

5. FUNDING NUMBERS
812-30-22

6. AUTHOR(S)
Laura Iseler and Joe De Maio

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Ames Research Center, Moffett Field, CA 94035-1000 and
Aeroflightdynamics Directorate,U.S. Army Aviation and Missile Command, Ames Research Center, Moffett Field, CA 94035

8. PERFORMING ORGANIZATION REPORT NUMBER
A-00V0027

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001 and
U.S. Army Aviation and Missile Command
Redstone Arsenal, AL 35898-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/TM–2002-209615
AFDD/TR-00-A-010

11. SUPPLEMENTARY NOTES
Point of Contact: Laura Iseler, Ames Research Center, MS 210-5, Moffett Field, CA 94035-1000
(650) 604-0872

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified — Unlimited
Subject Category 53 Distribution: Standard
Availability: NASA CASI (301) 621-0390

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A study of rotorcraft accidents was conducted to identify safety issues and research areas that might lead to a reduction in rotorcraft accidents and fatalities. The primary source of data was summaries of National Transportation Safety Board (NTSB) accident reports. From 1990 to 1996, the NTSB documented 1396 civil rotorcraft accidents in the United States in which 491 people were killed. The rotorcraft data were compared to airline and general aviation data to determine the relative safety of rotorcraft compared to other segments of the aviation industry. In depth analysis of the rotorcraft data addressed demographics, mission, and operational factors. Rotorcraft were found to have an accident rate about ten times that of commercial airliners and about the same as that of general aviation. The likelihood that an accident would be fatal was about equal for all three classes of operation. The most dramatic division in rotorcraft accidents is between flights flown by private pilots versus professional pilots. Private pilots, flying low cost aircraft in benign environments, have accidents that are due, in large part, to their own errors. Professional pilots, in contrast, are more likely to have accidents that are a result of exacting missions or use of specialized equipment. For both groups judgement error is more likely to lead to a fatal accident than are other types of causes. Several approaches to improving the rotorcraft accident rate are recommended. These mostly address improvement in the training of new pilots and improving the safety awareness of private pilots.

14. SUBJECT TERMS
Helicopter, Rotorcraft, Accident, Safety

15. NUMBER OF PAGES
36

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	