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This award is given for outstanding contributions to technical excellence in accident investigation. Not more than one award will be made annually and presentation is at the ISASI Seminar. The recipient is selected by an ISASI Board of Award.

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This award is one of the most significant honors an accident investigator can receive, and so considerable care is given in determining the recipient. Each ISASI member should thoughtfully review his or her association with professional investigators, and submit a nomination when they can identify someone who has really been outstanding in increasing the technical quality of investigation.

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The Annual Seminar of the International Society of Air Safety Investigators (ISASI) will be held in Montreal from 24 to 27 September 1979.

Authors wishing to present a paper are invited to submit a 200-300 word abstract. Abstracts must be received by 30 April 1979, and final papers by 31 August 1979. Papers preferable should be presented in English, French, or Spanish.

The theme of the Seminar will be "THE INVESTIGATOR'S ROLE IN ACCIDENT PREVENTION" but presentations on other topics will be considered.

Abstracts should be mailed to:

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Allen R. McMahan (l.) Program Manager, Technical Projects and Fleet Support, Sabreliner Division, Rockwell International, receives the 1978 Award from Jerome F. Lederer.

Helicopter Pilots Do It Better

A
Presentation On The Human Factor Aspects Of Helicopter Accidents

Jerry T. Dennis
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The views expressed by the author do not necessarily reflect positions taken by the National Transportation Safety Board

Several years ago Harry Reasoner published a short dissertation on helicopter pilots that has been widely circulated within the rotary wing community; it is entitled, "Helicopter Pilots Are Different," and goes like this:

> "The thing is, helicopters are different from planes. An airplane by its nature wants to fly, and if not interfered with too strongly by unusual events or by a deliberately incompetent pilot, it will fly. A helicopter does not want to fly. It is maintained in the air by a variety of forces and controls working in opposition to each other, and if there is any disturbance in this delicate balance the helicopter stops flying immediately and disastrously.
>
> "There is no such thing as a gliding helicopter.
>
> "This is why being a helicopter pilot is so different from an airplane pilot, and why in general, airplane pilots are open, clear-eyed, bouyant extroverts, and helicopter pilots are brooders, introspective anticipators of trouble. They know if something bad has not happened, it is about to."

Those words hold a far greater meaning for me now than when I read them some years ago.

During the 15 years that I have been flying fixed and rotary wing aircraft, I have accumulated several thousand hours. I, as you, have seen many competent aviators lost in tragic accidents. In 1970, I began probing accidents professionally with the idea that pilots can't make that many mistakes.

In the ensuing years with the military and the National Transportation Safety Board, I estimate that I have investigated approximately 350 accidents, and at least 150 have been helicopters. And, as we all have found, the pilot is the primary factor in most accidents. This paper is being written because of the on-going criticism of rotary wing investigations currently being conducted. Hopefully, it will assist investigators in understanding the human factors aspects of helicopter investigations; thus improving the quality of their reports. This does not negate the need to upgrade the technical knowledge of investigators that might be required to participate in rotary wing investigations. The FAA offers a very good course in Helicopter Familiarization and the University of Southern California presently hosts an excellent two-week short course in Rotary Wing Investigation. Publications such as *Rotor* and *Wing* and membership in societies such as "The American Helicopter Society" (AHS) and the "Helicopter Association of America" (HAA) provide a continual update of the current state of the art. Mr. George Saunders, a member of ISASI, has published an excellent book entitled, *Dynamics Of Helicopter Flight.* It makes a very good reference book, uses high school math and is easy to follow. Gessom & Meyers' *Aerodynamics Of The Helicopter* is more suited to the engineer or student of aerodynamics. It too is an excellent reference book. These are only two of many excellent publications that investigators need to have in their libraries.

Every presentation must have statistics. I shall not disappoint you; I, too, have accumulated some data from current statistics. These statistics are taken from the NTSB Briefs of Accidents Involving Rotorcraft,[5] for the years 1974, 1975, 1976, and the HAA Safety Bulletin 3-78, dated 20 February 78, entitled, "Helicopter Accident Statistics[3]." HAA, an international organization having over 600 members in more than 40 countries, gives more of an international flavor to these statistics; but it must be emphasized that most of the members are corporate or air taxi operators, thus the data is not complete. The NTSB data does not include all public aircraft where the HAA data does include some public use operations. Additionally, the NTSB included all classes of rotorcraft; i.e., gyrocopters and autogyros where the HAA is concerned with helicopters. Additional data has been obtained from the FAA and the U.S. Army Agency for Aviation Safety (USAAVS). The Army principally because they are the largest military user of helicopters. In 1974, the NTSB reported that there were 284 rotorcraft accidents; FAA data for that year indicates that there were 3,100 rotorcraft in the United States. Data for 1976, yielded 273 rotorcraft accidents with a population of 3,800 rotorcraft. This number of accidents is small when you consider the 4,000 plus general aviation accidents that occurred during each of those years. The total number of rotorcraft also appears insignificant when compared to the estimated 1976 general aviation fleet of 168,500 aircraft (including rotorcraft). This data indicates that approximately 8% of the rotary wing fleet is involved in an accident annually versus less than 2.5% of the general aviation fleet. However, while rotary wing aircraft comprise only 2.2% of the total general aviation fleet, they account for over 4.7% of the total flight hours. All this means is that the average helicopter flies more hours annually per aircraft than fixed wing aircraft.

The traditional method of presenting accidents is number of accidents per given hours flown. The HAA data, which is based on 10,000 flight hours, gives the rate and total number of hours flown for the years indicated.

Year	Rate/10,000 hours	Total Hours Flown
1976	1.49	1,706,973
1975	1.89	1,546,520
1974	1.81	1,424,310

These rates are over three times higher than the fixed wing air taxi rates during the same years, and as a comparison, in 1976, the U.S. Army helicopter accident rate was .65 per 10,000 flying hours. However, in my opinion this is like equating apples and oranges. The traditional fixed wing method of using flight hours as a unit of measure does not give an accurate measure of exposure for helicopter operations. Helicopters have many more takeoffs and landings per hours than fixed wing aircraft. I think if a comparison were made of the number of sorties conducted, the helicopter would be very competitive with air taxi statistics.

Before we leave the world of the statistician there is one other area worthy of consideration. For three years covered by the NTSB Briefs, there were 869 rotorcraft accidents; in over 88% of those accidents the pilot held at least a Commercial Pilots Certificate. This means that a considerable number of highly skilled professional pilots are involved in helicopter mishaps. In fact, NTSB data indicates that the pilot was a factor in 70% of the 1976 rotorcraft accidents.

The Pilot

From the previous paragraph it appears that professional helicopter pilots are the cause of their own demise 70% of the time. Are they highly trained professionals? I believe they are. Lets look at the "average" pilot involved in an accident. A personal evaluation of the briefs for the years 1974 through 1976 revealed some very interesting information. The first thing that it revealed was that there was no average pilot. The Vietnam conflict created a tremendous number of pilots in a very short time. These pilots are generally in the same age group and came into the public sector at approximately the same time. This is borne out by the research that indicates in 1974, 26 year old pilots were involved in accidents more than any other age group. In 1975, age 27 was the highest; 1976 age 29 (28 was the next highest) and preliminary data for 1977 shows 29 with a slight lead. Of course the age group indicated, presently 26 thru 32, probably comprises the majority of the helicopter pilots available which would have the greatest exposure. Another result of the Vietnam conflict is the high number of flight hours gained by many individuals during each tour. This, coupled with alternate tours as instructor pilots, resulted in a very high flight time for relatively young pilots. A great amount of experience in a short period of time. However, most of that experience was gained in a wartime environment where the emphasis is on accomplishing the task, no matter what the cost. Aircraft and men are expendable. A can–do attitude existed with individualism encouraged. The Vietnam helicopter pilot was a "free spirit," a throw back to the fighter pilots of the First World War when it was just the pilot and his machine. In fact, it is easy to equate the operation of a modern scout or attack helicopter to the individual combat of yesterday. The thrill of the encounter is there–it is up front and personal.

Perhaps the key word is "discipline" or more specifically self–discipline. In many accidents we can readily see where a lack of self–discipline directly contributes to the sequence of events. The young undisciplined aviator is given a machine with which he can express himself, and he enjoys it. In the past that was true; it is true now. This is heightened by a wartime environment where innovation is a necessity and cost no factor. Habits and attitudes develop. As Chaytor Mason[4] has stated in his paper "Manhood Versus Safety," pilots have an urge to express their "manhood" by flying dangerously. While training may control this urge, it does not destroy it. It is interesting to note that accident rates decreased in the Army after the Vietnam conflict when increased emphasis could be placed on training and management. Was the decrease a result of forced self–descipline? Increased surveillance? Or was it just a result of changing the environment?

The helicopter industry is very seasonal which results in an instability from a lack of permanent full time employment. From my own observations, I have taken note that many of the "seasonal" pilots are single, usually divorced and of necessity, nomadic in nature. They are individualistic and proud. They not only think they are good, they know it! The sad part is that they are right. They are good, and they will do their utmost to please the customer. In many cases this results in a considerable amount of pressure being applied by the customer when he indicates he wants to land next to the objective or indicates that another pilot last season was able to land at a more hazardous, but closer location. This is a stress that very seldom will be documented in an accident; but I would say that a significant number of accidents are directly attributable to this.

The Machine

In light of pressure applied by the customer, perhaps it would be proper to enter into a discussion on the machine and how it affects the pilot. As Harry Reasoner pointed out–a helicopter does not want to fly, in fact, it can be said that it is an inherently unstable device that requires constant attention. The control system, utilized in conventional helicopters, requires the use and coordination of both the hands and feet. The left hand must manipulate the collective and throttle while the right hand directs the motion of the cyclic. Obviously, it would be quite difficult to operate a microphone, so a headset and boom mike are provided, naturally, operated by one of the many buttons placed on the cyclic. In a way this is a boon; the headset does help attenuate the noise.

As you have probably already surmised, helicopters are flown primarily by kinesthetic feedback, or seat of the pants. Certainly, the more expensive machines are equipped with full IFR instrumentation and autopilots, but they cost well over a million dollars. The average machine is a light utility helicopter flown by a single pilot with a minimal amount of instrumentation. In comparison to fixed wing, the constant attention required to operate a helicopter increases that illusive factor, fatigue. By how much? Two, three times–it is difficult to say but it is definitely there. Helicopter pilots compensate partially by relaxing at every opportunity because while they are flying they are forced to assume an unnatural slump so that they can effectively manipulate the controls. According to a Canadian Surgeon, Major Ron Goede, research has indicated that 87.5% of the helicopter pilots investigated, all of whom had more than 500 hours, suffered from a lower back pain while flying. I know of very few helicopter pilots that do not have some back pain. In fact, like the fighter pilot's disease, it is accepted as being a part of the industry. This backache problem is intensified by vibration, and vibrations are ever present in the world of the helicopter pilot. One per rev, two per rev, high frequency, medium frequency; they are the norm and accepted. In fact, it is amazing that the abnormal vibration is noted at all when you consider the number of basic vibrations and harmonics that exist in helicopters. Manufacturers have spent millions of dollars in research reducing the vibratory characteristics of their machines and the research is bearing fruit. The new generation machines are surprisingly free of vibration; but the current machines are still with us and will be for many years to come.

