Human Factors in 1988 General Aviation Accidents

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Variations in human behavior and performance are responsible for a large percentage of aviation accidents. Selected human factors that contribute to general aviation accidents are identified and classified and their frequency of occurrence is determined with the intent of providing means to reduce the accident rate. The purpose of human factors research in aviation is twofold. First, human limitations and capabilities are defined in terms of interaction with people and with mechanical, technical, and procedural systems. This definition spells out what a human can and cannot do; thus the limits of the human performance envelope are established. Second, knowledge concerning the envelope can be used to provide direction for modification of flight training, system design, and aircraft design. A checklist based on a systems approach to understanding human behavior in aircraft accidents was used to identify human factors that contributed to general aviation accidents. Accidents studied were selected randomly from all 1988 National Transportation Safety Board (NTSB) accident reports. Some types of human factors were readily identifiable from NTSB reports. Other factors were not identified directly by NTSB; it was difficult to detect their influence from the body of the reports. Although use of the modified checklist identified human factors as contributing to 90 percent of the accidents studied, it is likely that some contributing human factors were not detected, and that the actual percentage is higher. The high incidence of human factors contributing to general aviation accidents points out a need for increased or modified training in several areas. Incorporation of a human factors checklist into the NTSB accident investigation procedure would be a step toward identification of all factors contributing to aviation accidents. This information could then be used to modify pilot training and aviation systems development to reduce the accident rate.

Variations in human behavior and performance are responsible for a large percentage of aviation accidents. In this study 1988 general aviation (GA) accident reports were analyzed to identify human factors and determine how often they occur in accidents. The purpose of aviation human factors research is to provide a means to reduce the number of aviation accidents. The identification of which human factors contributed to GA accidents was particular concern.

NATURE OF GA INDUSTRY AND PILOT FLYING TASKS

GA safety is of concern because GA is vital to the American economy. GA is much more than private owners flying for pleasure; it is important to agriculture and business (approximately 35 percent of flying is for business purposes). Corporate flying and personal flights are other aspects of GA. It is also important in flight instruction. GA is nearly the only source of pilot training for the future. The military used to be a significant source of pilots for airlines, but now longer terms are required and forces are decreasing.

More airports and communities are served by GA than by air carriers. The U.S. business community relies on GA, which is the only means of air travel available to many small communities (1). In 1988 approximately 96 percent of U.S. airports and 89 percent of U.S. public use airports were served exclusively by GA. Air carriers served only 4 percent of the nation's 17,327 airports. In 1988 there were 210,000 GA aircraft, 98 percent of the active U.S. fleet, and 96 percent of certificated pilots were GA.

GA pilots flew 33.6 million hr in 1988, compared with 13 million hr flown by air carriers (2). "The number of hours flown by GA aircraft is expected to increase . . . to 36.8 million by fiscal year 1988" (3). The majority of hours flown by the U.S. GA fleet in 1988 were in piston engine aircraft, with 26.2 million hr flown. Turboprop aircraft flew 2.4 million hr, jets flew 1.7 million hr, and rotary wing and other aircraft accounted for 3.3 million fight hr (4).

GA pilots perform a wide variety of in-flight tasks, including primary control, machine management, navigation, communication, and compliance with air traffic control. These tasks are defined by hardware and required procedures. Pilots must interpret information from visual cues, radio, flight controls, instruments, printed materials, and their own memories. Integration of all this information is complicated because it requires shifting between an understanding of aerodynamic principles and how the aircraft responds to control movements, and interpretation of information provided by avionic systems and pilot sensory systems reacting to the real-world environment.

Campbell (5) maintains that skill and knowledge are necessary ingredients of a good pilot, but that good judgment, which leads to correct decision making, is essential. Good judgment is more difficult to learn than flying skills. According to Ritchie (6), a professional level of flying skills can be achieved in approximately 1,000 hr of flying time, if accomplished within 2 or 3 years. This is seldom a pattern followed by GA pilots, who are often part-timers, limited in the rate at which they can develop and maintain their skills. Ritchie says, "Some GA pilot tasks, particularly flying single-pilot instrument flight rules (IFR), are among the most difficult of flying tasks. Despite this, GA pilots must live and operate in a system which is designed for somebody else" (6, p; 587). The system, which consists of airspace structure, regulations, air traffic control, aircraft control, and instrument interpre-

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tation, was designed for professional pilots operating air carrier aircraft. The GA pilot must fit into this system, and it can be an uncomfortable fit.

