Cooperation in the Analysis of Data and the Improvement of Aircraft Engine Safety

Although engine failure rates are low, uncontained failures remain a serious concern.

by
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Engine problems account for a small share of air transport accidents (12 percent between 1959 and 1989). Nevertheless, this percentage must be reduced even further. This can be achieved only through broad cooperation in the analysis of operating data and coordination in research and development. The following examples of recent research into the main causes of engine-related aviation accidents illustrate the importance of such cooperation (Figure 1, page 2).

Uncontained Failures Remain Subject of Concern

Joint Airworthiness Requirements (JAR) and U.S. Federal Aviation Regulations (FAR) require containment of a large number of rotating parts, including fan blades, if an engine fails. In addition, vital structural and equipment components must be arranged in such a way that they cannot be affected by fragments from rotating parts (discs or shafts) that cannot be physically contained. In spite of technological improvements, uncontained failures remain a serious problem. Under the aegis of the U.S. Federal Aviation Administration (FAA), a Society of Automotive Engineers (SAE) working group (including engine and aircraft manufacturers and airlines) is preparing a detailed analysis of the causes and consequences of uncontained failures. Summarized conclusions are contained in the SAE *Air 1537* report for the period 1962-1975 and the SAE *Air 4003* report for the period 1976-1983. A third report for the period 1984 to the present will be published soon.

Considering the period 1976-1983 for transport aircraft only (the SAE *Air 4003* report also deals with helicopters), the total uncontained engine-part failure rate is 0.58 per million flight hours. A little more than 25 percent of these failures (Figure 2, page 2) involve discs, with a rate of 0.14 per million flight hours. Because of the storage of kinetic energy in disc fragments, disc failures produce the most serious consequences. Of the 52 cases recorded between 1976 and 1983, 12 were classified category three: significant damage to the aircraft (damage to the primary structure, rapid depressurization, fire, slight

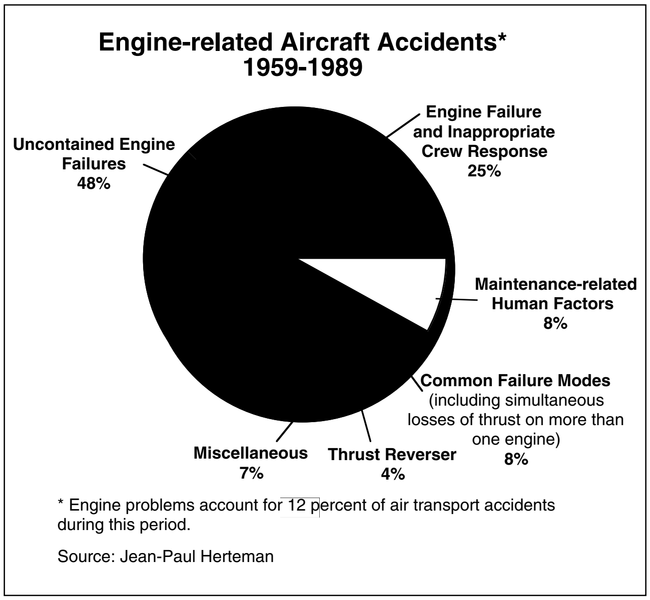

Figure 1

injuries to the passengers). Three were classified category four: severe damage to the aircraft (crash, loss of the aircraft, serious or fatal injury to the passengers).

Disc separations are usually fatigue-related, whether oligocyclic (induced by engine operating cycles) or high-cycle (intrinsic dynamic modes of the rotor or rotor/stator interactions, sometimes of aerodynamic origin). The origin of fatigue cracking and fracture often lies in the design of the part, but fractures are also encountered as a result of maintenance faults (seven of the 52 cases), machining and surface treatment faults (also seven cases) and material defects (six cases). Although not the most frequent, these latter cases are of particular importance because they can be located anywhere in the volume of the disc and can produce particularly dangerous fragments.

Catastrophic Failure Can Lead to a Loss of Confidence by The Traveling Public

One of the rare major accidents rooted in a material defect occurred in the summer of 1989 in Sioux City, Iowa, U.S. — an emergency landing of a nearly uncontrollable DC-10 following the burst of a fan disc in the No. 2 engine that caused the loss of all the aircraft's hydraulic control systems. [The crew maintained some control of the aircraft by adjusting the power of the remaining engines. The aircraft crashed at the airport 45 minutes after the engine failure. Of the 285 passengers and 11 crew members aboard the aircraft, 174 passengers and 10 crew survived— Editor.]

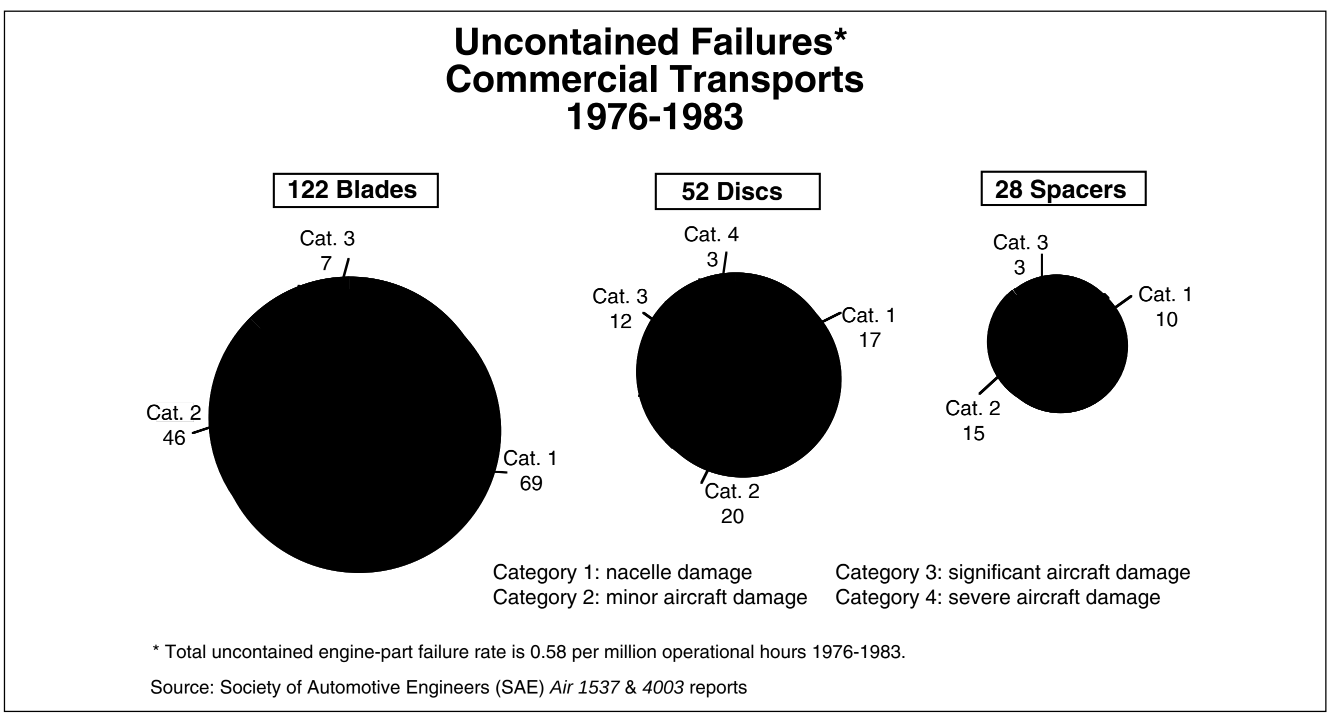

Figure 2

The subsequent accident investigation conducted by the U.S. National Transportation Safety Board (NTSB) showed that a disc fracture was caused by the development of a crack (undetected during in-service inspections), which initiated a melting defect specific to titanium alloys of the hard-alpha or I interstitial segregation type that was not detected during manufacturing inspections.

The Sioux City accident led to the creation of three separate groups:

- Engine Hazard Working Group under FAA aegis;
- FAA Titanium Rotating Components Review Team; and,
- Jet Engine Titanium Quality Committee (JET-QC).