In an earlier paragraph I touched on noise. Needless to say, helicopters are noisy; in fact, the helicopter pilot is bombarded by noise. This noise may come from the main rotor with its low frequency beat to the whine of a compressor shattering the air at 60,000 rpm. The intensity may be as high as 128 decibels which is only sligtly less than the din of a discotheque. Considering the given condition, it would be difficult for an individual to work for even a short period of time, much less a prolonged exposure. But the human body is adaptable; the vibrations are accepted and headset attenuates the noise to an acceptable level. But what effect does this have on the decision making process? Dr. Martin Allnutt[1] states that man has only a single decision channel and *all* information must be passed through this channel. Further, it does not matter where the message comes from; the eye, the ear, seat of the pants, or instinct. Man can still only attend to one thing at a time. In addition, E. C. Poulton[6] states in his book, *Environment and Human Efficiency,* that it is not possible to make two decisions simultaneously and that decision errors increase with the number of displays that must be monitored. How does the constant bombardment from noise and vibration affect the actions of the lone helicopter pilot? How hard is it to interpret a vibrating instrument? Or do you even bother trying? In some cases you don't, you must react to movement without interpretation. A number of helicopters have been involved in accidents when the only problem found was the failure of the engine tachometer. But the pilot was reacting to a conditioned response that was brought about because of the absolute necessity to react to an emergency situation and a lack of available information, sometimes due to the environment. In this book, Poulton relates a test where, "Control of the simulated aircraft during one-half hour immediately after the vibration was found to be reliably worse than control during one-half hour immediately before the vibration."

I am not going to comment on noise and its effect other than to say that it is fatiguing, irritating, and distracting. Communication without headsets is impossible in some helicopters. Additionally, hearing loss is a common occurence among helicopter pilots; in fact, one may be able to generally identify the type of equipment flown by an individual, just by the nature of the hearing loss.

In addition to all of this, the helicopter pilot must cope with a variety of equipment. Turbine, recip, some you fly on the left side, some the right side; even others from the center. The main rotor blades turn one direction on American helicopters, the opposite for European; thus necessitating an opposite anti-torque response. Not important some say; just keep the nose pointed in the desired direction. However, old habits have been known to come forward in times of stress and the two systems require different responses; documented in an accident? Seldom. Add to this, a lack of standardization in instrumentation, control placement; i.e., auxiliary switches on cyclic and collective, and even terminology. A very confusing state of affairs indeed, yet seldom identified as a factor.

Unfortunately, the machine itself has not proven to be the most reliable. In 1976, the powerplant was a cause/factor in 19.64% of the mishaps according to NTSB statistics; with main or tail rotor difficulties accounting for an additional 12.82%. However, the powerplant was involved in 30.77% of the first type accidents as recorded by the NTSB.

HAA data closely correlates with the powerplant being involved in 31% of the mishaps and "material failure/malfunction" being involved in 14% of the mishaps. Let's look at this powerplant failure a little closer. For the three year period being used, '74-'76, the NTSB recorded 242 powerplant malfunctions that ultimately resulted in an accident. If there was an engine failure or malfunction, and a successful autorotation was accomplished with no damage, then there is no accident. In any event, over 27% of these "powerplant" related accidents were in aerial application, cropdusting, etc. This is something I want you to remember when the environment enters the picture later.

Just because the engine quits we don't throw up our hands and crash by the numbers; we still can perform an "autorotation." I am not going to get into a technical discussion of an autorotation in this presentation. However, it suffices to say that the aerodynamic characteristics of the rotor system makes it possible to store and use energy in the dissipation of forward airspeed and vertical velocity. Mr. Saunders presented a paper during the sixth annual ISASI Seminar entitled, "Autorotations and Their Influence on Helicopter Accidents."[8] In that paper he goes into the various factors influencing an autorotation. It is interesting to note that the average success ratio for the study period was 1.12 to 1. Generally, for every autorotation that was successful (no damage) one was unsuccessful. However, as Saunders points out in this paper, the Air Force and Navy enjoyed a higher success ratio due to their environment; i.e., higher operating altitude and general terrain conditions. These are factors that must also be considered in the investigation of civil helicopter accidents. If the engine quits over a 10,000 acre forest with 100 foot trees, there is going to be an accident. However, the pilot involvement, if any, is going to have to be a judgement decision on your part as to whether you think he reacted properly. In fact, terrain is the third highest factor noted during the period being evaluated according to HAA statistics. NTSB statistics differ indicating that terrain is the second highest contributory factor in accidents (34.07% in 1976). The difference between the statistics is not important; the important factor is that terrain plays a significant role in helicopter accidents.

One area where helicopter manufacturers have excelled is in crash worthiness. As a "starch wing" friend of mine said, "They have had a lot of examples to look at." Possibly so, but from a human factors point of view, helicopter manufacturers, promoted by the U.S. Army, are leading the field in seat design, fuel containment, and container survivability. This is important to a pilot and his passengers, but marketing personnel have not yet gotten to the point where they will advertise potential survival as a selling point. In fact, quite obviously they would rather not discuss the possibility of a crash.

No paper on human factors would be complete without some mention of visual illusions. The same visual illusions that affect fixed wing operations have an effect on rotary operations. There is, of course, the advantage that the helicopter pilot has in being able to slow his machine so that he has more time to evaluate the situation. However, many approaches are made to an unknown area or to a potentially hazardous area; this also must be evaluated when considering the accident. One unusual phenomenon that does occur more frequently in helicopters than fixed wing is Flicker Vertigo. This normally occurs on a clear day where the rotation of the rotor blades breaks up the sunlight coming into the aircraft. The flicker thus created stimulates brainwave activity which may result in a Grand Mal seizure. Documented occurrences of this are rare and significantly only in crew served aircraft.

The Environment

The helicopter is an extremely versatile tool that is capable of going up, down, left, right, forward, and backward. You can hover above a specific point or land on a mountain peak. This versatility makes the helicopter an exciting machine to fly; but as I have previously indicated, some operations will be over very inhospitable terrain. This specialization makes the cost of operation very high, thus making rotary wing operators competitive with other modes of transportation only when the unique characteristics of the helicopter can be used to advantage. However, only in a very few applications does the pilot for a helicopter operator enjoy the stability of a home life as does his fixed wing air taxi brethren. Normally, the helicopter pilot is out on contract for a few months, then back home, out for a few more, then back again. This continues throughout the year if the pilot is fortunate enough to be employed by a firm that has a number of year-round contracts and he has enough seniority to stay on during the off-season. If not, he may go with another operator in another state or even another country flying different types of equipment and performing different tasks as he goes. Even within one organization it is not uncommon to be qualified in several types of aircraft and perform different tasks on different days. Let's go into these two areas a little deeper. First, the type of operation.

Airline Operations–Presently there is a very limited number of scheduled helicopter operatons. Quite obviously there would be considerably more stability than most of the other type of operations. Unfortunately, there has been limited success with scheduled helicopter airlines.

The Offshore Operations–This is a steady, planned operation where the pilot can develop considerable expertise and seniority. Living conditions are generally good and the equipment of good quality as a result of the customer desires. Weather conditions are the main limiting factor.

The Corporate Operator–The pilot is the chief cook and bottle washer. Normally there is some security and only a set distance to go with a return to home each night. It has been said that the type and condition of the equipment reflects the importance the company places on the individuals being transported. The same thing can be said about the pilots' position within the company and the way he is treated.

Logging–A demanding task with specialized aircraft. Normally conducted over adverse terrain but with two pilots in a well-maintained machine having considerable backup. A highly skilled pilot is required with specialized experience. Some aircraft are modified so that you can look out the left side through bubble doors, even the instruments are placed in the door. Fatiguing? I would say so.

Aerial Application–The use of helicopters in aerial application is becoming very common and will increase in the future. The helicopter is unique in its ability to dispense products and have the rotor wash insure near complete coverage on the ground. The operations are hazardous.

Air Taxi–The medivac, local charter operation that normally takes place in the vicinity of the home base or base of operations. In certain cases, fire season, the pilot might be gone from his home for several months at a time.

Bush Operations–Field sites operating from tents or if you're lucky a motel. The crew moves with the party until the contract is concluded; then may go on to another contract or go home. During the season every available hour is used. I know one individual that flew an average of 200 hours a month for the three month season, and performed most of his own maintenance.

Another area that is gaining rapid acceptance is I.F.R. operations. Presently some operators have I.F.R. authority with two pilots in specific areas approved by the F.A.A. However, more helicopters are being approved for single pilot operation with massive application of electronic aids and automatic stabilization equipment. These I.F.R. machines will be used to a greater extent in the coming years, especially when the unique characteristics of the helicopter are realized in the realm of instrument operations.

Now the Second Part, *The Job*–One month the pilot may be hauling drill bits in a Bell 212 in support of an oil field operation in South America, then two months later be flying a Hiller 12EJ3 returning choker cables supporting logging in the Northwest. Different tasks, but not that different. However, the next day he might be required to sling concrete to a mountain construction site. Now, we have a different job entirely. A task that requires precision placement and control touch. Additionally, some external load operations require the use of a mirror so that the pilot can look under the aircraft. Yet others require you to look straight down on the left side of the aircraft. A definite problem in visual perception. Long line operations require yet another sling skill that is completely different. In general, it must be said that to survive, the helicopter pilot must adapt to his environment, be very flexible in his job skills and be mobile. Perhaps, this last factor accounts for the high divorce rate among helicopter pilots.

In most operations, the helicopter pilot is his own boss when he is on the contract. This independence or lack of higher authority in the immediate vicinity probably accounts for a considerable number of accidents. In fact, it must be pointed out that 25% of the engine failure mishaps previously documented were pilot induced due to fuel exhaustion, mismanagement or starvation, according to FAA statistics. Discipline? That word again. In his summation to a presentaton at the 15th Joint Services Aviation Safety Conference, Gerard M. Bruggink indicated that there must be "a deliberate attempt to increase human reliability through character assurance." If a given standard could be found or at least an effort put forth, then the self-discipline problem might be controlled to some degree. More emphasis must also be placed on the continued training and evaluation of pilots throughout the season, and decrease the reliance on experience based on "flight hours." Reliability is a key factor in the reduction of helicopter accidents when you consider the independence afforded a great number of helicopter pilots while on contract.