OVERALL GENERAL AVIATION ACCIDENT PICTURE

Statistics from the National Transportation Safety Board (NTSB) (7) and FAA (4) indicate that in 1988 the accident rate for GA was approximately 10 times that for air carriers.

The GA accident rate is decreasing. In 1979 there was one accident in about every 10,000 flight hr. In 1989 that had decreased to one accident in almost 14,000 flight hr. Some types of flying within general aviation are more hazardous than others. NTSB (7) offers a comparison of risk for different types of flying (see Table 1).

The number of GA accidents continues to decrease even as hours flown increases. Though the numbers are moving in a favorable direction (8), it should not be overlooked that 805 people were killed in GA accidents in 1988. In addition to the loss of life, the cost due to legal liability are enormous and affect all pilots, airframe manufacturers, and suppliers, including engine and avionics firms (9). According to the General Aviation Manufacturers Association (GAMA), "unfair, exorbitant product liability costs have had a devastating effect on U.S. general aviation manufacturers, consumers and service organizations. Claims paid by the industry soared from $24 million to over $210 million the past decade" (10). Liability costs have made new piston airplanes too expensive for most customers and have shaped an industry in which almost no single-engine piston training aircraft are being built.

NTSB is usually accurate in its description of what happened in an accident but does not always explain why the accident happened (11). Accident investigation is difficult because human memory is fallible and adversely affected by trauma, and eyewitness accounts can give a distorted view of what happened (12). Identifying the complete train of events leading up to an accident is problematic, especially in GA accidents, because voice cockpit recorders are not required. The threat of litigation can bring about suppression of essential facts (9).

THE HUMAN COMPONENT IN GENERAL AVIATION ACCIDENTS

Purpose of Human Factors Research

Engen (13) said, "We spent over fifty years on the hardware, which is now pretty reliable. Now it's time to work with the

people." Human factors research is one way of addressing the people side of the accident equation.

One point of agreement among agencies investing or reporting on aviation accidents is that the pilot is responsible for a large percentage of these accidents. According to *The National Plan for Aviation Human Factors* (14), "Human error has been identified as a causal factor in 66 percent of air carrier accidents, 79 percent of commuter fatal accidents and 88 percent of GA fatal accidents."

The term "human error" implies that pilots are at fault. It is broad and general, and implies failure. Aircraft manufacturers set up weight and balance parameters for the loading of an aircraft (how fuel and cargo are to be loaded and where passengers sit). Human factors research identifies and sets out parameters for the human performance envelope. It is not appropriate to imply neglect or fault on the part of the pilot. Accidents occur as the result of human variables, some of which are inexperience, inattention, oversight, control reversal, apprehension, and distraction. They are not caused by one single factor. These accidents are caused in part by a mismatch between the human performance envelope and aircraft/aviation systems. Human factors were identified in 90 percent of the accidents studied during this research. That does not mean that human factors caused these accidents, but they were identified as contributing to the accidents.

Nance (15) clarifies the problem faced by researchers attempting to discover the causes of aviation accidents:

> Pilots and controllers and maintenance people err and cause accidents because they are human, and we imperfect humans are all prone to make such mistakes. Discovering that a human error—pilot error or otherwise—has occurred is merely the starting point. To have any hope of preventing such an error from causing such an accident again and again, the *reason* the error was made in the first place must be discovered, and the underlying cause of that human failure must be revealed and addressed in future operations.

Human factors research can provide a means to reveal these reasons and reduce the number of aviation accidents. This study was designed to identify which human factors contribute to GA accidents. Aviation agencies, institutions, and manufacturers may be able to use this information to modify aviation education objectives and methods, aircraft design, and design of procedural systems such as communication with air traffic control.

Pilot Error

Accidents in complex man-machine systems such as GA aircraft are typically caused by a progression of events that occur in an unforseen manner or sequence. "A malevolent deity does not strike down aircraft or hurl them to the ground with a mighty blow. Accidents require the coordinated occurrence of several flawed decisions, performance breakdown or oversights" (16). It is wrong to assume that a pilot involved in an accident is ignorant, careless, or lacking in knowledge. Pilots are often intelligent and highly skilled. Lack of technical or procedural knowledge is rarely the sole cause of an aviation accident (17).