Engine Hazard Working Group

This group is made up of representatives from the worldwide aviation community: FAA, Joint Airworthiness Authority (JAA), U.K. Civil Aviation Authority (CAA); aircraft manufacturers (Airbus Industrie, The Boeing Co., Douglas Aircraft Co.); engine manufacturers (General Electric (GE) Aircraft Engines, Pratt & Whitney Group, Rolls-Royce, SNECMA; airlines (American, British Airways, Delta, United); and pilots (Air Line Pilots Association). The main recommendations submitted in late 1990 by this group were:

- To analyze each uncontained failure occurring in operation — to search for the initial cause of the failure and to determine why the fragments were not contained — to improve containment technologies;
- To promote research and development of more advanced containment technologies (ceramic shielding, etc.); and,
- To generalize the concept of a family of parts "liable to be uncontained in the event of separation" for which special rules should be formulated and followed in design, manufacturing processes and related inspections, and maintenance and operational inspections.

[The FAA] ... identified 25 cases of cracking or fracture that occurred in service since 1962 that involved titanium material defects.

FAA Team Reviews Titanium

This group, made up of FAA personnel, presented its conclusions to the engine manufacturers in May 1991 and to the airlines in September 1991. During its exhaustive and in-depth review, it identified 25 cases of cracking or fracture that occurred in service since 1962 that involved titanium material defects: 19 type-I defects (hard alpha, as with the Sioux City disc) and six type II defects (segregation without sudden rise in hardness or cracks and voids). Four engine makes experienced cracking or fracturing — which clearly showed that the problem is widespread and is not isolated to a specific design or manufacturing process. The very high chemical reactivity of liquid titanium contributes to the occurrence risk throughout cycle of the defects (ore reduction, repeated meltings, etc.). In addition, the metallurgical structure of titanium gives it a high background noise, thus making inspection of these faults (using ultrasonic scanning of the forged blanks) more difficult compared with other materials. But the unique corrosion-resistance properties and the excellent strength/density ratio of titanium make it irreplaceable in the production of high performance turbomachinery. FAA recommendations for critical titanium alloy parts are summarized as follows:

- Further improve quality control and quality assurance procedures for titanium manufactured parts;
- Identify safer melting processes than the current triple vacuum arc remelting process;

- Determine the probability of fault detection by nondestructive testing of defects in titanium parts, both at manufacturing stage (metallurgical defects) and inservice (fatigue cracks);

- Extend and coordinate certification of nondestructive testing systems and operators both at manufacturing stage and inservice;

- Periodically inspect the titanium discs of engines in service, using high-reliability techniques; and,

- Consider a damage tolerant design for new engines that presupposes the existence of defects and ensures that their propagation does not become critical during the period between two inspections.

The cost of these recommendations, their technical difficulty and the effect of their implementation (e.g., more field inspections could lead to more disc handling in the shop and enhance exposure to surface damaging) indicate that close cooperation between the involved companies, from those that produce the raw materials for parts to the airline maintenance shops that perform inspections and repairs, will be critical to success.

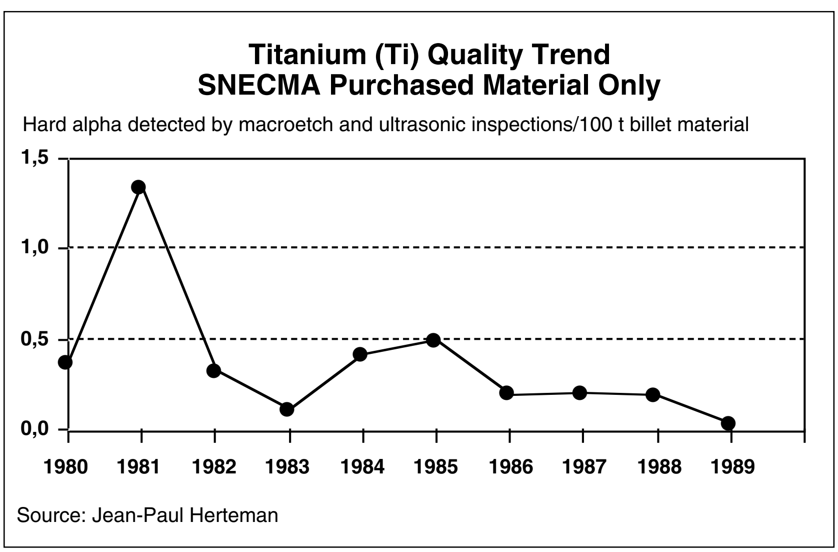

Figure 3

JET-QC

This group is intended as a permanent monitor of titanium manufacturing quality throughout the industry. It is made up of representatives from the certificating authorities and virtually all the engine manufacturers: Allison Gas Turbine, Garrett Engine Division, GE, Pratt & Whitney, Pratt & Whitney Canada, Rolls-Royce, SNECMA, Textron Lycoming Turbine Engines Division and Turbomeca Engine Corp. Its data base is designed to include all titanium producers and includes currently 17 companies. The quality results are presented in a standard format making them easier to use. They are distributed every quarter in accordance with strict guidelines to ensure that industrial rights and fair competition are not adversely affected. This cooperation increases the effectiveness of quality improvement actions. The frequency of defect observation is too low for a single producer or user to be able to identify statistically significant trends (one event for several hundred tons of titanium). Pooling of information, however, allows identification of ingot areas that present the greatest risks and quantification of the progress made on a data base many times greater than normally accessible to a single user (Figure 3).

Inclement Weather Power Losses

Power loss during inclement weather conditions (turbulence, water, hail, snow, dust, etc.) is an example of the importance of close observation of in-service events and in-depth analysis of the mechanisms involved. An Aerospace Industries Association (AIA) working group (Subcommittee 338-1) was assigned this task. It is made up of aircraft manufacturers (Airbus, Boeing, Douglas, Lockheed Corp.) and engine manufacturers (Allison, Garrett, GE, Pratt & Whitney, Pratt & Whitney Canada, Rolls-Royce, SNECMA, Textron).

For high bypass ratio turbofans, the number of inflight shutdowns or thrust losses due to weather (excluding simple turbulence problems) was about 10 per million takeoffs in the 1970s. In the 1980s, this level fell to between one and two events per million takeoffs (Figure 4). These events occurred mainly in the descent, approach and holding phases of flight when engine speeds are the lowest and the weather threat the greatest. Twenty-eight inflight shutdowns have been recorded in these phases since 1980, a rate of 1.4 per million takeoffs. The majority of these events (24 of the 28) were linked to ingestion of water or hail. The scenario identified most frequently unfolds as follows:

- The water ingested by the high-pressure compressor demands an increase in the fuel flow, which is limited by the engine control unit acceleration stop;

- The high-pressure spool rotating speed begins to fall;

- The saturating vapor limit is reached in the T3 section (compressor outlet). Water condensation enters the combustion chamber;

- Vaporization of this water consumes combustion energy; and,

- The acceleration stop limits an increase in the fuel flow, the phenomenon diverges and the engine rotating speed drops.

One of the troubling aspects of this phenomenon is that it can affect more than one engine at the same time on multi-engine aircraft. This was observed in nine of the 28 cases mentioned above, a frequency of 0.4 per million takeoffs. In five out of 28 events, engine restart was difficult.

This type of event has affected the products of three aircraft manufacturers and three engine manufacturers. Following is an examination of the analysis and corrective action taken on the CFM 56-3 powerplant on the Boeing 737-300, -400 and -500 aircraft. (CFM is a joint company of SNECMA and GE Aircraft Engines)

Hail Ingestion by the CFM 56-3

Four events of inflight shutdown in inclement weather conditions were observed on the Boeing 737-300/CFM 56-3 between 1987 and 1989. In three of these events, both engines were affected. In two events, attempts to regain power failed. One of these two failures occurred after dual flameouts forced an emergency landing (which did not result in significant consequences). This event led to a requirement to increase the flight-idle speed (from 32 percent to 45 percent) when in adverse weather conditions. This is achieved by automatic offset of the auto-throttle threshold when the crew triggers the continuous reignition button. But this was considered only a temporary remedy because it limited the aircraft's maneuverability and required pilot action.