People tend to think that helicopters can land anywhere, with anything, at any time. Unfortunately, the same laws of physics that are used to explain the flight of a helicopter are used in the analysis of the accident. The planning is quite detailed and the coordination absolute when a heavily loaded helicopter begins an approach to a pinnacle on a hot summer day. The pilot must bring his machine to zero forward speed and arrive at the point of landing at the same time. Turbulence, winds, effects of rotor wash . . . all these must be evaluated continually by the pilot and *he* must decide; there is no one that can advise him. If he errs in judgement or his experience cannot carry him through; we have an accident. In this light, what steps did the operator take to insure that the pilot was proficient in this type of operation? Helicopters are expensive, with operating costs of $500 to $600 per hour, some costing $2000 or more, and at this time there are no simulators in the civilian sector. Can an operator afford a training program? Just how much actual training can an operator afford and still be competitive? Unfortunately, I have investigated too many accidents where the pilot received his training in the machine enroute to the job site or shortly after arrival. The operator is the entreprenuer that must risk the money and compete for a profit in a very competitive market with high stakes. The costs of the machines being used vary from $50,000 for a used recip to over $200,000 for a Bell 206L or Hughes 500D; then up to $1,400,000 for IFR 212 or the new S-76. It is difficult to have an operation with only one or two aircraft; if one machine goes down for an extended period then the contract may be lost. The active season is relatively short and intense. Training is next to impossible in a small operation and adequate maintenance can be prohibitive; therefore, helicopter operators tend to be relatively large. Still, the overhead is high and the first accident is paid for by the insurance, so the temptation is there to cut corners in maintenance, operations, and training. As in all businesses, the non-revenue areas are the first to be cut back when business slows. As a result, good mechanics are hard to keep as they also are looking for positions with greater security.

Wire strikes are interesting phenomena of the helicopter accident. Why so many in such a maneuverable aircraft that has such great visibility? Primarily because helicopters have limited endurance and make frequent stops at unlikely locations; therefore, the exposure is extremely high. To emphasize that point it must be pointed out that once again aerial application had more than its share of wire strikes; 41 out of the 88 recorded during the three year period being evaluated. Of those 41, only *one* occurred during takeoff or landing; the remaining 40 occurred either while performing the work or enroute. That data does not include crop strikes. For the remaining 47 strikes, 25 of those occurred during takeoff or landing. It appears that aerial application gets more than its share of accidents due to wire strikes and engine failures. Both types of accidents can be attributed to the low level operation. Obviously the wires are near the ground creating a hazard, and an engine failure that low to the ground is well inside the H-V curve and will almost always become an accident statistic.

Not much has been mentioned about the mechanic and his role, but environmental working conditions for mechanics ranges from excellent at a fixed base operation to terrible at a bush site. This can definitely be a factor which is seldom considered even when maintenance is identified as a factor in the accident.

In the near future, it appears that there may be a shortage of qualified helicopter pilots. As pilots have grown older they have gravitated towards the positions of responsibility or into areas of the industry that offer greater security. Some, however, tire of the seasonal work and are unable to find the satisfaction and security they desire so they leave the industry and find steady employment elsewhere. The pilot shortage that appears to be on the horizon is exactly the opposite of the condition in previous years when there was considerable surplus and operators could pick and choose. In fact, some operators held this out as a threat to the pilots in that they could always find someone to do the job, a tremendous psychological pressure that is very effective. To add to this, industry sources estimate that the helicopter market will double in size in the next six years. With the pilot shortage coming up, I am sure that there will be some economic adjustments that will occur in the industry; but there definitely will be more inexperienced pilots entering the market. This same type of situation has occurred in the fixed wing community, but normally is overcome by the law of supply and demand. However, not many neophyte pilots can afford the high cost of a commercial helicopter certificate, and at this time the monetary benefits are not enticing nor is there the "glamour" associated with the airline industry.

In conclusion, I again would like to emphasize that this is a general overview of the helicopter pilot. I have not gone into any of the technical aspects of investigation or any of the many emergencies that the helicopter pilot may encounter. They would be more adequately covered in a technical course of investigation. I hope that you now have some feel for the environment of the helicopter pilot and why I say, "HELICOPTER PILOTS DO IT BETTER."

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Why Doesn't Aircraft Accident Investigation Prevent Accidents?

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The Ideal

The profession that we are involved in has as the ideal the prevention of accidents. To be precise, the International Civil Aviation Organization states in its *Manual of Aircraft Accident Investigation* that:

> "The fundamental purpose of inquiry into an aircraft accident is to determine the facts, conditions and circumstances pertaining to the accident with a view to establishing the probable cause thereof, so that appropriate steps may be taken to prevent a recurrence of the accident and the factors which led to it." (1)

The same premise is incorporated in the policies of the National Transportation Safety Board (NTSB) and the United States military services. The objective of the safety investigation is prevention. (2)

The Reality

The truth of the matter is that virtually all of today's aircraft accidents occur as a result of a repeated cause. A cause or causes that have perpetuated for a long time – the continuation of a previously recognized cause, commonly referred to as a *known precedent*. McDonald and Barnhart presented a paper at last year's International Society of Air Safety Investigators (ISASI) annual seminar that included an example of the repeat accident:

> "...we have not learned from our past accidents. In December of 1972 a DC-9 took off in heavy fog at O'Hare International Airport and struck a Convair 880 taxiing across the runway. In March of 1977 a B-747 took off in fog at Tenerife, Canary Islands and struck a B-747 taxiing on the runway. In five years we didn't learn a thing." (3)

Further research would prove that 1972 was not the first occurrence of this cause which produced the worst aircraft disaster of all time. Just as the second worst accident, the Turkish Air Lines Paris DC-10 explosive decompression, was preceded six months before by the American Airlines DC-10 explosive decompression mishap; and, previously to that, by similiar accidents to the C-5 and C-141.

Complacency was the subject of McDonald and Barnhart's repeat accident thesis – a cause involved in a great many aircraft accidents. Unlike the DC-10 cause factor, the nontechnical nature of complacency makes it difficult to eliminate. In actuality, most of the persistent repeating cause factors are non-technical. The technical problems once identified are tangible, it is easier to establish procedures which control them. Those of a human nature are much more intangible and difficult.

A close look at the statistics reveals that we are not doing quite as well as we might believe. Using General Aviation as an example, the impression is that with a reduction in the number of accidents and the rates, that we are making significant improvement in the prevention of accidents. Figure 1 indicates that in the last eleven years the number of General Aviation accidents has dropped from 6,115 per year to 4,476. And the accident rate has dropped from 27.6 accidents per 100,000 flight hours per year to 11.8. (4)

Figure 1. U.S. General Aviation Statistics (4)

	Accidents			Accident Rate/ 100,000 Hours		Aircraft Hours Flown
Year	Total	Fatal	Fatalities	Total	Fatal	(000)
1967	6,115	603	1,229	27.6	2.72	22,153
1968	4,968	692	1,399	20.6	2.86	24,053
1969	4,767	647	1,413	18.8	2.55	25,351
1970	4,712	641	1,310	18.1	2.46	26,030
1971	4,648	661	1,355	18.2	2.59	25,512
1972	4,256	695	1,421	15.8	2.57	26,974
1973	4,255	723	1,412	14.2	2.40	30,048
1974	4,425	729	1,438	13.6	2.24	32,475
1975	4,237	675	1,345	12.4	1.97	34,165
1976	4,193	695	1,320	11.6	1.92	36,128
1977	4,476	693	1,395	11.8	1.82	38,000

Any rejoicing is dulled by the observation that there has not been a reduction in fatal accidents or fatalities. Most of us know that the definition of an accident has changed over the years, reducing the accident rate. Also, for insurance and other reasons not all accidents are reported. Rates are also based upon the number of flight hours flown and this figure is only an estimate. It has gone up every year, and as it goes up the rates go down. There is no way of adjusting a fatality or fatal accident. When they do not go down the ugly reality is apparent. Note that since 1967 there were five years with both lower fatalities and fatal accidents than in the year 1977.

There is a wide variation of accident experience in the six categories of flying that make up General Aviation. Figure 2 depicts the 1976 statistics for these categories.

Kind of Flying	Accidents	Accident Rate	Fatal Accidents	Fatal Acc. Rate
Pleasure	2,203	20.38	419	3.88
Instructional	542	9.59	57	1.01
Business	294	4.09	61	0.85
Corporate	57	1.43	13	0.33
Aerial Application	433	17.33	39	1.56
Air Taxi	188	4.76	46	1.17

Figure 2. Accident Statistics by Category, 1976. (5)

Pleasure Flying accounted for 2,203 of the 4,193 accidents, or 52.5 percent. It also accounted for 419 of the 695 fatal accidents, or 60.3 percent.

A comparison of the Pleasure Flying accident rate (20.38) with the U.S. Air Carrier accident rate (0.45) reveals a differential of 45.3 times more accidents per 100,000 flight hours. A comparison of the Pleasure Flying fatal accident rate (3.88) with the Air Carrier fatal accident rate (0.064) gives a differential of 60.6 times higher.

Pleasure Flying experienced a fatal accident rate 2.5 times that of Aerial Application.

A comparison of the Pleasure Flying accident rate with the United States Air Force accident rate (2.8) for 1976 indicates that it was 7.28 times higher. In comparison with the Air Force fatal accident rate (1.07) the spread drops to 3.63 times higher.

This analysis clearly indicates the hazardous nature of General Aviation, and Pleasure Flying in particular.

Cause Factors

NTSB lists the ten most frequently cited cause factors of the 1976 fatal General Aviation accidents: (5)

1. Pilot – Failed to obtain/maintain flying speed (185 citations)
2. Terrain – High obstructions (143 citations)
3. Weather – Low ceiling (137 citations)
4. Pilot – Continued VFR flight into adverse weather conditions (100 citations)
5. Weather – Fog (95 citations)
6. Pilot – Improper inflight decisions or planning (93 citations)
7. Pilot – inadequate preflight preparation or planning (82 citations)
8. Pilot – Spatial disorientation (80 citations)
9. Miscellaneous –Unwarranted low flying (66 citations)
10. Pilot – Improper operation of flight controls (53 citations)

Note: The above citations total 1,034 cause factors for 670 fatal accidents. Many accidents have more than one cause factor cited, most having multiple causes.

As expected pilot factor was listed most; in fact, a close evaluation of the circumstances would indicate that probably all of the citations listed in the ten could be, fundamentally, categorized as pilot factor.

The Repeat Cause

Thirteen years ago I was privileged to have an article published in *Private Pilot* magazine. The subject concerned weather accidents in General Aviation and cited an example of a well experienced private pilot involved in a fatal accident – the cause was listed as "non instrumented pilot attempted continued visual flight in adverse weather conditions." (6) A review of the ten most frequently cited causes of General Aviation fatal accidents in 1977 indicates that 412 of the citations involve weather. This 40 percent of the citations. It also indicates that one of the most common and serious repeat cause factors is flying in adverse weather conditions. The worst aircraft accident of all time, at Tenerife, involved adverse weather conditions. One of the most experienced pilots of our day, Frank Tallman, was recently killed in a weather involved accident, an accident that has not been reported as yet but the fact that the accident took place in IFR weather conditions, and that the flight was made without a flight plan, will certainly include it in the *continued VFR flight into adverse weather conditions* category. As this paper was being written, in one week there were two Pleasure Flying accidents in the Los Angeles area. Both light aircraft crashed soon after take off in adverse weather: fog. Neither pilot had filed a flight plan, and there were four fatalities in each of the two accidents.

There are so many General Aviation fatal weather caused accidents each year that NTSB publishes a special report just of that area. In 1976 this report was 271 pages long and included over thirteen pages just listing the fatal accidents. Figure 3 details a summary of the weather caused General Aviation accidents in the United States and Canada in 1976.