Gay (18) explains that behavior is influenced by the context in which it occurs, and analysis of the behavior demands

TABLE 1   1988 ACCIDENTS PER 100,000 AIRCRAFT hr FLOWN (7)

Type of Flying	Total Accidents	Fatal Accidents		Fatalities Aboard
	(#)	(#)	(%)	(#)
personal	1575	297	18.8	558
business	180	46	25.6	92
corporate	19	4	21.1	7
aerial application	175	11	6.3	10
instructional	337	30	8.9	56
ALL AIRCRAFT	2459	431	17.5	796

understanding of that context. Human beings have built-in physical and cognitive limitations that are not always taken into account when aircraft are designed and built. There are obvious limitations, such as limits of reach and ability to lift. Less obvious limitations include time lags in sensory perception systems and in neuromuscular response (*19*).

The human brain has greater memory capacity than the most powerful computers and the ability to correlate and use the stored data in creative ways. However, the brain is slower than its electronic counterparts, and it is "prone to some rather bizarre perceptual distortions. It can make us see things that don't exist, not see things that do exist, see stationary objects seem to move and conjure up associations that are totally inappropriate to the circumstances" (*17*).

Poor judgment, decision making, and risk-taking contribute to aviation accidents. A pilot may do something potentially dangerous many times before that behavior results in an accident. Pilots do not believe that they are taking chances when forming a bad habit; they simply do not believe that an accident will happen to them. Bad habits are reinforced when a pilot makes a mistake or does something wrong and the action does not result in an accident. A poorly trained pilot, or one who has personality traits incompatible with aviation tasks, such as aggression or low self-esteem, can likewise continue to fly for a period of time without negative consequences (*20*).

Accident Prevention Strategies

The findings of this study substantiate a statement by Hansen (*17*) in which he proposes that in order to prevent GA accidents, pilots must improve their self-knowledge; they must gain insight into their own thought processes, behavior, and personalities. Through that increased knowledge they can then improve their performance. A Royal Canadian Air Force axiom makes a good point about judgment: "A superior pilot is one who stays out of trouble by using superior judgment to avoid situations that might damn well require the use of his superior skill" (*21*). The results of this study underscore the idea that good judgment and decision making skills are critical to safe flight. Over and over when accidents happen, "the pilot is brought down not by a failure of knowledge or skill, but of judgment" (*21*).

Most aviation training is directed toward the development of psychomotor skills and to the absorption of the large body of technical knowledge necessary for safe flight. An additional dimension necessry in pilot training is decision making and pilot judgment. According to Jensen, it may not be possible to change a pilot's personality, or even to screen potential pilots for personalities incompatible with safe flight, but attitudes can be changed (*21*). Judgment and decision-making skills can be taught.

According to Melton (*22*), accident investigation has not been effective in the prevention of human factors accidents. Factors precipitating aviation accidents have not changed over the years. Increased spending or stricter regulations will not necessarily reduce accidents (*17*). In an environment where total system management is feasible, such as the military, it is possible to reduce accidents. Civilians, however, are less likely to respond to regulation because training and enforcement of regulations is not as rigorous as it is in the military.

Education and peer pressure are the most practical methods of change available (*22*).

Included in the objectives and recommendations in *The National Plan for Aviation Human Factors* are the following (*14*):

- To encourage the improvement of basic scientific knowledge and facilitate understanding of the factors, both positive and negative, that significantly influence human performance in aviation;
- To develop better techniques for the assessment of human performance in the aviation system;
- To develop enhanced methods of training and selection for aviation system personnel; and
- To develop formal procedures for evaluating human factors issues as part of every major system development and acquisition, modeled after the U.S. Army program, MANPRINT, and "Total Quality Management" programs in government and industry.

The information provided by the modified checklist (described later) can help achieve these objectives. Pilots need to be "confident of their abilities but know their limitations and [be] able to recognize and admit that they always have room for improvement" (*22*). Education is one way to reach this goal. The incorporation of a human factors checklist into NTSB procedure would increase the information available in accident reports and give flight teachers and instructors valuable tools to use in the education of safer aviation professionals.

RESEARCH PROBLEM STATEMENT AND STUDY DESIGN

The problem of this study was to identify human factors in 1988 GA accidents and to determine how often they contributed to the accidents. A checklist was used to categorize human factors as identified in NTSB 1988 GA accident reports. Answers were sought for the following research questions:

- In what percentage of 1988 GA accidents can human factors be identified from NTSB accident reports as contributing to the accident?
- NTSB assigns primary cause and contributing factors when reporting on an accident. Which of these are most frequently assigned by NTSB?
- How often does each of the human factors listed in the modified checklist contribute to GA accidents?

Fifty accidents were randomly selected from all GA accidents that occurred during calendar year 1988, and accident reports for them were obtained from NTSB. Human factors causes, NTSB primary causes and contributing factors, and demographics were recorded on an individual tally sheet for each accident. These data were summarized and evaluated.