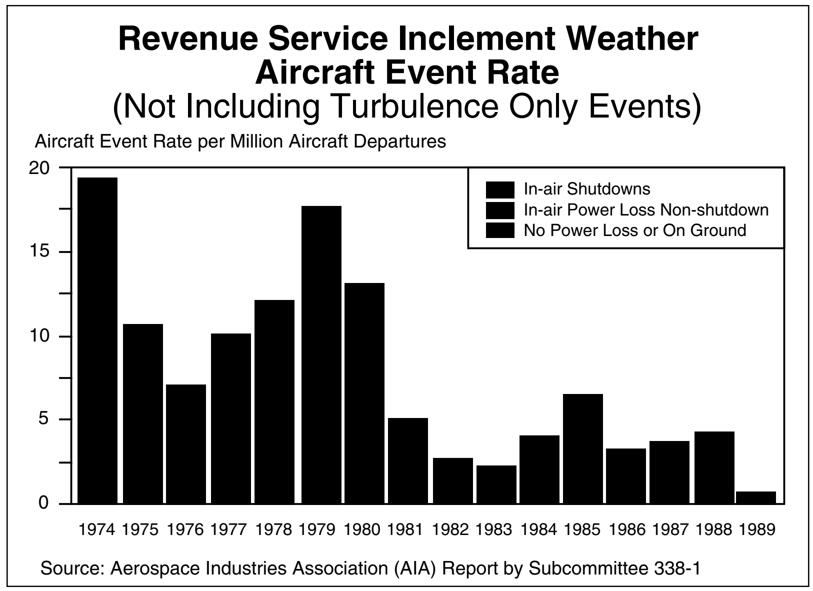

Figure 4

Further studies were conducted by GE and SNECMA in close cooperation with Boeing. The ingestion of rain and ice and the associated flameout mechanisms were modeled. A hail ingestion test bench was constructed with a capacity of 50 tons of ice per hour. An in-flight ingestion test program using a KC-135 aircraft was run with a CFM 56-3 powerplant, with a CF 6-50 powerplant as a reference. These studies revealed that the engine was far more sensitive to hail ingestion than to rain. Its wide margin in relation to the 4 percent flow requirement established by the FAR-JAR was fully confirmed, even at ground-idle. But it appears that the dynamics of hailstone ingestion are different from those of rain, which, at least in natural blowing in conditions, tend to follow aerodynamic flow lines closely. The impact behavior of hailstones and their greater inertia produce (for a constant total mass-flow) a greater concentration of water within the high-pressure core.

Hail, therefore, constitutes a specific threat and an improved understanding of this threat is necessary. Two meteorological institutes undertook this task: the Alberta Research Council (Canada) and the Groupement National d'Etudes des Fléaux Atmosphériques (Clermont-Ferrand, France). The results were presented in the form of a probability of exceeding a given hailstone flow-rate during a given period of exposure, at the altitude and speed in question. Initial estimates were made after analysis of 962 storms. They were produced after analyzing measurements made with weather radar. Their interpretation, however, will require further refinements because they are, for example, affected by the statistical distribution of hailstone size, a distribution that is poorly documented.

Based on this more realistic understanding of the threat and on lessons learned from modeling and ice ingestion tests, it was possible to make engine design modifications to provide safe and reliable performance in all weather conditions, even at idle speeds. These modifications are related to the shape of the forward spinner, position of the splitter between the primary and secondary flows, and also involved doubling the number of outflow valves and adding an aerodynamic scooping device.

These modifications move the CFM 56-3 flameout threshold away from what is seen today as a hail threat probability of 10^{-8}. Cooperative work is continuing with the goal of standardizing, or even regulating, simulation and testing methods, along with the associated criteria for the development of engines with reduced hailstone ingestion risks.

Many additional areas where cooperation is needed to collect and analyze engine data and to coordinate corrective action include the following:

- Assembly fault-tolerant design;
- Design of instrumentation systems and pilot/machine interfaces that minimize the risk of inappropriate reaction in the event of an engine failure; integration of systems (especially the increasingly large number that rely on software that is extremely tempting but extremely delicate to modify frequently); and,
- Human factors, which remain predominant among accident factors.

Progress requires sharing experience and know-how on common problems. The foundation of flight safety is the ability to be aware of and react intelligently to the in-service data available from aircraft and engine manufacturers and the operators. This presupposes a strict organization for collecting, analyzing and classifying data. Efficiency is essential when integrating these data, because daily management of immediate flight safety issues and the wealth of experience that is accumulated feeds design and project reviews. The term "concurrent engineering" finds its fullest expression here, so strong and multifaceted are the links between research, development, promotion, quality assurance and product support. ♦

This article is based on material presented by the authors at the International Federation of Airworthiness (IFA) Conference, Auckland, New Zealand, October, 1991, and supports the initiatives for the 1990s jointly sponsored by IFA and FSF. The initiatives include Continuing Airworthiness Assurance, World Aviation Standards, Standardization of Airworthiness Records for Transfer of Aircraft, Improving Aviation Safety with Current Technology and Human Factors.

Aviation Statistics

Report Analyzes Helicopter Accidents Near Heliports, Airports and Unimproved Sites

U.S. data for 26-year period provide valuable safety review of civilian helicopter operations.

by
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In February 1992, the U.S. Federal Aviation Administration (FAA) released the report, *Analysis of Helicopter Accident Risk Exposure Near Heliport, Airports, and Unimproved Sites* (DOT/FAA/RD-90/9), by R.J. Adams of Advanced Aviation Concepts; E.D. McConkey and L.D. Dzamba, Systems Control Technology Inc.; and R.D. Smith , FAA. The report is one of a series dealing with helicopter accidents near heliports, airports and unimproved landing areas. [The other reports were *Analysis of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites* (DOT/FAA/RD-91/1) and *Composite Profiles of Helicopter Mishaps at Heliports and Airports* (DOT/FAA/RD-91/1). The documents can be ordered from the National Technical Information Service, Springfield, Virginia 22161. Editor.]

The study assesses the risk associated with helicopter operations on an annual basis and develops an apportionment of that risk to movements on and near the landing site. The study provides the public with a responsible review of landing site accidents and guidelines to reduce such accidents. Heliport proponents may find this document useful as an authoritative reference in responding to community concerns about risks associated with having a heliport as a neighbor.

Accident and operational data used for the study are based upon U.S. National Transportation Safety Board (NTSB) accident data files and FAA general aviation survey and air traffic activity reports. In this study, “risk” refers to the likelihood of a helicopter accident resulting in substantial damage to aircraft and property and/or injury to occupants of the involved aircraft and/or third parties within one mile of a designated landing site.

Safety Trends Analyzed During 26-year Period

The number of helicopter accidents varied from year to year during the 26 years from 1964 through 1989. As shown in Table 1, helicopter annual accidents fluctuated between 217 and 298 with an average of 249 accidents for the 11-year period between 1964 and 1974. It then increased slightly to the range of 261 to 308 accidents a year with an average of 283 from 1975 to 1983. However, helicopter annual accidents have been steadily decreasing since 1983 to less than 200 a year.

Figures 1 and 2 show total accident rates and fatal accident rates, respectively, of helicopters compared with fixed-wing aircraft operated by air carriers, scheduled commuters and general aviation. The figures show that the total helicopter accident rate decreased by nearly a factor of 10 (from 60 to 6.2) and fatal accidents by a factor of five (from five to one) during the 26 years.

A further analysis of helicopter accidents in flight time and aircraft operations reveals that the helicopter accident rate per 100,000 hours is generally higher than fixed-wing aircraft. But in operations or mission segments, the helicopter accident rate and fatal accident rate in the most recent seven years (1980-1986) are lower than the fixed-wing rates.

Although the helicopter accident rate has steadily decreased during the 26-year period, the ratio of fatal accidents as a percentage of total helicopter accidents, as shown in Figure 3, reveals an upward trend.

Helicopter accident rates by operation category are shown in Figure 4. The rate for personal flying is significantly higher than any other category (by an order of magnitude in many cases). The personal category includes amateur-built helicopters. These are classified as experimental and are usually built from kits. With amateur-built aircraft — helicopters and fixed-wing — it is not unusual for such aircraft to crash in initial flight tests. The pilot functions as manufacturer, student, instructor and test pilot in what may be a type and size of aircraft in which the pilot has never flown.