(US)	Total accidents	4,193
(US)	Weather caused accidents	908 (22%)
(Can)	Total accidents	695
(Can)	Weather caused accidents	126 (18%)
(US)	Total fatal accidents	695
(US)	Fatal weather caused accidents	262 (38%)
(Can)	Total fatal accidents	85
(Can)	Fatal weather caused accidents	26 (31%)
(US)	Fatal weather caused accidents	262
(US)	Total VFR into IFR weather accidents	138 (53%)
(US)	Total VFR into IFR with no flight plan	103 (75%)
(US)	Total VFR into IFR with VFR flight plan	35 (25%)

Figure 3. 1976 U.S. and Canada Weather Accidents (7) (8)

It should be noted that a large share (38 percent) of the fatal General Aviation accidents have a weather cause involved. Considered over the last twenty to thirty years, the toll from weather flying is staggering. The fact that this is one of the most numerous causes every year makes the repeat accident equally staggering. It is also tragic.

The comparison with Canada was made for 1976 only and there was a similar experience in both countries. The problem is a common one world-wide.

Symptomatic Versus Root Causes

The investigator has as his objective the identification of the accident cause factors so that they can be prevented from being repeated. But is "continued VFR flight into adverse weather conditions" a real cause? Or is it but a symptom of the cause? Is it not an act or unsafe condition rather than a cause?

In his text on safety management Dan Petersen reminds us that:

"...with any accident, we must find some fundamental root causes and remove them if we hope to prevent a recurrence...When we are looking only at the act and the condition, we are looking only at symptom not at causes....Root causes are those which would effect permanent results when corrected." (9)

With this in mind, an examination of the causes listed for aircraft accidents would indicate that they are not causes but identification of acts and conditions. For example, the cause "pilot – failed to maintain flying speed" is an act not a cause. "Weather – fog" or "weather – low ceiling" are both conditions not causes. Like almost all causes listed, they are symptoms not root causes.

Responsibility For Accident Prevention

The investigators expect that people in management are responsible for carrying out the recommendations contained in the accident report, and are at fault if the mishap cause repeats. Of course, the validity of the end product is also dependent upon the quality of the investigation. The investigation must discover the evidence, qualify it, analyze it, and produce conclusions identifying causes and recommendations for prevention. If this process fails it is the failure to not only identify the classic "W's" of investigation: the *when, where, who,* and *what,* but to substantiate these facts with proof. If the facts are not substantiated then the causes are really guesswork. However, even when the facts are substantiated the process may not prevent recurrence of future mishaps of the same causes because the investigation did not answer the most important "W"–*why* did the cause occur and *why* has it repeated?

The action of management is usually influenced by the information supplied by the investigation report, mainly the findings or cause factors. The investigator may not realize, when he criticizes the action agencies in prevention for allowing the mishap to repeat, that the repeat may have been the result of his failure to determine *why* the accident occured and his failure to review the history of the cause and make it part of the findings. He must provide the root causes not symptoms.

Preventing The Weather Accident

If we are to prevent the weather accidents we must get to the root causes. Listing the cause as "continued VFR flight into adverse weather" provides only the *what,* it does not give the *why*. Information that will effect prevention will answer such questions in the cause as:

1. Was the pilot aware of the extreme hazards inherent in weather flying?
2. Was the pilot capable of recognizing weather conditions that were beyond his level of proficiency?
3. Did the pilot know how to plan a safe flight?
4. Are there built-in traps in General Aviation flying that set up a pilot for weather accidents?
5. Is weather forecasting reliable for safe flight planning?
6. Is enroute weather information utilized and reliable?

Very little, if any, human factors evaluation is accomplished in General Aviation accident investigation. As applied to the weather accident, we should make every effort to determine the following type of human factors information:

1. Was the pilot psychologically fit to fly in marginal weather conditions?
2. Was he complacent about the hazards of flying?
3. Was he likely to take unnecessary chances in flying?
4. Was he under any stress that would affect his performance and judgement?

Chaytor Mason, USC's Aviation Psychologist who is also an active General Aviation pilot, feels that the pilot who is likely to have a weather caused accident lives a fantasy about his flying. When he sees a cloud he flies through it thinking that the cloud is nothing but vapor. Chaytor feels a good pilot flies with a sense of reality or negative fantasy – he expects clouds to contain rocks and other airplanes and is careful in how he deals with them. (10)

Chaytor says too little attention is given to the problem of stress on pilots. Much emphasis is now being placed upon the effects of stress in accident causation in motor vehicles. The same application should be given to aircraft accidents.

In a paper prepared for the Irish Airline Pilots Association, Brendan McGann studied the elements of stress on pilot performance. One of these elements was fatigue, about which he says:

". . .it is certain that deterioration in the performance of a tired person starts with the complex and intellectual elements of human behavior such as a co-ordination, decision-making and social interaction, causing dissociation or scattered patterns of behavior, narrow-minded, blinkered or faulty decision-making, and culminating in the development of a personality like a broken bottle! (11)

A recent stress/alcohol and accidents study conducted at USC involved analysis of the extensive library of motor vehicle autopsies of the Los Angeles County Coroner. This analysis indicated a surprising 61 percent of driver fatalities to have evidences of various stress diseases, often in very advanced forms (12). It is expected that such a study on pilot fatalities would be similar. Fatalities involving alcohol have been noted, but the *why* or the *reason* for a pilot to be drinking and flying has not been determined. Little change is expected without the answer to the *why*.

The effects of social stress are now being recognized as an important factor in accident causation. Holmes and Rahe conducted studies that resulted in a table that rated relative stress potentials of social events. Life events such as "death of a spouse" received the highest mean value. Many of the forty-two events listed are likely to be a factor in aircraft accidents. Examples, in order of mean value, would be:

"Marital separation
"Marriage
"Change in family member's health
"Business readjustment
"Change in financial state
"Change to a different line of work
"Change in the number of arguments with spouse
"Change in work responsibilities
"Outstanding personal achievement
"Change in living conditions
"Revision of persnal habits
"Trouble with boss
"Change in work hours, conditions
"Change in residence
"Change in sleeping habits
"Change in eating habits" (13)

There are many stresses that are involved in the experience of pilots. The fall into four basic categories:

1. Social stresses
2. Environmental stresses
3. Emotional stresses
4. Physiological stresses

Other than in the area of autopsies, little has been done to make an evaluation of these problems in aircraft accident investigation, particularly in General Aviation accidents. One of the problems is the availability of expertise and the cost. However, until these areas are included we will not get answers to the *why* and the accidents will continue repeating.

Conclusion

The weather accident has accounted for a very large share of General Aviation fatalities for decades. It is the classic repeat accident cause. Management has been ineffective in preventing it. But investigation must share in this ineffectiveness in not providing the root causes of the problem.

It is recommended that the following suggestions be seriously considered to attack the weather accident problem:

1. *Determination of root cause*. This is a fundamental solution to the prevention of the weather accident. It is also the fundamental solution to he prevention of all other accident causes. All accidents involved repeat causes, a fact that is seldom mentioned as a cause itself – an indication that the system of accident prevention has failed to work. The effectiveness of the accident report would take on a new meaning and emphasis if the cause was listed as: *Supervisory-this was the 262nd repeat fatal weather accident in 1976*. This would put the responsibilty for continuation of the accident right where it belongs.

2. *Pilot education on weather and safety.* Emphasis is now being given this area by the FAA in its accident prevention program for General Aviation. However, there is a long way to go if the private and commercial pilots are to be made aware of the extreme hazards involved in flying into adverse weather. This realization must become common knowledge to all pilots, it must begin in their initial training and follow them as long as they fly. A comparison with the experience of this problem in air carrier and military flying shows the value of pilot education.

3. *Improvement of forecasting and operations procedures.* Most General Aviation pilots have a dubious respect for present-day weather forecasting. Much of this is a lack of coverage of areas these pilots fly in and the difficulty in precise forecasting. Pilots must also know more about flight planning so that they can carry out their flying safety. In that the majority of General Aviation pilots do not file flight plans may be a good indication of the attention given to flight planning. Again, the comparison can be made with air carrier and military pilots who never fly without a proper flight plan and briefing.

4. *Enforcement of regulations.* To force all pilots to file flight plans will invoke immediate cries of discrimination and deprivation of rights. It is a different matter, however, when the rights of the innocent are concerned. What about the pilots, crew and passengers in aircraft being properly flown IFR in the same air space that is invaded by the irresponsible pilot VFR into adverse weather? What about the innocent people on the ground who are endangered by crashing aircraft? And what about the passengers aboard the errant aircraft who become victims of the betrayal by those responsible for their safety? Any of these acts would involve serious action taken against an air carrier or military pilot. Perhaps the solution is to establish criminal punishment for infraction of Federal Aviation Regulations. It is sad to suggest such action but the people who would be involved certainly deserve it. And – the same may be said of those in responsible positions who have jurisdiction over my first three recommendations. The failure to take action to prevent recurrence, be it failure to enforce, advise, educate, and/or determine root cause, is not that of the pilot involved in the accident.

It is sad to say, but it may just be possible that there are not enough people concerned about the fatalities in General Aviation to shoulder the responsibility and cost required to prevent these accidents. After all, 1,395 people killed in one year is a very small slice of the total transportation fatalities pie. It is only 3 percent of the motor vehicle fatalities. Hopefully, there are enough of us in the aviation business who have the pride to decry the lack of professionalism in these unnecessary aircraft losses. Isn't it too bad that the same cannot also be said of automotive safety?

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Supervision: The Neglected Human Factor

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The "Five-M" Theory of accident causation and prevention cites the inevitable interaction among five major sets of factors in the chain of events leading up to an accident: Man, Machine, Medium (or Environment), Mission and Management. The importance of these interactions during the development process preceding the actual accident event is often restated by experts in rare-event theory. Dr. Nestor Kowalsky, formerly of the Lovelace Foundation and Eastern Airlines, has offered the following definition of "aircraft accident" with which few experienced investigators would find fault:

"An aircraft accident, in our view, is a positive, eminently successful event that is inevitable when preceded by a series of one or more 'accident-enabling factors' or conditions *which have to be present and without which the accident cannot occur.*"[1] (Emphasis supplied.)

He goes on to add:
"This approach deemphasizes pilot 'fault' and focuses on the actions and decisions (both proper and improper) that are carried out, as well as those factors that prompt these actions and decisions. The concept encompasses all conditions leading to accidents in the Man-Machine-Environment complex."[2]

Despite general agreement among investigators with the theory of systemic etiology of accidents and systematic approaches to their investigation, the common official attitudes toward aircraft accident analyses in the United States have been, in general, superficial. Our current body of data is totally inadequate both for explaining past accidents and for preventing future recurrence. Contributory factors which fall into the first three of the "Five-M's" – Man, Machine and Medium – are often obvious within the immediate accident scenario, although their manifestations are usually by effects rather than by causes. The real underlying cause factors, as well as contributory cause factors falling in the Mission and Management categories, do not yield to superficial investigation. They may often be implicated at the outset by oblique inference, but the task of determining interrelationships among all factors in the chain of causation requires analysis of "Human Factors" which defy robust mathematical quantification. Most experienced investigators will agree that "attitudes" play a significant role in the development cycle of aircraft accidents. The same is true for ignorance, misinformation and plain stupidity. Yet few investigators are willing to take the time to delve into these subjective areas when there is "physical" evidence to support a superficial finding which may be not only irrelevant, but inaccurate as well.