RESEARCH METHOD—MODIFIED FEGGETTER CHECKLIST

The model for the checklist used was developed by Feggetter (*12*), a British accident investigator. Her checklist was based

on a systems approach to understanding human behavior in aircraft accidents. The purpose of the checklist was to assist investigators in identifying the more subtle human factors contributing to aviation accidents, while avoiding the use of the ambiguous description human error.

Feggetter (12) divided human factors in aviation accidents into three systems: cognitive, social, and situational. The cognitive system is concerned with how human beings acquire, store, manipulate, and use information, and is subdivided into three areas. Factors in the information-processing area include attention deficiencies, memory, judgment, decision making, and communication errors. Problems in the psychological/emotional area can arise from habits, motivation, fear or panic, complacency, and pilots' personalities. The third area involves skills and knowledge and includes problems due to training, experience, or currency deficiencies.

The social system includes pilots' perceptions of role and role conflicts and pressures from those with whom pilots interact. These include crew members, employers, family, air traffic control, and ground crew. Major personal events such as divorce or the death of a relative are also included in this system.

The situational system consists of physical, environmental, and ergonomic factors that stress the pilot. Physical condition, substance abuse, hypoxia, noise level, visual illusions, and cockpit organization are examples of factors in this system. Physical factors include lack of sleep, hunger, or substance abuse. Environmental conditions such as haze, fog, or visual illusions are included in this system. Ergonomics includes cockpit organization and placement of controls.

Feggetter's checklist (12) was modified by the author because NTSB accident reports in their final form were the sole source of information for this study, and there was no opportunity to use the more direct methods of interviews and questionnaires. Sensory perception factors were moved from the cognitive to the environmental area of the situational system, where they are designated as the acquisition phase preliminary to the thought process. Complacency was added as a factor in the psychological/emotional area of the cognitive system. In the situational system, the category of toxic fumes was added under environmental stress, and policy for dealing with emergencies was deleted from ergonomic stress. Seating and presentation of materials were combined into cockpit organization. The modified checklist is shown in Figure 1.

Validity

Copies of Feggetter's human factors checklist and the author's modified checklist were sent to five human factors experts for examination and comment. The five represented the DOT Transportation Safety Institute, Human Resources Research Division of the University of Kansas Medical Center, FAA, and human factors research.

One expert expressed concern that human factors are seldom recorded in NTSB reports. Because the purpose of this study was to identify human factors when they contributed to accidents, this reply led to speculation that results of the study might be negative. This was found to be partly true, and led the author to suggest changes in NTSB procedure.

Another expert suggested moving visual illusions and spatial disorientation from the environmental stress category to
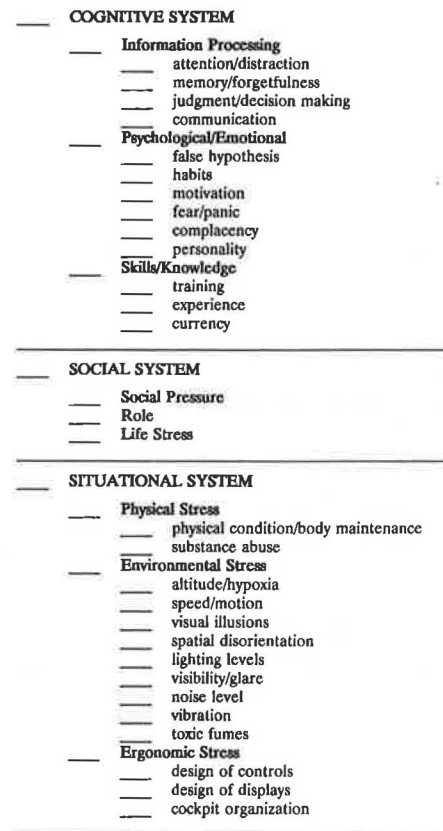

FIGURE 1 Human factors checklist.

the cognitive system. This was not done, because the author believed that these factors deal with the pilot's perception of environment and did not directly involve the thought process. A further suggestion, that crew interaction be moved from the personality category in the cognitive system to the social system, was accepted. A third expert provided suggestions for expansion of the training category in the cognitive system; other experts made several small suggestions for change. These were all accepted.

The overall response to the modified checklist was positive and lent support to the validity of the checklist as a research tool.

Reliability

Three aviation professionals (herein referred to as reviewers) were chosen to perform a reliability test. One held a Ph.D. in educational psychology and research and was past Chief of Operational Hazards Analysis Division, U.S. Army Agency for Aviation Safety. The second was an aviation ground school and flight simulator instructor, and the third was a certified flight instructor.