Table 1
Helicopter Accident Data Analysis, 1964-1989 (1)

Year	Total Accidents	Fatal Accidents	Fatalities	Annual Hours	Accidents/ 100,000 Hours	Percent Fatal Accidents	Fatal Accident Rate (2)
1964	259	19	29	447,000	57.94	7.34	4.25
1965	244	16	24	450,000	54.22	6.56	3.56
1966	298	24	50	492,000	60.57	8.05	4.88
1967	239	21	42	538,000	44.42	8.79	3.90
1968	230	26	80	617,000	37.28	11.30	4.21
1969	265	31	51	778,000	34.06	11.70	3.98
1970	244	19	29	867,000	28.14	7.79	2.19
1971	217	21	29	890,000	24.38	9.68	2.36
1972	224	31	61	1,000,000	22.40	13.84	3.10
1973	258	25	44	1,158,000	22.28	9.69	2.16
1974	265	40	65	1,414,000	18.74	15.09	2.83
1975	302	25	50	1,547,000	19.52	8.28	1.62
1976	261	28	58	1,762,000	14.81	10.73	1.59
1977	270	26	57	1,868,000	14.45	9.63	1.39
1978	308	48	76	2,228,000	13.82	15.58	2.15
1979	280	34	60	2,555,000	10.96	12.14	1.33
1980	302	46	92	2,338,000	12.92	15.23	1.97
1981	291	33	66	2,685,000	10.84	11.34	1.23
1982	289	49	83	2,350,000	12.30	16.96	2.08
1983	253	33	58	2,271,000	11.14	13.04	1.45
1984	265	39	74	2,495,000	10.62	14.72	1.56
1985	224	37	61	2,155,000	10.39	16.59	1.72
1986	213	42	99	2,625,000	8.11	19.72	1.60
1987	179	29	66	2,283,000	7.84	16.20	1.27
1988	190	26	43	2,707,000	7.02	13.68	0.96
1989	185	28	51	2,800,000	6.61	15.14	1.00
Total	6,555	796	1,498	43,320,000			
Average	252	31	58	1,666,154	15.13 (3)	12.14 (3)	1.84 (3)

(1) Includes all helicopter operations.
(2) Fatal accidents per 100,000 flight hours.
(3) Weighted average based on 26 year total values.

Source: A) *General Aviation Activity and Avionics Survey*, U.S. Federal Aviation Administration.
B) *Annual Review of Aircraft Accident Data*, U.S. National Transportation Safety Board.