This paper examines a specific Management factor: Supervision, to compare its prevalence as an attributed cause in military accident investigations with similar citations in the civil sector.

The military services' definition of "Supervisory Error" in the causal chain of aircraft accidents generally encompasses those contributions which arise from the exercise of discretionary functions at organizational levels above that of the immediate aircrew. These decisions may exert an influence on the attitudes and decisions of the aircrew itself; e.g., training, mission assignment or criticality of mission completion; or may be influential on external circumstances; e.g., facilities, maintenance policies or design and configuration.

Table I displays the "Factor Frequency" (F^f) of Supervisory Error by military service as reported over a seven-year period. (For the statisticians among you, F^f is merely the number of times that Supervisory Error was cited as a contributory cause factor divided by the total number of major accidents during the same period. It is statistically crude and provides only comparative information.)

	USA	USAF	USN/USMC
1971	.13	.38	.27
1972	.32	.90	.35
1973	.36	.69	.34
1974	.29	.72	.34
1975	.39	1.07	.29
1976	.35	*	.30
1977	.41	*	.31

Overall Mean F^f = .43
* = data not furnished

TABLE I
Frequency Factor (F^f) of Supervisory Error, U.S. Military Services, 1971-1977

Attempts to compile comparative data from the civil sector encounter immediate problems. The NTSB does not segregate either "Supervision" or "Management" into definitive factors as do the military services. In order to achieve an attempt at commonality we extracted those subcategories of civil aviation cause factors reported by the NTSB which appear to correspond functionally with the military's definitions. The following categories were included:
Check Pilot; Flight Instructor; Non-owner/Pilot Maintenance, Servicing and Inspection; Operational Supervisory Personnel; Airport Supervisory Personnel; Airways Facility Personnel; Production-Design Personnel; and Dispatching.

Table II depicts the Frequency Factors of these attributed causes among the various categories of civil aviation, in 1976.[3]

	F^f
Air Carriers	.24
Commuter Airlines	.28
Corporate Operators	.23
Air Taxi Operators	.14
Private Operators	.07
All General Aviation	.10

TABLE II
Frequency Factor (F^f) of Supervisory Error, U.S. Civil Aviation, 1976

Rank-order listings by operator category shows the military services highest (.43), followed by the commuter air lines (.28), air carriers (.24), corporate operators (.23), air taxi operators (.14), and private general aviation operators last (.07). This relative ranking may appear logical when compared with the strictness of supervisory accountability practiced by the affected operators. The military services have the most rigid management, and well-established hierarchies of authority and responsibility. In addition, internal military regulations often exceed the stringency of the Federal Aviation Regulations, particularly with regard to training and operations. Air carriers, commuter airlines and corporate operators are subject to internal management oversight. The air taxi operator has the ever-present threat of liability to motivate his attention toward exercising sound management over his aircrews and equipment.

But what supervision is exercised over the private general aviation pilot? An occasional flight instructor (during the biennial flight review), the aircraft owner (if he's not the pilot), the pilot's wife (if she's a passenger), and – precious little and seldom – the FAA. Unless the private GA pilot has strong personal motivation for survival and even stronger self-discipline enough to demand of himself the kind of competence we call "professionalism," he can be considered to be totally unsupervised by any responsible authority until after he has committed a breach of regulation of sufficient magnitude to attract disciplinary action.

Extending these arguments leads to the conclusion that the frequency of Supervisory Error is directly proportional to the amount of supervision exercised. However, if we look deeper into the specificities of Supervisory Error we can find that it is as often *lack* of supervision as it is improper supervision. If that be true, then the data should reflect supervision implicated more often by its absence among the less-supervised populations of operators than among those enjoying greater supervision. And that, of course, is our problem: we have yet to comprehend that an absent factor may be as potent a cause in precipitating an accident by its absence as the most glaring "BGO" – Blinding Glimpse of the Obvious.

A few examples may help illustrate the manner in which Supervision, or the absence thereof, interacts with the "Five-M's":

(1) Supervision and Man: The Multi-Engine Class Rating

The laxity of FAR Part 61 with regard to requirements for the multi-engine class rating combines insidiously with the operational limitations of light twins certificated under FAR Part 23 to establish a cheap and effective license to die. One need merely read the advertisements in the popular aviation press to identify the level of incompetence required to achieve the minimum requirements. Thus, from AOPA's *Pilot* Magazine: "Multi Rating $345.00 in Two Days in Apaches."[4] There is an FBO in the Washington area who will "qualify" a pilot for a multi-engine rating in an Aeronca Lancer, a twin-engine, fixed-prop, fixed-gear, high-wing anomaly long since relegated to the junk pile by most knowledgeable operators. Yet the product of this "transition training" is fully legal to command a Part 23 light twin with retractable gear, full-feathering props and little (if any) single-engine capability.

(2) Supervision and Machine: FAR Part 23

Part 23 was a suitable technical specification at the time when aircraft were built of wood and fabric. Technological advances in materials, powerplants and structural techniques have rendered it inadequate. Exemplary is the T-34C, a turboprop-powered derivative of the twenty-year-old T-34A/B military primary trainer. The T-34C was developed basically in response to a U.S. Navy requirement for a higher performance primary and basic training aircraft, but it has been certificated under the Acrobatic Category provision of FAR Part 23. The aircraft is red-lined at 195 knots by the FAA at the manufacturer's recommendation.

However, Navy aeronautical engineers were convinced that the combination of turboprop power in the light airframe could lead to problems if a solo primary student inadvertently – or euphorically – exceeded red-line speed. The Navy insisted that the manufacturer demonstrate structural integrity to 350 knots in 1-"g" flight. During the demonstration flight series the aircraft's horizontal stabilizers failed in aeroelastic divergence at 335 knots.

Part 23 doesn't deal very well with aeroelasticity; at the time it was developed aircraft didn't fly fast enough to make it a problem. Today they can, but Part 23 deals with static loads. The T-34C to my knowledge still has its certificate, with a thin red line at 195 knots to separate safety from disintegration.

(3) Supervision and Medium: The Instrument Rating

In accordance with FAR Part 61 a pilot may qualify for an instrument rating without ever having flown under actual instrument conditions. In fact, only five hours of simulated flight in a real aircraft need be under instruction. Fifteen may be simulated in an aircraft *without* an instructor. Twenty hours may be under instruction in a simulator. The minimally qualified, "instrument-rated" pilot is then *legally* competent to fly under any actual instrument conditions. How many investigations have you reviewed involving weather or IFR operations in whch the investigator took the time and effort to determine the total and current actual IFR experience of the pilot? So long as he's "legal," we quit.

(4) Supervision and Mission: Schedule Pressure

Item: A Cessna 207 departs near midnight on an air cargo flight and crashes a fourth of a mile beyond the runway. The aircraft is over weight and the load is out of balance limits. The pilot was heard arguing with the company's cargo agent about excess weight before the flight. A company truck was seen unloading more cargo next to the aircraft while the pilot was away filing his flight plan.

Item: A Twin Otter flies into a glacier in IFR conditions, resulting in the death of thirteen persons. The aircraft was improperly dispatched with inadequate equipment for the overwater flight. The operator's dispatching, maintenance, scheduling and training procedures are found to be deficient. Another pilot was recently fired for refusing to fly in what he considered to be adverse weather. The FAA's oversight of the operator has been neglected. Yet the Findings in both these cases was that Pilot Error was the primary cause, despite the fact that the factors given above were noted in the investigation.

(5) Supervision and Management: The NTSB Data Base

By way of preamble I would like to share some comments by Dr. Julian Waller of the University of Vermont, from a Workshop on Rare Event/Accident Research Methodology sponsored by the National Bureau of Standards:[5]

> "One of the important problems of dealing with real world phenomena, usually after the fact, is that the quality of data, especially those collected through official sources, can only be described as generally execrable whether one refers to information about the extent and nature of populations at risk, frequency of injury events, severity, causation or countermeasures." – "(One) study identified 668 contributory factors among 104 randomly selected motor vehicle crashes in Iowa. Fifty percent of these factors were reported to be vehicle related, 31% involved the environment, and 19% the driver.
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I invite your comparison between Dr. Waller's example and the NTSB Data Base, which cites as the most frequent cause of fatal accidents in 1976: "Pilot – failed to obtain/maintain flying speed," and as the most frequent cause of non-fatal accidents in the same year: "Miscellaneous Acts, Conditions – Overload Failure."[6]

I consider it an insult both to our professional integrity and our intelligence that we should be expected to accept a "Miscellaneous Act" or "Condition" as the most definitive bit of data linking 542 accidents. However, this seeming absurdity is no stranger than the logic which finds that the operator which exercises the greatest amount of supervision is guilty of the greatest incidence of Supervisory Error.

The common denominator characterizing the superficiality of these results is also, to a great extent, Supervision, the lack of professional supervision adequate to ensure that we have not neglected the errors of omission and the "Human Factors" rendered inconspicuous by the Blinding Glimpses of the Obvious. The public is no longer naive enough to accept meaningless platitudes in lieu of real underlying cause factors. "Pilot Error" only has meaning when we can demonstrate why the pilot erred, and "Overload Failure" is no substitute for design error. Let's start examining Supervision, and start with ourselves.

References

1. Kowalsky, Dr. Nestor, quoted in *Hazard Control Manager*. Spring, 1978, p. 6.

2. *Ibid.*

3. Data Derived from:
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4. *The AOPA Pilot*. Vol. 21, No. 10, October 1978, p. 116.

5. Waller, J.A., Epidemiologic Approaches to Injury Research. *Rare Event/Accident Research Methodology*, National Bureau of Standards Special Publication 482, July 1977.

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No Fault Insurance

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I come from that amazing little country of New Zealand where the number of committees and commissions (those substitutes for decision) are already notorious and exceeded in numbers only by welfare beneficiaries and sheep. We would without doubt be probably the world's overcommitteed and over-commissioned country, and the latest addition to these is a human rights commission. I am sure the next commission will be a commission to oversee all the other commissions. Among the commissions which we have is one which has so far functioned smoothly, satisfactorily and efficiently, the exception to the rule, and that is our accident compensation commission, which in effect has taken over dealing with all matters of personal injury. We have no fault liability for personal injury from whatever cause. Whether it be a household accident, a motor accident, an aircraft accident, a work related accident, etc., there is no claim against anybody and you merely fill in a form and send it to the accident compensation commission with the necessary medical evidence of your indisposition or death certificate, and the commission pays out in some cases a lump sum and in some cases a lump sum plus weekly or monthly benefits which are related to your income loss. The commission also provides other practical benefits. For example if you have been involved in an accident and end up a paraplegic the commission will not only give you income at a certain level depending on your income prior to the accident, but will also provide you with a car which has been suitably altered so that it can be operated by a paraplegic. It will also install ramps, etc., in your home; alter the bathroom facilities and other facilities in the house so that they can be used by a paraplegic; pay all hospital, specialist and medical expenses, etc. This type of remedy and result seems much more responsive to human needs than the lottery that there was when you had to prove liability and sue somebody for negligence, accident compensation, etc. To me it is a scheme which should be looked at by international air carriers and government agencies to take the lottery out of buying an airline ticket. It is my contention that the matter of liability for any aircraft mishap or accident on international routes should not be a matter of proof on the part of the passengers. It is so often the case now. The Warsaw Convention, the Montreal Protocol and other international agreements are in my view inadequate, out-moded and quite unrelated to the requirements of the the jet age.