Five accident reports were chosen at random from the 50 selected for the study. Photocopies of the reports were made for the reviewers, who were given a joint briefing by the author on the use of the checklist and on the meanings of the terms used in the checklist. Use of the checklist by these three aviation professionals achieved very similar results. It was concluded that the modified checklist is a suitably reliable instrument.

Overall, the reviewers identified a greater number of human factors than did the author. The reason for this is that it was easy to read emotions, motivations, decisions or events into the accidents that were not documented by NTSB. It would be improper, however, to assume these factors to be present when there was no evidence of them in the NTSB reports.

Two minor changes in the checklist were made as a result of the reliability test. Judgment and decision making were combined when it became apparent that a distinction could not be made between them with the information available. The term "training" was changed to "skill/knowledge" and three subdivisions of the term were added—training, experience, and currency.

FINDINGS

Human factors were identified in 90 percent of the accidents studied. This does not mean that human factors were the sole cause of the accidents, only that they contributed to the accidents.

Using the cognitive, social, and situational systems as a basis for comparison, NTSB reports identified human factors as either probable cause of factors relating to 41 (82 percent) of the 50 accidents studied. Use of the modified checklist identified human factors as contributing to 90 percent of the accidents studied. Cognitive factors were most easily identifiable using both methods. Because this study is limited to the identification of pilot human factors, the percentage of accidents to which human factors actually contribute is probably greater than 90 percent.

Reliability

A statistical comparison was made of the number of accidents attributed to human factors by the use of the checklist and by NTSB. Chi square was used, with $\alpha = .05$. The null hypothesis was that there was no difference in the identification of human factors when using the modified checklist or the NTSB reports.

$$H_0: \chi = 0$$

The Yates correction for continuity was used because of low frequencies in the social category. The critical table value of χ^2 was 1.39.

$$\chi^2 = 0.603$$

There was no significant difference between the two methods. This outcome further supports the reliability of the modified checklist.

Sample Characteristics

NTSB reports gave an excellent overview of each accident in terms of what happened and when it happened. Human fac-

tors that contributed to these accidents were not always mentioned in NTSB's summary (primary cause and contributing factors). It was possible, though, through the use of the checklist and careful reading of pilot statements and narrative portions of the reports, to identify additional human factors as having contributed to the accidents. Frequencies of human factors identified in this study are presented in Table 2.

Human factor–induced problems in the cognitive, or thought process, area were the easiest to identify using the checklist and NTSB reports; they were identifiable in 84 percent of the accidents studied.

Flaws in mental information processing were identified as having contributed to 80 percent of accidents studied. Two primary information processing factors accounted for this high percentage; judgment/decision making at 66 percent, and attention/distraction at 30 percent. An example of the judgment/decision making area is the case of a commercial pilot who had made an initial application of fertilizer. The weather was bad—rain showers, moderate turbulence, 30-knot gusts, and forecast thunderstorms. For unspecified reasons the owner of the airplane, a private pilot, took the airplane out for the second application flight. He was not rated for the aircraft, had a waiver on his medical certificate for a prosthetic leg, and was taking medication. He crashed the airplane and died.

Distraction was a factor in an accident off the coast of Florida. The pilot took off in an amphibious aircraft from an inland airport. He noticed that the elevator trim was not working right, so he decided to make a precautionary landing on the ocean. His passengers were excited and making of lot of noise. There was a lot of distracting radio traffic, and a harbor patrol rotorcraft was flying so close to him that it was splashed by the spray when he went down. He set up his landing and habit took over; he put the gear down and finished upside down in the water.

Psychological factors were identified as contributing to 52 percent of the accidents. Deficiencies in the third area of the cognitive system, that of skills and knowledge, were present in 40 percent of the accidents. Lack of experience and currency were problems in these accidents; insufficient training was evident, but to a lesser degree.

Social system factors were positively identifiable in only one of the accidents studied. In a number of the accidents it was easy to interpolate that these factors were present, but impossible to make an objective determination of whether they contributed to the accidents. This information was not in the NTSB reports.

Some factors in the situational system were identifiable. Physical stress contributed to 10 percent, and environmental stress was present in 12 percent of the accidents. There was no way to determine whether ergonomic stress was a factor in the accidents studied.