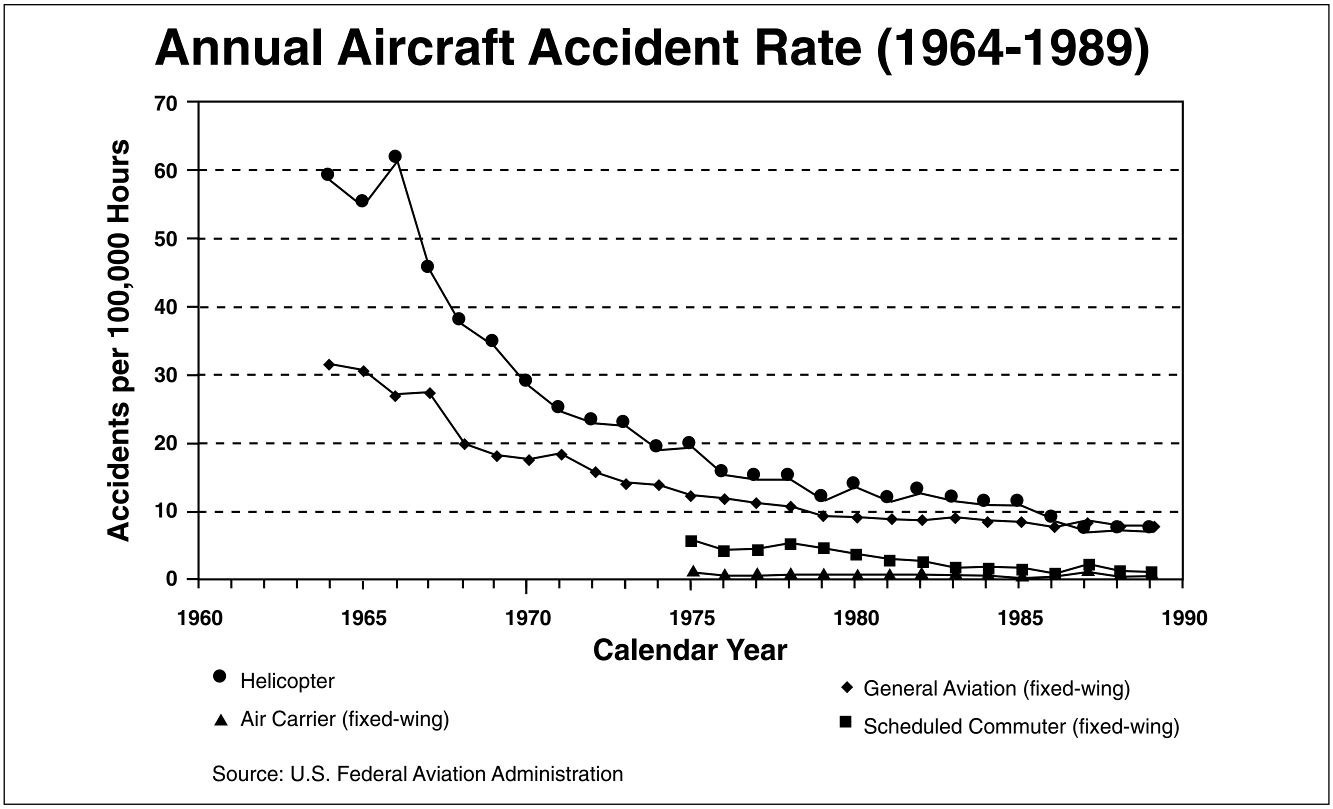

Figure 1

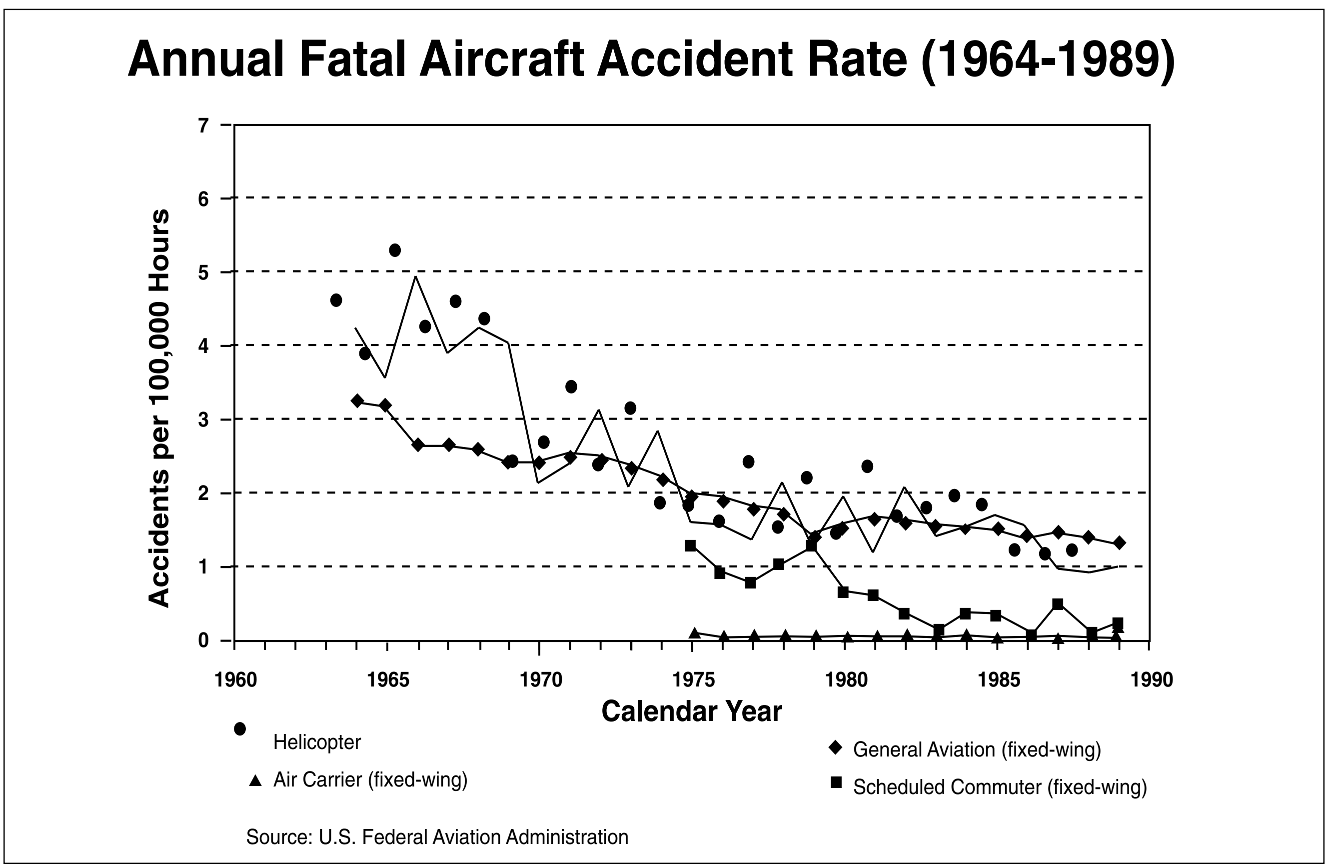

Figure 2

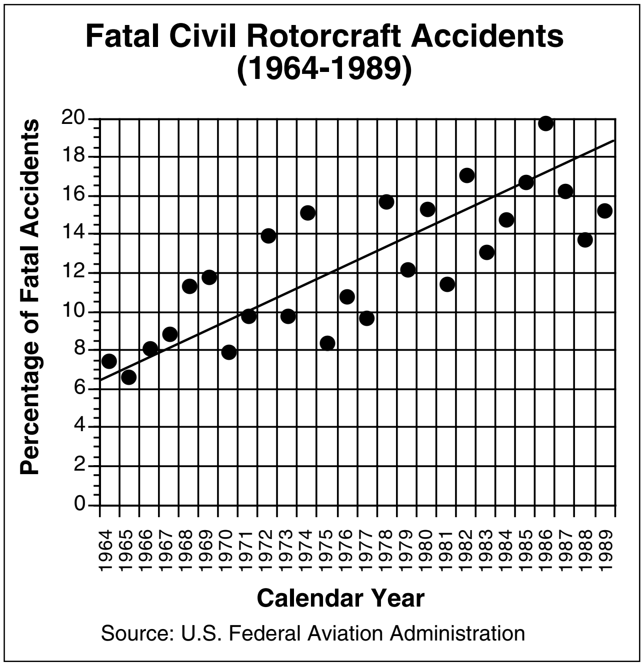

Figure 3

In 1989, NTSB records show that seven amateur-built helicopters were substantially damaged or destroyed in accidents; only one of the accidents involved injuries.

The accident rate for the business category is somewhat greater than the average of all rotorcraft. On the other hand, the accident rates for corporate/executive, aerial observation and air taxi are significantly less than the average for all rotorcraft.

Greatest Number of Accidents Occur Near Landing Sites

The report evaluated the relative risk of a helicopter accident occurring on or within one mile of a heliport, airport or other landing site. These other landing sites include unde-

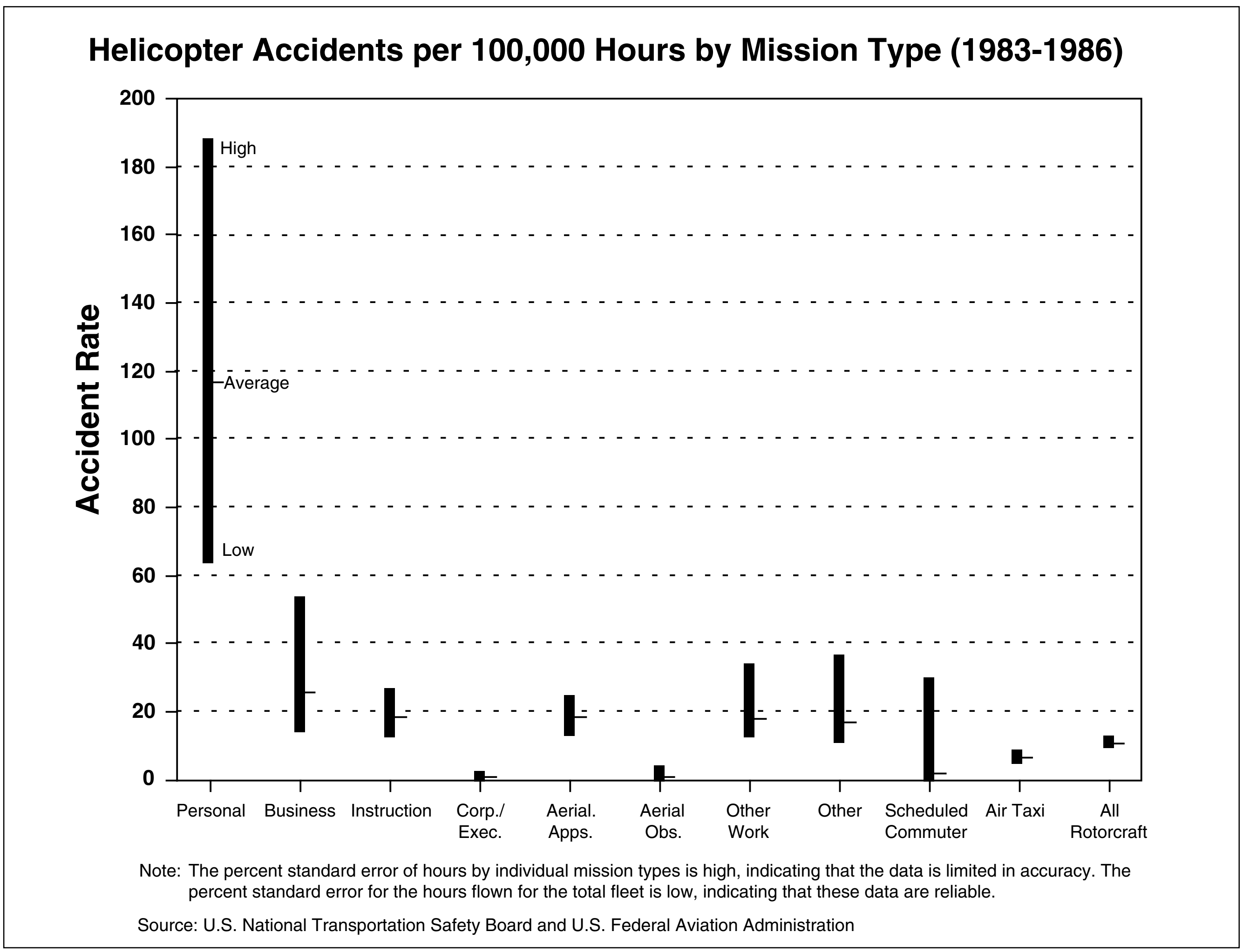

Figure 4

signated, unimproved and remote heliports. The study identified accidents occurring near landing sites during the following phases of flight:

- Standing — pre-flight; engine operating; idling rotors
- Taxi — to takeoff; from landing; serial takeoff
- Takeoff — ground run; initial climb
- Approach — visual flight rules (VFR) pattern final approach; final approach fix (FAF)/outer marker to threshold instrument flight rules (IFR)
- Landing — flare/touchdown; roll-out
- Hover

Table 2
Accidents Near Landing Site Based on Location

Year	Airport	Heliport	Unimproved	Unknown	Total Landing Site Accidents	Total Helicopter Accidents
1977	53	6	*	30	89	270
1978	35	18	*	56	109	308
1979	43	12	*	36	91	280
1980	39	14	*	45	98	302
1981	56	9	*	39	104	291
Subtotal	226	59	*	206	491	1,451
1982	**	**	**	**	**	289
1983	43	9	54	8	114	253
1984	36	9	31	24	100	265
1985	42	14	33	11	100	224
1986	27	15	28	14	84	213
Subtotal	148	47	146	57	398	955
Total***	374	106	—	263	889	2,406