If there is anybody whose fault it is *not*, it is certainly not the fault of a fare-paying passenger that an aircraft has an accident. There can be no contributory negligence on the part of the passenger. All the passenger has done is sit strapped into his or her seat drinking out of plastic cups and eating plastic wrapped sandwiches, unless of course he is a first class passenger, in which case the cups are china and the sandwiches convert to chicken salad. Travelling as a passenger by any airline, I always hope that the pilot is a happily married man and wanting to get home to his wife and children. I am sure many passengers think likewise. I do not think under the present hap-hazard system of dealing with claimants following an aircraft accident that justice is done–it is in any event far from being even-handed, fair and equitable, and any present international conventions do not meet the demands of this day and age. We are badly in need of some no-fault system in the international airline world where there should be no necessity for court actions, expensive litigation, delays and what, in the final analysis, amounts to a miscarriage of justice in many cases.

If you are travelling by an international airline at the present, it always seems as though it is advantageous to travel on either one of the United States international carriers or some airline which has a principal place of business within the United States. Awards from courts (especially in California), settlement of damages claims by insurance companies, and the like are always much more generous in America than elsewhere, and it is my contention that this should not be the case. In other words the lottery element, the element of chance as to whether you get what is provided by the Warsaw Convention, nothing, or a vast amount in damages is removed and all the chance and uncertainty is taken away from death or injury during carriage by international aircarriers.

As I said before, the passenger can in no way be at fault and should not have to prove anything. He is entitled to recompense or, if killed, his dependants are entitled to recompense promptly, without cost, and on a fair and equitable basis. To get involved in any court procedure is quite unfair and unnecessary. I do not think that the court system either in the U.S.A. or elsewhere is equipped to deal with such claims responsively, quickly and effectively. Thanks to overcrowded and harried courts lawyers can find ways to protract a case indefinitely. Postponements, recesses, objections, motions, depositions, unavailability of client or lawyer–the list of stalling techniques is endless. All that happens is that it puts a squeeze on the cash-starved claimant and forces him into a disadvantageous settlement. Another way that the defendants in any such case can wear down the opposition is to start a paper war by filing motion after motion, each requiring a time consuming a costly response.

Such paper wars only lead to endless procedural wrangles, legal technicalities, etc., which do not impress the man in the street and which do not help him get his just due. Discovery in law suits is such that in my view it allows any party involved to delay the proceedings endlessly by demanding what I would term fringe information relating to the law suit. I am sure the defendants adopt a "wear-them-down" philosophy. The fare-paying passenger who is injured, or the dependants of fare-paying passengers who are killed, should not have to put up with this type of nonsense and indignity. If we had an effective international convention covering the international air traveller these difficulties would not arise. To the layman the mumbo jumbo of the law can intimidate him and irritate him. He resents the ability of the legal profession to muddle and cloud issues and to keep the case alive long after he thinks it should be settled or terminated.

The cosmopolitan nature of any list of aircraft passengers is a fact of life which I think should now be accepted. The jet age, the speed of travel, the relative cheapness of travel has brought all this about and what airline a person is travelling on or what country he comes from should in no way determine what damages he or she gets as a result of any mishap or accident during the course of that international airtravel. There will be in the course of the next few years, I think, a steadily growing body of opinion that says that all or any of the remedies now available have serious defects. Most are a slow and expensive charade–a lottery in which the prizes go to a favoured few. The Warsaw Convention is now hopelessly inadequate because passengers have rights outside that system based on many things such as manufacturing or design faults, fault by other aircarriers, airtraffic controllers' negligence, the fault of meteorogical services, and last but by no means least hijacking. A new convention is needed to cover all possible contingencies and I submit that the only satisfactory basis is to have a no fault principal where the injured passenger or deceased passenger's dependants are not in any way called upon to prove whose fault the accident was. That is quite unfair, and in this day and age socially and morally unacceptable. The present system does not do justice. No passenger should have to become involved in a court action to get what I think we would all regard as his just due. Court actions in my view give the facade of justice; not only must justice be seen to be done, but it must be done. The present system is no way of doing justice to any claim. Some immediate assistance and payment is needed; and while Warsaw was meant to provide this, it has not.

It is only with pressure from people involved in the airline and in the aircraft industry that a new international convention could be brought into being. Even if this meant some small additional charge for what in effect would amount to an insurance cover for every passenger on an international flight, it would be worth while. I know the type of discussion any such proposition brings about, the cries of anguish from the present insurers, the legal profession and the airlines; but I think the duty of care which the international air scene and all its various components, whether they be governments, manufacturers, carriers, airport operators, etc., owe to the passengers is a high duty of care, and that duty of care is such that the passenger should be taken care of in the case of any loss, without the necessity of having to prove fault, having some unnecessary and arbitrary low limit fixed for the amount of his claim (as is done under the Warsaw Convention), or having to go to great lengths to obtain any money. It should be his right to obtain adequate compensation promptly without fuss and without the terrors and mumbo jumbo of court proceedings. I am sure the insurance companies, the legal profession and the airlines would soon accommodate themselves to the new situation without the tribulations and upheaval which they would no doubt anticipate. I think after an initial settling down period that all the arguments and anxiety of the new system would die away and there would be general acceptance of what a lot of you would now label as unvarnished heresies on my part.

Any new system or international convention would have to cover such matters as the classes of persons to be protected and covered by the scheme, the nature of the contingencies to be covered, the position of the travellers of various nationalities and income levels, the method of assessment of compensation to be paid, the processes to be involved in determining such compensation, the administrative arrangements to control the scheme, the formula for fixing compensation, the social, political and personal implications of the scheme and, above all, have sufficient and adequate machinery to deal with changing situations and future developments without having to start off from scratch again. Any scheme which was too rigid and which did not make provision for change would, I submit, have in it the seeds of its own destruction. A scheme such as this would have to be a continually evolving one and should mirror social thinking of the times.

The days when everything could be judged by the standards, values and aspirations, ideals and mores of the United States are gone. We are living in an international era and every airline passenger should have the certainty of knowing that compensation is going to be paid in the case of injury or death. There should no longer be a lottery and there should be no need for expensive legal procedures to prove a point. Any scheme should go beyond just providing for adequate compensation for passengers, and should enlarge upon any existing schemes and codes of accident prevention, etc., so that any new scheme is a comprehensive scheme of accident prevention, rehabilitation and compensation which will avoid the disadvantages of the present varying processes and will itself operate on a basis of consistent principle. The priorities of any compensation which is paid should be the economic rehabilitation of the claimant or his dependants, the physical rehabilitation of any injured persons, and some duty to compensate for actual financial loss. In the present scheme of things we all tend to think about compensation for actual economic loss whereas in my view the task of mental rehabilitation and physical rehabilitation are the most important, and any compensation scheme should be such as to put prime importance on any efforts being made to restore a man to health and gainful employment.

I would anticipate that the main opposition to any such no fault liability or compulsory insurance, call it what you like, would come from the United States. This is because I think the thinking here is that each claim is so large that if this was multiplied throughout the world then some of the sums involved could be astronomical.

Your thinking has to be changed. I would not anticipate for one moment that the rest of the world would anticipate a scheme which made provisions in accordance with award and settlements in terms of what has happended in the past in the United States. In fact some of these awards and settlements are from the practical point of view quite useless when you take into account the socio-economic background and the way of life of some of the claimants. Let me give you an example: I was recently involved in litigation in which the case was brought in California, and in which one of the passengers concerned came from a small island republic in the South Pacific. At the time of the crash the person concerned was returning from New Zealand to his island home having gained permanent entry into New Zealand and having organized himself a job, which by his island home standards, was fantastic.

The salary he was to get was four or five times what he could have obtained in the islands, and because of his education and background at one of the mission schools he was determined that his own family were going to be given greater opportunities and educational chances. In the same way the Chinese value education, some of these island people also value it as an asset in itself. It has no monetary value; it has no translatable terms into cash–all the people want is an opportunity for education, and furthering their own economic lot thereby. In this particular case the amount of settlement after torturous negotiations and long delays in court was settled at a figure in excess of a quarter of a million dollars U.S. currency. The time within which to do this was nearly five years.

The position is of course that all the children who would have been able to come to New Zealand five years before and partake of our primary, secondary and if possible technical and university educations are now not able to do it even though they have by the standards of their island home vast sums of money. Five years is too late in the educational life of a child or an adolescent to enable him or her to catch up, and hence the opportunity that these children were to be given by their father is not now available to them by passage of time. However, the village they live in will now have two new coconut trucks and the biggest and best church and the biggest and best statues of the Lord and Virgin Mary that would be conceivable. The community as such may have benefited but how misguided the whole system is when at the end of five years this family are given a large sum of money for which they neither have the ability nor the chance to use advantageously. They have been deprived of their education and their chance in life to get out of the coconut environment in which they are living.

Their father had seized a chance which had been snatched from him by his untimely death in an aircrash. If only there had been some means immediately following this aircrash to convey the family to New Zealand to stay there with relatives and receive the education that they were entitled to, everybody would have been happy. An initial amount of $8,000.00 or $9,000.00 would have done this. If there could have been some means of paying for board and maintenance for four or five years on the basis of say $1,000.00 per child per year, everybody would have been happy. They would have achieved their goals, their father's life-long ambition would not have been frustrated, and the total cost in terms of U.S. dollars would have been something well under $30,000.00 and not $250,000.00. This type of example can be repeated time and time again.

The $250,000.00 is completely wasted, has involved the insurance company in paying out far more than it need have, and in effect the final losers were not only the family but the airline itself whose premium is based on these large payouts. I submit they are not necessary nor desirable in such cases as I have outlined above; justice has certainly not been done. The lives of four children have been frustrated. The chances they had to better themselves and rise above their present environment has been effectively stopped. No amount of money can compensate for this. I think this and many other examples I can give you show that any compensation should be related to the social aspirations and needs of the people and not just to a monetary value. People have different standards and different values, and money in some communities and in some countries is meaningless because it never goes to the right people.

You can not compensate for this sort of loss of amenities of life by way of a long delayed cash payment. That four to five year hiatus is too long. The damage done is irrepairable. No amount of money could compensate these four children for what they have lost.

To sum up then, what I am saying is that I do not think the international air passenger receives a fair go under the present haphazard system of compensation. It does not meet the social requirements, the moral obligations or the aspirations of the people involved. Somehow or other we have to widen our horizons to not only think of compensation in terms of plain straight money, but also to ensure that compensation is such that opportunities are not lost, that people's lives are not too disrupted, that their life standard, life style and family set up can continue.

Compensation is more than just a monetary payment; it is about time we all took a look at the present system with a view to overhauling it. If all I have done is stimulated thought and discussion on the topic I have achieved my object. I would not anticipate that an audience such as this with its diverse interests and opinions could in any way accept without qualification the scheme I have outlined. The present adversary situation of the courts is not suited to giving social justice. Justice and fairness are forgotten, as is the dignity and feelings of people. In this push button age, the age of travelling to the moon, the age of travelling from New Zealand to Europe in 18 hours by Concorde, the age of social welfare, we still have not managed to grapple effectively with the aftermath of an aircrash.