Demographics

Pilot-in-command certification varied greatly throughout the accidents in the study (see Figure 2). Fifty percent of the accidents involved student or private pilots. Flight instructors appeared to be more likely to have an accident than student pilots, but they were in the airplane with the students. When the student messed up, the flight instructor was pilot-in-command and got credit, so to speak, for the accident. Private

TABLE 2   HUMAN FACTORS CONTRIBUTING TO ACCIDENTS STUDIED

Human Factor	Frequency[a]		
	factor (#)	area (#)	system (#)
COGNITIVE SYSTEM			42
Information Processing		40	
attention	15		
memory	5		
judgment/decision making	33		
communication error	1		
Psychological/Emotional		26	
false hypothesis	14		
habits	5		
motivation	3		
fear/panic	2		
complacency	13		
personality	1		
Skills/knowledge		20	
training	7		
experience	15		
currency	10		
SOCIAL SYSTEM			1
Social Pressure		1	
Role		0	
Life Stress		0	
SITUATIONAL SYSTEM			10
Physical Stress		5	
physical condition/body maintenance	4		
substance abuse	2		
Environmental Stress		6	
altitude/hypoxia	0		
speed/motion	1		
visual illusion	0		
spatial disorientation	2		
lighting levels	3		
visibility/glare	1		
noise level	0		
vibration	0		
toxic fumes	0		
Ergonomic Stress		0	
control design	0		
display design	0		
cockpit organization	0		

[a] The numbers presented in this table add up to more than 50 because frequently more than one factor contributed to an accident.
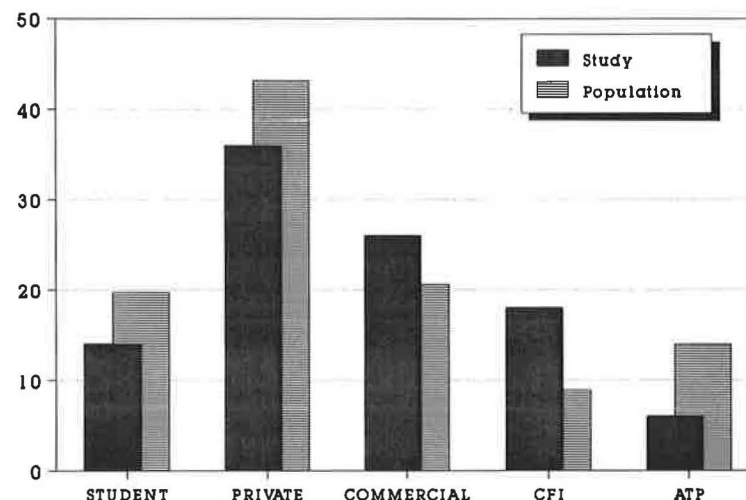

FIGURE 2   Flight certificate held.

pilots had many accidents, although the percentage of private pilots who had accidents was lower than the percentage of private pilots in the population at large. No certificate area was immune from having accidents.

The number of flight hours, an indicator of pilot experience, ranged from 18 to 20,000, with a mean of 3,055 and a median of 1,400. Peaks in the accident rate occurred at both low- and high-experience levels. Forty percent of the pilots in the sample had 1,000 to 5,000 flight hr, indicating substantial experience.

Of the 50 accidents studied, four pilots held a first class medical certificate, 23 held a second class, and 20 held a third class. Three of the pilots had no current medical certificate.

Forty-six pilots involved in the study were men and four were women. This distribution was not significantly different from the 1988 active pilot population, in which 94.2 percent were men and 5.8 percent were women. Sex was not a factor that affected the likelihood of having an accident. Data on pilot age and sex were compared with pilot population data using chi square, $\alpha = .01$.

Pilot ages are shown in Figure 3. The mean and median age of the pilots-in-command in this study are the same, 44 years. Ages ranged from 21 to 78. The ages of pilots who had accidents differed significantly from the age distribution of pilots active in 1988. Pilots between the ages of 40 and 54 had the highest accident rate compared with the pilot population. This ties in with the large number of accidents over 1,000 hr experience, and could be for a variety of reasons. Pilots under 40 may be in better physical condition, may be more current in their training, or may have been more affected by educational changes and safety programs than older pilots. It could be that pilots in the 40 to 55 age group have been flying a while and are getting complacent and too relaxed in the cockpit. Also, in that age group there are a lot of professionals with a fair amount of money. They may buy an airplane that is more complex than they are ready to handle. These pilots probably do not have enough time to stay current, flying maybe once a month.

Forty-six of the 50 accidents occurred during visual meteorological conditions (VMC). Of the four that took place in instrument meteorological conditions (IMC), only one pilot (the one that survived) was instrument rated and had filed an

IFR flight plan. VMC does not always mean good weather. There can be adverse conditions, thunderstorms in the area, that are not necessarily identified as IMC.