* Unimproved was not included as a separate category prior to 1982.
** The 1982 U.S. National Transportation Safety Board data base does not contain enough information to support an analysis of accidents within 1 mile of landing site.
*** Excluding 1982.
Source: U.S. Federal Aviation Administration

The study used two methods to estimate the number of accidents occurring within one mile of landing sites. The results are shown in Tables 2 and 2A. It is estimated that for the nine-year period from 1977 through 1986 (excluding 1982), approximately 34 to 39 percent of total accidents occurred at or within one mile of land-

Table 2A
Civil Accidents Occurring within 1 Mile of a Landing Site (1977-1986)

	Number	Sample Size	Percent
Helicopter Accidents Occurring within 1 Mile of a Landing Site (Flight Phase Method, 1977-1986)	1,287	2,695	48
Helicopter Accidents Occurring within 1 Mile of a Landing Site (Accident Location Method, 1977-1981, 1983-1986)	889	2,406	37
Helicopter Accidents Occurring within 1 Mile of an Airport (1977-1981, 1983-1986)	374	2,406	16
Helicopter Accidents Occurring within 1 Mile of a Heliport	106	2,406	4
Helicopter Accidents Occurring within 1 Mile of an Unimproved Site (1983-1986)	146	955	15
Helicopter Accidents Occurring at Unspecified Locations (1983-1986)	57	955	6

Table 3
Risk of Serious Injury Data at All Landing Sites

Year	Fatal Injury*	Major Injury*	Fatal & Major	Total Occupant*	(Fatal + Major) Total	Accidents/ 100,000 Hours**	RSI/100,000 Occupant Hours
1977	5	14	19	174	0.109	14.46	1.58
1978	7	19	26	200	0.130	13.78	1.79
1979	14	24	38	171	0.222	10.88	2.42
1980	22	11	33	196	0.168	12.70	2.13
1981	0	13	13	169	0.077	10.84	0.83
1982	9	11	20	165	0.121	12.17	1.47
1983	5	19	24	248	0.097	11.14	1.08
1984	13	22	35	250	0.140	10.62	1.49
1985	9	14	23	177	0.130	10.35	1.35
1986	6	20	26	156	0.167	8.11	1.35
Total	90	167	257	1,906	0.136***	11.51***	1.56***

* U.S. National Transportation Safety Board accident records
** Table 1
*** Weighted average based on 10-year total values

ing sites; about 13 to 18 percent of all helicopter accidents occurred at or near airports; three to five percent occurred at or near heliports; nine to 18 percent at or near unimproved landing sites; and three to eight percent at unspecified landing sites.

Fatalities Signal Need for Improved Crashworthiness

The data for the 10-year period from 1977 to 1986 were reviewed to compute the relative risk of serious injury (RSI), which includes all injuries that are fatal or major (referred to as serious). The results are shown in Table 3.

The ratio varied from a high of 0.222 in 1979 to a low of .077 in 1981. This indicates that given one was an occupant (pilot, crew or passenger) of a helicopter and an accident occurred, the chance of serious harm ranged from 7.7 percent to 22.2 percent. During this period, the helicopter occupant RSI was 1.5 per 100,000 occupant hours, a trend that has shown little improvement in the last several years.

The percentage of accidents with fatalities increased during the 26-year period. The lowest percentage of fatal accidents, 6.61 percent, occurred in 1965. The highest percentage, 19.7, occurred in 1986. However, this increase in fatal accidents is much lower than the six-fold increase in the number of flight hours during the same period. Annual helicopter utilization increased from 447,000 flight hours in 1964 to 2,800,000 flight hours in 1990. The bulk of the increase in annual hours flown by helicopters has been in the air taxi, aerial observation and executive transport categories. Also during this period, the size of the typical helicopter increased from the Bell 47 (two occupants) to the Bell 206/Hughes 500 (five to seven occupants), and the accident rate due to mechanical failures decreased.

Because helicopters are becoming larger and carrying more people, the percentage of fatal accidents is expected to continue to increase. This illustrates the need for more crash survival features in helicopters. The report emphasizes that manufacturers know how to build crashworthy helicopters.

However, it cites two problems that have impeded progress in crashworthiness. First, certification requirements did not mandate shoulder harnesses for all occupants. In addition, the FAA did not require the installation of energy attenuating seating, crash-resistant fuel systems [originally developed by Flight Safety Foundation], etc., even though these technologies are available and widely used by the military and some civilian organizations. (Amendments to Federal Aviation Regulations (FAR) will require helicopters reviewed for type certification in the future to have energy attenuating seats and shoulder harnesses for all occupants.)

Second, said the report, operators seldom voluntarily request these options because of cost and weight considerations.

Risks to Ground Personnel Greatest at Remote Landing Sites

During the five-year period from 1982 through 1986, there were 15 accidents causing fatal or serious injury to ground personnel, or 0.13 fatal/major accidents per 100,000 flight hours. Data shows one serious personnel injury at heliports about every other year. The risk to ground personnel at remote sites was higher, where eight of the 15 persons were killed or injured during the five-year period.

A total of 18 residential/commercial buildings, 22 vehicles and seven other properties in residential areas were damaged by helicopter accidents occurring within one mile of landing sites. One approach used in the study to determine neighborhood risk is based on the overall helicopter accident rate (10.1 accidents/100,000 hours average for the years 1983 to 1986) for all helicopters and the estimated percentage of time spent over the neighborhood during normal operation.

It is estimated that if there are 400 missions flown annually from a given heliport, the average likelihood of an accident in the neighborhood is one accident every 495 years. This risk will vary by the number of helicopter operations at the heliport. When coupled with low probability of risk to persons on the ground if an accident does occur, a helicopter is statistically a very low risk to neighborhood residents and property.

Safety Projected to Improve In this Decade

The 1964-1989 period provided a reasonable statistical base for projecting safety levels through 2000 based on the following facts:

- The mature activity of piston helicopters, up to about 1980, when they represented approximately 50 percent of the fleet;
- The emergence and growth of the turbine helicopter;
- The increasing use of sophisticated twin-engine helicopters;
- The emerging demand for heliports; and,
- Periods of both growth and decline in helicopter utilization rates.

Because the annual helicopter accident rate per 100,000 flight hours has dropped continually and dramatically during the period, a reasonable projected improvement is to sustain the improvement demonstrated between 1979 and 1989. Because annual operating hours have remained fairly steady for the 1986-1989 period, an annual average of 2.725 million hours flown would mean that about 98 accidents would be expected in 2000.

Also, based on the 185 accidents in 1989, the projection indicates a reduction in total accidents of 87, or 47 percent. Of these accidents, 19 would be fatal. This appears to be an aggressive, yet achievable, projection based on recent trends says the report. ♦

Reports Received at FSF Jerry Lederer Aviation Safety Library

Reports

Guidelines for Integrating Helicopter Assets into Emergency Planning/Sandra Henninger, Jack Thompson, Catherine Adams. Washington, D.C. U.S. Federal Aviation Administration (FAA), Research and Development Service; Springfield, Va. Available through the National Technical Information Service*, [1991]. Report No. DOT/FAA/RD-90/11, Contract No. DTFA01-87-C-00014. 62 p.; ill.

Key Words
1. Helicopter Ambulances.
2. Heliports.
3. Disaster Relief.

Summary: This set of guidelines contains recommendations on how to best integrate helicopters into existing emergency planning to provide maximum protection and lifesaving services in the community. The guidelines are based on accepted disaster planning concepts, tempered with lessons learned through the analysis of case histories. The intended audience is emergency planners who often do not take the best advantage of helicopter assets within their planning area — public service, private and military helicopters — that may be available to help with crisis situations. Further information is provided on developing an inventory of helicopter resources; surveying helicopter operators' capabilities; determining communication capabilities and requirements; designating; establishing and controlling landing zones; and implementing a planned helicopter response. [Summary from modified author abstract]

The Prevalence of Artificial Lens Implants in the Civil Airman Population/Van B. Nakagawara, Faredoon K. Loochan, Kathryn J. Wood. Washington, D.C. U.S. Federal Aviation Administration, Office of Aviation Medicine; Springfield, Va. Available through the National Technical Information Service*, [1992]. Report No. DOT/FAA/AM-92/14. 18 p.