The trauma, the grief, the psychological and physical damage are inadequately catered for. We can do better.

Marty Speiser, Don Knutson, Prater Hogue, Dick Taylor

Colonel Jerry Schwene, Bjarne Prendal

Psychophysiologic Factors in USAF Aircraft Accidents, 1974-1975

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The views expressed herein are those of the author and do not necessarily reflect the views of the US Air Force or the Department of Defense.

Human error, or more specifically operator error, has long been recognized as a significant factor in aircraft accident causation. Historically, 45 percent of USAF aircraft accidents have been attributed to pilot error, 40 percent to materiel factors or maintenance error, and 15 percent to undetermined or other causes. These percentages remained fairly constant throughout the 50's and 60's, while the major aircraft accident rate was reduced by 90 percent and the destroyed aircraft rate by 75 percent. As more reliable equipment was trimming the number of accidents due to materiel failure; safety consciousness, better procedures, improved training, and the application of human engineering similarly reduced those due to operator error.

The decrease in accident rates appears to have slowed in the 70's, but the distribution of mishaps by cause category remains fairly constant. Institution of "all cause" reporting and changes in mishap definition prevent exact comparison. However, if the accidents are grouped by the presence or absence of "operations factor" and "logistics factor" causes, statistics reasonably comparable to earlier years can be obtained (Table I). (Changes in mishap reporting for 1977 produced a 1400 percent "paper" increase in minor accidents. That anomaly was minimized by limiting the data to accidents in which a life sciences report was prepared.) Forty percent of recent accidents had operator errors without material malfunction or failure; 39 percent had materiel problems without operator errors; and 16 percent had both. An operator error was considered important in the genesis of 56 percent of the accidents. Clearly, room for improvement still remains. A prime-limiting factor is the adequacy of the human factors investigation.

A list of psychophysiologic and environmental variables that could be factors in accident or injury causation was developed several years ago by a joint services committee. They were incorporated into the mishap reporting forms of the uniformed services for assessment by the medical member of the board (Figure 1). The difficulties in sophisticated analysis of the data obtained and in using the analysis to drive accident prevention programs are well documented[1, 2]. They suffer from a lack of definitions–they are neither all inclusive nor mutually exclusive–and there are inconsistencies in reporting. Nevertheless, they have proven useful in two practical ways. First, they can be used as a guide in developing topics for safety awareness programs[3]. Second, and most important, they serve as a checklist to stimulate the board to consider the entire spectrum of human factors and particularly to force the flight surgeon to expand the scope of his investigation[4]. The variables and the frequency with which they are assessed in USAF mishaps may also be useful information for investigators of civil aviation accidents. They are presented for that reason.

Data on psychophysiologic and environmental factors were available in reports of 475 major or minor accidents occurring from 1 January 1974 through 31 December 1977. It was first limited to that from the forms prepared on the operator(s) in control, then further reduced to those factors assessed as definitely contributing or suspected of contributing during the accident phase of the mishap. More than one factor was identified in most accidents. No attempt was made to weigh their relative importance.

Of the supervisory variables (Table II) listed, poor crew coordination was the one most frequently cited. It usually involved controlled flight into the ground when none of the crew was watching the altimeter. In a few cases, the pilot may have precipitated the abandonment of surveillance tasks by directing the other crewmembers' attention out of the aircraft. In at least one instance, his attitude may have made it difficult to provide appropriate assistance. Supervision is found causal in more accidents than the remaining factors would suggest. Indirectly, it is responsible for most of the training and design problems listed below.

Preflight factors were infrequent offenders (Table III). This is not surprising considering the effort expended in the area. Inadequate weather analysis followed by inadvertent thunderstorm penetration or attempts to stay visual in deteriorating conditions still traps a fair number of our pilots.

Failure to use accepted procedures, as a result of a training deficiency, was considered a definite factor in 10.5 percent of the accidents and suspected in another 8 percent (Table IV). These vary from instances in which complex tasks were being performed at very low altitude for the first time to omissions in emergency procedures. Limited, recent and total experience are also suspected of contributing to an appreciable number of accidents. Making the best use of the flying time available is a significant concern in the USAF today and will likely remain so.

Failure of instruments/controls was the most frequently assessed design variable (Table V). It was noted in association with control linkage disconnects, hydraulic system problems, and nose gear steering malfunctions as well as a few failures of primary flight instruments or radar. In many of these mishaps, there was no operator error. Design of instruments/controls likewise often referred to metallurgy or electronics rather than human engineering. Lighting of other aircraft becomes a factor in mid-air collision prevention. All three of the definite cases involved collision during attempted night join-up. In each, the wingman ended up in trail trying to join on a single light.

Communication difficulties (Table VI) have decreased drastically from the early days. Considering the number of foreign students trained and the USAF's global mission, language barrier was cited in a surprisingly low number of accidents. Most of the accidents in which it was considered a suspected factor involved foreign students. In one, the student departed controlled flight, then made repeated spin recovery attempts, always beginning with pro-spin controls. Misinterpreted communications also included some in which the communication failed to provide adequate information for proper interpretation.

Psychologic and physiologic perturbations rarely leave hard evidence. It is much more difficult to be sure they contributed to an accident than it is with materiel failures. Yet the circumstances of the mishap often lead one to suspect they are operative. Table VII clearly demonstrates this difficulty. Channelized attention was used in the broadest sense and overlapped with distraction. Both included cases where the attention of all crewmembers was directed to outside events or emer-

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FIGURE 1

III. PSYCHOPHYSIOLOGICAL AND ENVIRONMENTAL FACTORS

INSTRUCTIONS: Complete on all occupants of aircraft, all injured persons, and all persons possibly contributing to the cause of the mishap. Supervisory factors attributed to persons not in the aircraft and such factors as design or weather should be reported only for the person in primary control of the aircraft. Factors contributing to injury during mid-air collisions, crash landings, ditchings, etc., are to be considered part of survival phase. Use codes at right to show only those factors present or contributing in each phase.

PHASES OF MISHAP
- A - ACCIDENT
- E - ESCAPE
- L - LANDING
- S - SURVIVAL *(Includes parachute landings)*
- R - RESCUE

FACTOR IMPORTANCE
- D - DEFINITELY CONTRIBUTED
- S - SUSPECTED FACTOR
- P - CONDITION PRESENT, BUT DID NOT CONTRIBUTE TO ACCIDENT OR INJURY.

FACTORS		A	E	L	S	R
1. SUPERVISORY FACTORS						
INADEQUATE BRIEFING	101					
ORDERED/LED ON FLIGHT BEYOND CAPABILITY	102					
POOR CREW COORDINATION	103					
OTHER *(Specify)*	199					
2. PRE-FLIGHT FACTORS						
FAULTY FLIGHT PLAN	201					
FAULTY PRE-FLIGHT OF AIRCRAFT	202					
FAULTY PREPARATION OF PERSONAL EQUIP.	203					
HURRIED DEPARTURE	204					
DELAYED DEPARTURE	205					
INADEQUATE WEATHER ANALYSIS	206					
OTHER *(Specify)*	299					
3. EXPERIENCE/TRAINING FACTORS						
INADEQUATE TRANSITION	301					
LIMITED TOTAL EXPERIENCE	302					
LIMITED RECENT EXPERIENCE	303					
FAILURE TO USE ACCEPTED PROCEDURES	304					
OTHER *(Specify)*	399					
4. DESIGN FACTORS						
DESIGN OF INSTRUMENTS, CONTROLS	401					
LOCATION OF INSTRUMENTS, CONTROLS	402					
FAILURE OF INSTRUMENTS, CONTROLS	403					
COCKPIT LIGHTING	404					
RUNWAY LIGHTING	405					
LIGHTING OF OTHER AIRCRAFT	406					
PERSONAL EQUIPMENT INTERFERENCE	407					
WORKSPACE INCOMPATIBLE WITH MAN	408					
OTHER *(Specify)*	499					
5. COMMUNICATIONS PROBLEMS						
MISINTERPRETED COMMUNICATIONS	501					
DISRUPTED COMMUNICATIONS	502					
LANGUAGE BARRIER	503					
NOISE INTERFERENCE	504					
OTHER *(Specify)*	599					
6. PSYCHOPHYSIOLOGICAL FACTORS						
FOOD POISONING	601					
MOTION SICKNESS	602					
OTHER ACUTE ILLNESS	603					
OTHER PRE-EXISTING DISEASE/DEFECT	604					
GET-HOME-ITIS	605					
HANGOVER	606					
SLEEP DEPRIVATION, FATIGUE	607					
FATIGUE, OTHER	608					
MISSED MEALS	609					
DRUGS PRESCRIBED BY MEDICAL OFFICER	610					
DRUGS, OTHER	611					
ALCOHOL	612					

FACTORS		A	E	L	S	R
VISUAL ILLUSIONS	613					
UNCONSCIOUSNESS	614					
DISORIENTATION/VERTIGO	615					
HYPOXIA	616					
HYPERVENTILATION	617					
DYSBARISM	618					
CARBON MONOXIDE POISONING	619					
BOREDOM	620					
INATTENTION	621					
CHANNELIZED ATTENTION	622					
DISTRACTION	623					
PREOCCUPATION WITH PERSONAL PROBLEMS	624					
EXCESSIVE MOTIVATION TO SUCCEED	625					
OVERCONFIDENCE	626					
LACK OF SELF-CONFIDENCE	627					
LACK OF CONFIDENCE IN EQUIPMENT	628					
APPREHENSION	629					
PANIC	630					
OTHER *(Specify)*	699					
7. ENVIRONMENTAL FACTORS						
ACCELERATION FORCES, IN-FLIGHT	701					
ACCELERATION FORCES, IMPACT	702					
DECOMPRESSION	703					
VIBRATION	704					
GLARE	705					
SMOKE, FUMES, ETC.	706					
HEAT	707					
COLD	708					
WIND BLAST	709					
VIS.RESTR.-WEATHER, HAZE, DARKNESS	710					
VIS.RESTR.-ICING, WINDOWS FOGGED, ETC.	711					
VIS.RESTR.-DUST, SMOKE, ETC., IN ACFT.	712					
WEATHER, OTHER THAN VISIBILITY RESTR.	713					
OTHER *(Specify)*	799					
8. OTHER FACTORS TO BE CONSIDERED						
HABIT INTERFER., USED WRONG CONTROL	801					
CONFUSION OF CONTROLS, OTHER	802					
MISREAD INSTRUMENT(S)	803					
MISINTERPRETED INSTRUMENT READING	804					
MISLED BY FAULTY INSTRUMENT	805					
VISUAL RESTR. BY EQUIP. STRUCTURES	806					
TASK OVERSATURATION	807					
INADEQUATE COORDINATION OR TIMING	808					
MISJUDGED SPEED OR DISTANCE	809					
SELECTED WRONG COURSE OF ACTION	810					
DELAY IN TAKING NECESSARY ACTION	811					
VIOLATION OF FLIGHT DISCIPLINE	812					
NAVIGATIONAL ERROR	813					
INADVERTENT OPER. SELF INDUCED	814					
INADVERTENT OPER. MECHANICALLY INDUC.	815					
OTHER *(Specify)*	899					

NAME OF INDIVIDUAL	SSAN

AF FORM 711GA, SEP 76 FOR OFFICIAL USE ONLY *(When filled in)* PAGE 2 OF 11 PAGES gency procedures and the aircraft was allowed to impact the ground. Channelized attention also includes some classical target fixation accidents. Disorientation was cited in 10.5 percent of the accidents. Visual illusions were often cited in the same mishap. Most of these involved fighter or attack aircraft on the range or in formation under conditions of restricted visibility. Three studies[5,6,7] using more restricted criteria found disorientation to be implicated in 8 percent of USAF aircraft accidents over a span of 20 years.