Out of the 50 accidents, 42 pilots did not file flight plans. Five pilots filed visual flight rule (VFR) flight plans, and three filed IFR flight plans. It is important to note that some pilots were doing touch-and-go landings or practicing near their home airports, but a large number of them were on cross-country flights.

The same trend shows up in weather briefings. Forty of the pilots either did not obtain a weather briefing or the source of their weather information was unknown. Of the remaining pilots, eight received flight service station briefings and two got information from television weather.

Of the 103 persons involved in the accidents studied, 49 were passengers, 2 were crew, and 2 were outside the aircraft. Fifty-five were uninjured, 12 sustained minor injuries, 18 were seriously injured, and 18 died. Twelve of the aircraft were destroyed, and 38 were substantially damaged. The high survival rate is due in part to the fact that GA aircraft are built to withstand a lot of crash stresses. The cockpit area stays pretty much intact. It also indicates that maybe there is some benefit from all the times that flight instructors pull the power and ask, "You just lost your engine—what are you going to do?" That type of education helps people stay in control during emergencies and makes many emergencies survivable.

CONCLUSIONS AND RECOMMENDATIONS

Suggested Further Research

Additional research into how human factors contribute to GA accidents is needed. The results of this study suggest several areas of further research, including replication for 1988 and more recent years.

There is need for research into the areas represented by the social and situational systems, as described by Feggetter (*12*). Little information was available about how human factors in these areas contributed to accidents.

Many studies have been done on human error and how the human brain recognizes and deals with error. This information needs to be correlated with current human factors knowledge.

Finally, there is need for the development and testing of a checklist to be used during the investigation of GA accidents. The checklist used in this study, in addition to Feggetter's checklist (*12*) and a Canadian checklist, which were designed for use during accident investigation, could be used as a basis for an improved GA accident investigator's checklist.

Implications of the Results

The results indicate a need for addition to aviation curricula in a number of areas, including judgment and decision making, distraction and attention overload, and self-knowledge. Education can improve a pilot's self-awareness of dangerous attitudes and habits and give the pilot important tools to use in making safe flying decisions.
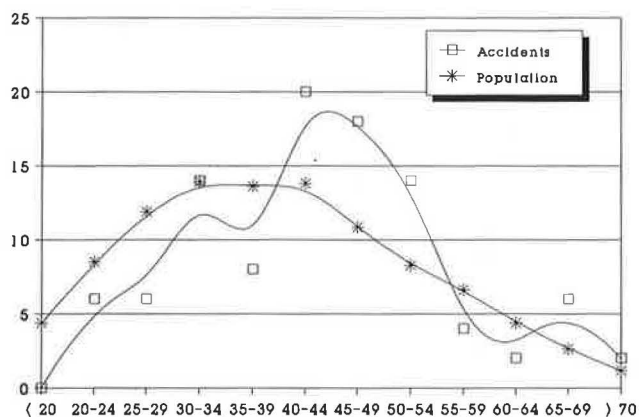

FIGURE 3 Pilot age.

Education can also be improved in attention/distraction. Pilots can be taught better scanning technique for use both inside and outside the cockpit. They can learn methods for reducing and coping with distraction. For example, the pilot who put down his gear for a water landing could have forcefully told his passengers to be quiet. He could have briefed them before takeoff that he was in charge. He could have turned off the radio to reduce the noise level. These actions might have enabled him to, first of all, fly the airplane.

Research into cockpit design and instrumentation and better cockpit management techniques are needed. Well-organized pilots will not spend time digging around looking for a chart or approach plate.

Pilots must somehow be made aware that accidents can happen to them; this awareness should lead to a decrease in complacency. Self-knowledge of their own personality factors, and counseling when appropriate, can aid pilots in flying safely.

Human factors in the social and situational systems that might have contributed to GA accidents were not readily identified using NTSB reports. Problems in these two systems are of the type that short-circuit the brain's error-detecting and correcting capabilities. The use of a human factors checklist by accident investigators would aid in developing a clearer picture of what went wrong in each accident. Interviews with pilots, crew, passengers, family, business associates, and witnesses, when appropriate, would add valuable insight into the human factors causes of the accidents. Information thus gained needs to be documented in an easily retrievable format, such as a checklist. It then could be used to modify pilot training and aviation systems development to reduce the accident rate.