Key Words
1. Air pilots — Medical examinations — United States.
2. Intraocular Lenses.
3. Vision — Testing.
4. Aphakia.
5. Medical Certification.

Summary: The use of artificial lens implants for aphakia has become increasingly prevalent in the United States. This study analyzes the distribution of intraocular lens (IOL) implants in the civil airman population by type (unilateral, bilateral), class of medical certificate and gender for a four-year period (1982-1985). Medical records were evaluated for all certified airmen who were carrying pathology codes for aphakia and had artificial lens implants during the study period. The percentage increase in the prevalence of airmen with artificial lenses was higher for bilateral, second-class medical certificate holders, and female aphakics. However, the incidence of total and unilateral artificial lens implants declined in 1985. The report discusses the implications of the study's findings for aeromedical certification and recommendations are made for changes in methods used to evaluate trends in the use of IOL in the airman population. [Summary from modified author abstract]

Survey of Aviation Medical Examiners: Information and Attitudes about the Pre-employment and Pre-appointment Drug Testing Program/Jennifer G. Myers. Washington, D.C. U.S. Federal Aviation Administration, Office of Aviation Medicine; Springfield, Va. Available through the National Technical Information Service*, [1992]. Report

No. DOT/FAA/AM-92/15. 42 p.

Key Words
1. United States Federal Aviation Administration — Employees — Drug testing.
2. United States Federal Aviation Administration — Recruiting.
3. United States Office of Aviation Medicine.

Summary: This report is a follow-up to a survey of aviation medical examiners (AME) who were designated to collect urine samples in the pre-employment and pre-appointment drug testing program. The survey was conducted to assess the examiners' attitudes about different aspects of the testing. Seventy-five percent of the sample responded to the survey. The responses were generally positive about the custody and control form; the amount of information received about the collection kits and the drug testing program; and the contacts they had with the agency medical staff. However, only about half of those surveyed reported they had been informed of drug testing program changes. Errors in the collection process were most often attributed to inaccurate completion of custody and control forms and lack of training. Few examiners had actually received information on their error rate in specimen collections. Recommendations were made to review the custody and control form for possible improvements to reduce errors, to restrict the number of AMEs designated to collect specimens, to provide training classes, materials or videotapes (especially for newly designated AMEs) and to clarify the alcohol and drug abatement program manager's position. [Summary from modified author abstract]

A New Test of Scanning and Monitoring Ability: Methods and Initial Results/A.M. Revzin, P.G. Rasmussen (Civil Aeromedical Institute). Washington, D.C. U.S. Federal Aviation Administration, Office of Aviation Medicine; Springfield, Va. Available through the National Technical Information Service*, [1992]. Report No. DOT/FAA/AM-92/12. 20 p.

Key Words
1. Air pilots — Medical examinations — United States.
2. Air Traffic Controllers — Medical examinations — United States.
3. Vision — Testing.
4. Visual Perception — Testing.

Summary: Most tasks in the FAA's air traffic control (ATC) system involve long-duration scanning and monitoring of continuously changing events occurring within a large visual space. Errors occur, so it is important to understand the causes of such errors to minimize or eliminate them by changing task design or improving personnel selection. This study describes a new system for testing, scanning and monitoring abilities. Different characters are presented at random intervals and locations within a work area on a computer display screen. The work areas are filled with constantly changing random dot patterns located on the screen. The test subject's task is to press a designated key on the computer keypad when a specified target character appears. Parametric manipulations can evaluate the effects on performance of many variables, including angular separation of work areas, differential workloads in the work areas and effects of visual noise. Results of the initial experiment show a highly significant performance decrement occurring as a function of increasing angular separation of work areas. The significance of this result is also discussed. [Summary from modified author abstract]

Aviation Safety: Users Differ in Views of Collision Avoidance System and Cite Problems: Report to the Chairman, Subcommittee on Investigations and Oversight, Committee on Science, Space and Technology, U.S. House of Representatives/ U.S. General Accounting Office. Washington, D.C. General Accounting Office**, [1992]. Report No. GAO/RCED-92-113. 19 p.; ill.

Key Words
1. Aeronautics — Communication Systems — Evaluation.
2. Airplanes — Collision Avoidance — Technological Innovations — Evaluation.

Summary: In response to the need to prevent mid-air and near mid-air collisions, the FAA,

after evaluating several systems, decided to develop and deploy the Traffic Alert/Collision Avoidance System (TCAS). TCAS is an airborne, aircraft-to-aircraft system that scans surrounding airspace, warns of potential intruders and recommends evasive maneuvers. This report discusses the views of pilots and air traffic controllers on TCAS, FAA's action to address TCAS problems and key aspects of the FAA's software engineering approach for TCAS, including FAA's plans to verify and validate the system. While TCAS is now installed in a substantial portion of the U.S. commercial fleet, the aviation community is nearly unanimous in recognizing that TCAS needs to be improved. According to the report, TCAS issues too many unnecessary alerts, causes excessive altitude deviations (more than 1,000 feet) and causes pilots to miss landing approaches. Moreover, these problems reduce users' confidence in TCAS and the margin of safety that the system provides. Although the FAA plans to test and implement an improved TCAS, the report states that TCAS users should have the opportunity to review the modification's interim test methodology and results before the system is modified. Such a step is critical to ensure that user problems are identified and corrected. [Summary from modified report introduction]

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[Citations in "Reports Received" are taken from MARC format records in the Library of Congress Online Union Catalog (OLUC). Editor.]

Accident/Incident Briefs

This information is intended to provide an awareness of problem areas through which such occurrences may be prevented in the future. Accident/incident briefs are based upon preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

Visual Night Approach Ends On Mountain Ridge

DC-9-30. Aircraft destroyed. Thirty-one fatalities.

The McDonnell Douglas DC-9-30, in radar contact, was on approach at night when the pilot report visual contact with the ground. Instead of following the NDB (non-directional beacon) approach procedure, the pilot descended to the west of it to avoid weather. A short time later, the aircraft crashed into a mountain ridge about nine nautical miles southwest of the airport at an altitude of 2,000 feet.

An investigation concluded that the pilot was overly self-confident about his ability to fly the approach visually at night and that the copilot was complacent by not objecting to the decision. Air traffic control was also cited for inadequate attention and assistance to the aircraft. The investigation said controllers were distracted by heavy traffic loads at the time of the accident and that pressure may have affected their judgment.

Vague Taxi Clearance Causes Potentially Disastrous Confusion

Boeing 757. No damage. No injuries.

Following pushback from the gate at a South American airport, the crew of the Boeing-757 was issued the following clearance: "Cleared to taxi holding position, runway zero nine."

According to an incident report, the crew understood the tower transmission to mean that they were cleared onto runway 09 to hold for takeoff clearance. As the aircraft approached the departure end of the runway, the captain spotted a Boeing 727 on two mile final. When the tower was asked about the possible traffic conflict, the flight was advised to hold short of the runway. Visibility at the time was three miles in light rain.

The Boeing 757 was cleared for takeoff about 45 seconds later after the Boeing 727 landed on runway 09. A subsequent inquiry determined that the tower routinely uses such terminology to clear aircraft to taxi and hold short of active runways.

Autopilot Malfunction Leads To 11,000-foot Dive

Boeing 747. No damage. No injuries.

The Boeing 747, on a transcontinental flight, was cruising at FL310 (31,000 feet) at night in smooth air. There were no visual ground or horizon references.

Shortly after completing engine monitoring checklists, the pilot noticed that the ADI (attitude direction indicator) horizon was in the vertical position and called this to the first officer's attention. Both pilots suspected an ADI failure. A few moments later, all three INS (inertial navigation system) red warning lights illuminated. The copilot also noted that the yoke was turned slightly to the left. The VSI (vertical speed indicator) was full scale down and the standby horizon was also in the vertical position.

The captain indicated that maximum roll and pitch exceeded 90 degrees and 30 degrees, respectively. The pilots reminded each other to pull out of the dive slowly and the first officer reported MAYDAY to ATC (air traffic control). During the dive, the engine ignition switches were turned on to prevent the engines from flaming out. Recovery was completed at FL200 (20,000 feet) and the aircraft diverted to a nearby airport.

An investigation suggested that the cause of the incident was an autopilot roll channel fault.

Air Taxi
Commuter

Open Cargo Door Proves to Be Fatal Distraction

Piper PA-23-250 Aztec. Aircraft Destroyed. Five fatalities.

The Aztec had just taken off when the aircraft's nose baggage door opened. The pilot informed the tower that the flight was returning to the airport and he immediately entered a 60-degree turn and leveled off at about 300 feet above the ground.

One and a half minutes into the flight and within a mile of the runway, the aircraft nosed down and crashed. The aircraft was destroyed in the crash and resulting fire. The pilot and four passengers were killed.

A subsequent investigation determined that the pilot had allowed the aircraft to stall without sufficient altitude for recovery. The accident report concluded that the defective baggage door was not an insurmountable threat to the aircraft's controllability, but that the distraction likely caused the pilot to divert his attention from control of the aircraft. Noise and vibrations in the cockpit associated with the open door may also have masked the symptoms of a stall and the stall warning horn.

Turbulence Causes Hard Landing

BAe ATP (Advanced Turboprop). Substantial Damage. No injuries.

The BAe ATP was on approach to runway 27 at night with 69 passengers and a crew of four aboard. There was moderate rain and winds gusting from the south at speeds up to 42 knots.

Just before touchdown, significant turbulence was encountered and the crosswind component reached 33 knots, one knot below the aircraft's tested limit. The aircraft touched down firmly, nosewheel first, and porpoised along the runway, bouncing twice. During the bounces the aircraft entered a divergent pitch oscillation caused by out-of-phase elevator inputs. The nose gear failed on the fourth impact with the runway and the propeller tips were destroyed on ground contact. The aircraft ran off the side of the runway and came to rest in soft ground. Passengers and crew evacuated without injury through the forward passenger door.

Cockpit Chatter Leads to Crash

DHC Dash 7. Aircraft destroyed. Thirty-six fatalities.

The four-engine Dash 7 was on an instrument approach to runway 04 when it crashed into high terrain about five nautical miles from the airport. At the time of the crash, the aircraft was slightly off course and flying at an altitude of 560 feet MSL (mean sea level). The published minimum altitude at the area of impact was 1,200 feet MSL.

A subsequent investigation indicated that the pilot was having a conversation with a passenger who was sitting on the jumpseat. The report said the crew was likely distracted by the conversation. The report cited the pilot and copilot for poor airmanship in not monitoring altitude and course information.

Corporate Executive

Handbook Omission Contributes To Gear Failure Crash

Beech 200 King Air. Substantial damage. No injuries.

On final during the daylight approach, the two-man crew noticed that the right gear light that indicated the gear was not locked down. The crew recycled the gear and completed an uneventful landing with three passengers aboard. A subsequent visual inspection failed to detect any abnormalities.

On the next flight, landing gear recycling was completed, but the right gear would not lock down. It collapsed during the landing roll.

An inquiry revealed that the crew had taken proper actions and had followed the manual, but should have continued to use the emergency hand pump throughout the landing roll to keep hydraulic pressure in the right gear actuator. An inspection of the aircraft showed that the down lock mechanism for the right gear was worn and would not engage.

The investigation also indicated that the warning in the operator's handbook was incomplete and should be changed to alert pilots to use the hand pump throughout the landing roll and until the gear is made safe by mechanical means.

Jet Fuel Brings Down Baron

Beech Baron. Aircraft destroyed. Two fatalities. Three injuries.

The Baron departed with sufficient fuel to reach its destination, Indianapolis, but stopped along the way to add fuel in anticipation of delays due to heavy traffic. On approach to Indianapolis, both engines failed and the pilot executed an emergency, gear-up landing. The aircraft impacted the ground short of a sports field, struck a tree stump and a pile of bricks and caught fire. Two passengers were killed; two others and the pilot were severely injured.

An investigation determined that both engines stopped because of fuel starvation and that it was likely that jet fuel, rather than aviation gasoline, was used during the refueling stop. The investigation cited the pilot for inadequate preflight checks and for improper emergency procedures. Flaps were not used during the emergency landing.

Other General Aviation

New Sign Posts Surprise Piper On Final

Piper J3C-65 Cub. Substantial damage. Two minor injuries.

The pilot of the Piper Cub was on final during the daylight approach when the landing gear struck a five-foot-high post in front of the runway threshold.

The impact collapsed the landing gear and pitched the nose of the aircraft down, causing it to the strike the ground with the underside of the nose cowling and the propeller.

A subsequent inquiry determined that two days before the crash, local authorities had erected a series of the wooden posts to mark a public right of way across the threshold of the landing strip. Neither the pilot nor his passenger was aware of the change. The pilot said the posts were not visible from the air in the sunlight from that approach direction.

Landing Skid Flips Beagle Pup

BAe Beagle B121 Series 2 Pup. Aircraft destroyed. One serious injury. One minor injury.

The single-engine Beagle took off from the grass field for a training flight within the circuit during a rain shower.

The pattern and approach were flown normally and the pilot reported that the aircraft touched down, on speed, about 300 meters down the strip. However, when brakes were applied, the aircraft skidded to the right. The brakes were then momentarily released and reapplied when the drift to the right had been corrected. Despite the corrective action, the aircraft left the grass runway and ran onto soft, tilled ground. The aircraft pitched forward and came to rest inverted.

The fuselage was distorted by the impact, forcing the occupants to smash through the door windows to escape. The pilot stated that it was common practice to land well down the strip because buildings and power cables were located on the approach. The pilot also noted that the wind had dropped and the direction had become variable when the aircraft touched down.

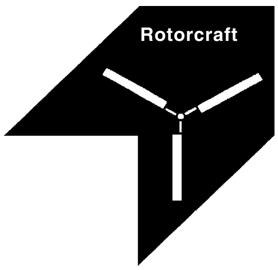
Cabin Fumbling Leads to Ground Collision

Cessna 152. Substantial damage to two aircraft. No injuries.

The student pilot had just started the Cessna's engine when he realized that one lead of his headset connection had fallen from its socket. The pilot said he made sure the parking brake was on and leaned forward to reconnect the plug. He said that, because of the tightness of his harness, he had some difficulty reaching the socket. While looking down, the pilot heard a "crunch" and the aircraft's engine stopped.

The 152 had moved forward and struck an aircraft parked nearby. The collision damaged the 152's propeller and engine and caused substantial damage to the second aircraft's wing and main spar.

A subsequent investigation revealed no fault in the aircraft's brake systems.



Approach Courtesy Snags Schweizer

Schweizer 269C. Minor damage. No injuries.

The helicopter was on daylight approach in clear weather conditions when the pilot elected to make his descent path slightly to the west to avoid distracting student pilots by coming from the side of their approach path.

Just a few meters from his flare point, the aircraft struck high-tension wires that were aligned across the flight path. The cables struck the chin cowling and skid supports and snapped, allowing the helicopter to make a very firm but balanced landing on the skids. The landing caused little damage to the aircraft and the pilot was not injured.

The pilot reported as he approached the landing site that the wires were not visible from the air because of the ploughed field background.

Clouds, Low Rotor RPM Lead to Emergency Landing

Robinson R22 Beta. Aircraft destroyed. One minor injury.

The pilot took off in satisfactory daylight weather conditions, but observed deteriorating conditions shortly after liftoff. Patches of fog and cloud continued to increase, further reducing ground contact.

Flying at 1,000 feet, the pilot received an amended clearance to proceed directly to his destination, but not above 500 feet. At that time the pilot decided to return to base and began a descending turn to 500 feet with the intention of informing air traffic control of his decision after the maneuver was completed.

On initiating the descent, the pilot experienced difficulty in controlling the helicopter in yaw and entered cloud. The pilot referred to instruments and noted a rate of descent of 550 feet per minute. The nose of the helicopter was lowered to increase airspeed and the pilot noted a rate of descent of 600 feet per minute. At this moment, the low rotor RPM warning sounded and the pilot immediately increased rotor RPM. The warning ceased and the aircraft broke out of cloud at an altitude of about 50 feet. The pilot made an immediate run-on landing in a ploughed field at about 40 knots. The helicopter rolled over and broke apart on impact.

The pilot was able to evacuate the aircraft with only minor injuries. The helicopter then caught fire and was destroyed.

A subsequent investigation revealed no defects that could have caused or contributed to the accident. ♦