NTSB reports miss key elements in the chain of events that ends in an accident, and often the flight crew is assigned responsibility for the accident. The limited scope of these reports reduces the likelihood that other factors will be detected. Factors that are not identified cannot be managed. Incorporation of a checklist into the accident investigation procedure would be a step toward identification of more, if not all, of the human factors contributing to aviation accidents. Everything that contributes to an accident needs to be identified and reported in a form that can be used and analyzed so that changes can be made.

SUMMARY

Aviation accidents are caused in part by a mismatch between the human performance envelope and aircraft/aviation systems. It is not a question of whether accidents are caused by this mismatch. Rather, it is a question of where the breakdown is occurring, and how often.

Pilots can be taught to break the chain of events that leads to accidents, but first educators must have a more complete definition of the human performance envelope. Educators need this fundamental information to teach pilots what to do and how to do it.

Accident investigation has not been effective in preventing human factors accidents because it is not providing the kind of information needed to combat this type of accident. Increased spending or stricter regulations are not the answer.

FAA passed a regulation requiring fuel reserves—but pilots still run out of fuel.

It is critical to have better identification or documentation of human factors by NTSB. Without information about exactly what is happening, not a lot can be done to build the necessary curriculum changes. The inclusion of a human factors checklist in the NTSB's accident investigation and reporting procedure can be a major factor in improving the aviation education system.

REFERENCES

1. J. L. Ethell. *NASA and General Aviation*. Report NASA SP-485. Scientific and Technical Information Branch, National Aeronautics and Space Administration, 1986.
2. *Administrator's Fact Book*. Federal Aviation Administration, U.S. Department of Transportation, 1990.
3. *Highlights from the General Aviation Reference Guide: General Aviation—America's Airline (1987)*. Aircraft Owners & Pilots Association, Frederick, Md., 1987.
4. *General Aviation Activity and Avionics Survey: Calendar Year 1988*. Federal Aviation Administration, U.S. Department of Transportation, 1988.
5. R. D. Campbell. *Flight Safety in General Aviation*. Collins Professional Books, London, 1987.
6. M. L. Ritchie. General Aviation. In *Human Factors in Aviation* (E. L. Wiener and D. C. Nagel eds.). Academic Press, San Diego, Calif., 1988, pp. 561–590.
7. *National Transportation Statistics Annual Report*. Report DOT-TSC-RSPA-89-A. Research and Special Programs Administration, National Transportation Safety Board, U.S. Department of Transportation, 1990.
8. *Annual Review of Aircraft Accident Data: U.S. General Aviation Calendar Year 1987*. Report PB90-138066 NTSB/ARG-89/01. National Transportation Safety Board, 1989.
9. J. McClellan. We're Better Pilots. *Flying*, April 1990, p. 32
10. *Product Liability: Unfair Tort Laws Devastate a Vital American Industry*. General Aviation Manufacturers Association, Washington, D.C., 1991.
11. R. B. Stone, G. L. Babcock, and W. W. Edmunds. Pilot Judgment: An Operational Viewpoint. *Aviation, Space, and Environmental Medicine*, Vol. 56, 1985, pp. 144–148.
12. A. J. Feggetter. A Method for Investigating Human Factor Aspects of Aircraft Accidents and Incidents. *Ergonomics*, Vol. 25, 1982, pp. 1065–1075.

13. D. D. Engen. The Airplane Accident and You. *American Bonanza Society*, Oct. 1989, pp. 2355–2356.
14. *The National Plan for Aviation Human Factors* (draft). Federal Aviation Administration, U.S. Department of Transportation, 1990.
15. J. J. Nance. *Blind Trust*. William Morrow & Co., New York, 1986.
16. R. O. Besco. Why Pilots Err: What Can We Do About It? *LPBA Journal*, Summer 1990, pp. 30–33.
17. P. E. Hansen. The Human Factor. *AOPA Pilot*, March 1980, pp. 117–122.

18. L. R. Gay. *Educational Research: Competencies for Analysis and Application* (2nd ed.). Merrill Publishing, Columbus, Ohio, 1981.
19. G. Ellis. *Air Crash Investigation of General Aviation Aircraft*. Capstan Publications, Greybull, Wyo., 1984.
20. W. A. Wagenaar and J. Groeneweg. Accidents at Sea: Multiple Causes and Impossible Consequences. *International Journal of Man-Machine Studies*, Vol. 27, 1987, pp. 587–598.
21. Judgment Daze. *The Aviation Consumer*, Nov. 1, 1984, pp.13–14.
22. C. E. Melton. Why Humans Err. *Air Line Pilot*, Jan. 1990, pp. 26–29.