Degraded pilot performance as the result of acute respiratory infection was suspected in three mishaps. Autopsy evidence of moderately severe or severe coronary artery disease was found in several mishaps. In five of these, the flight surgeon suspected it may have been causal. Fatigue was listed as a definite factor in two transport accidents and one fighter accident. The duty days for the two transport crews were prolonged. The fighter pilot was living up to the image. Methaqualone was found in the tissue of a pilot involved in a mid-air collision. Alcohol was not listed as a definite or suspected factor in any accident. Alcohol levels above .02 grams-percent were not reported in the absence of tissue putrefaction.

Flight surgeons were hesitant to ascribe significance to distracting emotional factors. Personal problems suspected of contributing to the mishap in only seven cases. Excessive motivation and overconfidence were found with more regularity, particularly in accidents occurring during exercises or tests. Most of the latter also involved a violation of flight discipline.

Structural failure of the aircraft as a result of pilot-imposed G forces or suspected performance decrements due to acceleration comprise the mishaps positive for that variable. Smoke and fumes distracted the crew from flying the aircraft as well as limiting vision. Heat refers to cockpit fires precipitating aircraft abandonment in addition to a few occasions where environmental heat load was suspected of reducing performance. As expected, restrictions in visibility were the most frequently cited environmental factors (Table VIII). "Other weather" usually referred to ingestion of ice into an engine, thunderstorm penetration or hail.

Other factors are listed in Table IX. Manifestations of errors in judgment were most frequent in this group. Misjudging speed or distance, delay in taking action or selecting the wrong course of action, and violations of flight discipline were prominent. While some of the discipline violations were of the gross, willful variety, several appeared to be actions tacitly approved by both peers and supervisors.

Summary

Operator error is involved in over 50 percent of recent USAF aircraft accidents. The psychophysiologic and environmental factors assessed by the flight surgeon during accident investigation serves as a stimulus for the human factors investigator and a convenient, albeit imperfect, classification of the human error involved. These factors as they applied to the operator at the controls were tabulated for USAF major and minor aircraft accidents which occurred during the period 1 January 1974-31 December 1977. Factors reflecting errors in judgment, disturbances in attention, training and experience deficits, disorientation, and aggressiveness were among the most frequently cited.

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TABLE I

MAJOR AND MINOR MISHAPS BY CAUSE CATEGORY 1974-1977

Category	1974	1975	1976	1977*	Total
Operations Factor, No Logistics Factor	51	42	50	48	191 (40%)
Operations and Logistics Factors	24	19	13	18	74 (16%)
Logistics Factor, No Operations Factor	52	50	42	41	185 (39%)
All Other	14	5	3	3	25 (5%)
TOTALS	141	116	108	110	475 (100%)

*Mishap classification changes in 1977. Includes all Class A, but only 21 Class B mishaps.

TABLE II

SUPERVISORY FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
Inadequate Breifing	13	2.7	16	3.4	6.1
Ordered/Led Beyond Capability	11	2.3	9	1.9	4.2
Poor Crew Coordination	22	4.6	35	7.4	12.0
Other (Supervisory)	10	2.1	7	1.5	3.6

TABLE III

PREFLIGHT FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
Faulty Flight Plan	2	0.4	4	0.8	1.3
Faulty Preflight of Aircraft	0	0	3	0.6	0.6
Hurried Departure	1	0.2	10	2.1	2.3
Delayed Departure	1	0.2	5	1.0	1.3
Inadequate Wx Analysis	4	0.8	8	1.7	2.5
Other (Preflight)	3	0.6	4	0.8	1.5

TABLE IV

EXPERIENCE TRAINING FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
Inadequate Transition	4	0.8	13	2.7	3.2
Limited Total Experience	18	3.8	50	10.5	14.3
Limited Recent Experience	12	2.5	33	6.9	9.5
Failure to Use Accepted Procedures	68	10.5	38	8.0	18.5
Other (Training)	9	1.9	13	2.7	4.6

TABLE V

DESIGN FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
Design of Instruments/Controls	3	0.6	8	1.7	2.3
Location of Instruments/ Controls	3	0.6	9	1.9	2.5
Failure of Instruments/Controls	19	4.0	14	2.9	6.9
Cockpit Lighting	1	0.2	7	1.5	1.7
Runway Lighting	3	0.6	3	0.6	1.3
Lighting of Other Aircraft	3	0.6	3	0.6	1.3
Work Space Incompatible with Man	3	0.6	0	0	0.6
Other (Design)	13	2.7	14	2.9	5.7

TABLE VI

COMMUNICATIONS FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
Misinterpreted Communications	7	1.5	11	2.3	3.8
Disrupted Communications	6	1.3	12	2.5	3.8
Language Barrier	0	0	5	1.0	1.0
Noise Interference	3	0.6	4	0.8	1.5
Other (Communications)	7	1.5	12	2.5	4.0

TABLE VII

PSYCHOPHYSIOLOGIC FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
Acute Illness	2	0.4	1	0.2	0.6
Other Preexisting Disease/ Defect	0	0	5	1.0	1.0
"Get Homeitis"	1	0.2	6	1.3	1.5
Sleep Deprivation, Fatigue	3	0.6	6	1.3	1.9
Fatigue, Other	0	0	14	2.9	2.9
Missed Meals	0	0	6	1.3	1.3
Drugs, Not Prescribed	0	0	1	0.2	0.2
Visual Illusions	6	1.3	21	4.4	5.7
Unconsciousness	0	0	12	2.5	2.5
Disorientation/Vertigo	14	2.9	36	7.6	10.5
Hypoxia	1	0.2	1	0.2	0.4
Hyperventilation	0	0	1	0.2	0.2
Carbon Monoxide	2	0.4	0	0	0.4
Inattention	3	0.6	20	4.2	4.8
Channelized Attention	19	4.0	69	14.5	18.5
Distraction	11	2.3	60	12.6	14.9
Preoccupation with Personal Problems	0	0	7	1.5	1.5
Excessive Motivation to Succeed	5	1.0	29	6.1	7.1
Overconfidence	7	1.5	20	4.2	5.7
Lack of Self-Confidence	0	0	5	1.0	1.0
Lack of Confidence in Equipment	1	0.2	4	0.8	1.0
Apprehension	1	0.2	20	4.2	4.4
Panic	2	0.4	17	3.6	4.0
Other (Psychophysiologic)	1	0.2	16	3.4	3.6

TABLE VIII

ENVIRONMENTAL FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
G-Forces, Inflight	3	0.6	20	4.2	4.8
Decompression	3	0.6	1	0.2	0.8
Vibration	5	1.0	1	0.2	0.8
Glare	1	0.2	6	1.3	1.5
Smoke, Fumes, Etc.	14	2.9	5	1.0	4.0
Heat	11	2.3	3	0.6	2.9
Cold	2	0.4	3	0.6	1.0
Visibility Restriction Wx, Hail, Darkness	48	10.1	13	2.7	12.8
Visibility Restriction, Icing, Windows Fogged	0	0	3	0.6	0.6
Visibility Restriction, Dust, Smoke in Acft	7	1.5	4	0.8	2.3
Weather, Other	14	2.9	6	1.3	4.2
Other (Environmental)	17	3.6	8	1.7	5.3

TABLE IX

OTHER FACTORS

Factor	Definite No.	Definite % of Mishaps	Suspected No.	Suspected % of Mishaps	Overall % of Mishaps
Habit Interference, Used Wrong Control	4	0.8	10	2.1	2.9
Confusion of Controls, Other	2	0.4	3	0.6	1.0
Misread Instrument	2	0.4	3	0.6	1.0
Misinterpreted Instrument	4	0.8	11	2.3	3.1
Misled by Faulty Instrument	5	1.0	7	1.5	2.5
Visual Restriction by Equipment/Structure	2	0.4	10	2.1	2.5
Task Oversaturation	8	1.7	32	6.7	8.4
Inadequate Coordination or Timing	12	2.5	24	5.1	7.6
Misjudged Speed/Distance	42	8.8	57	12.0	20.8
Selected Wrong Course of Action	89	18.7	43	9.1	27.8
Delay in Taking Action	76	16.0	36	7.6	23.6
Violation of Flight Discipline	33	6.9	12	2.5	9.5
Navigational Error	2	0.4	4	0.8	1.3
Inadvertent Operation, Self-Induced	10	2.1	17	3.6	5.7
Inadvertent Operation, Mechanically Induced	9	1.9	8	1.7	3.6
Other	11	2.3	5	1.0	3.4

Human Fallibility Versus Management Oversights

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The views expressed by the author do not necessarily reflect positions taken by Scandinavian Airlines.

"If you wish to speak with me, you must first define your terms."
—Voltaire

Recently there has been a tendency in listing of causes in accident reports, and in the minds of the preachers of loss control programs, to get Fallibility and Oversights mixed up—either out of ingenuity or out of lack of ability. This mix-up leads to the dissemination of misleading information, and I'm concerned with the impact. There are reasons for this calamity, at least two, I'm sure: "The good one and the real one"—take your choice.

Oversight, says Webster, is an "inadvertent omission or error."

I question the validity of this definition when applied to investigation and loss control programs. We can hardly call it inadvertent when we ask for and get legislation which permits the investigation authorities themselves to determine the extent of an investigation down to the most minute detail. Yet, as an outside viewer, this access to follow–through is still only utilized to a limited extent. I submit that too much up-to-date feedback is lost. I get particularly disturbed when manpower and resources are wasted on loss control programs of a dubious nature such as those based upon assimilation of information on a voluntary basis.

Do I have an ancient, banal, and academic point of view? Perhaps, but not everywhere. Just a little over a year ago a major business enterprise in this country, with 3200 aircraft in its corporate and executive fleet, lost an airplane under instrument conditions.[1] The investigation disclosed that policies prescribing minimum equipment when operating under instrument conditions were unwritten. They were probably unwritten for a number of good reasons, the same good reasons given for (a) lack of prescribed routine inspections by the authorities, and (b) lack of indepth investigations of previous mishaps inside the company. Both actions might have caught the deficiency.

At first glance it simply doesn't make sense. At a second glance it does, and here the situation can best be described by quoting a former dean at USC, Carl Hancey:

> Follow-up and feed-back are two essential, and easily neglected, ingredients of accident prevention. Both are readily postponed because the urgent has priority. Yet the urgent can often be prevented by prompt and adequate follow-up and feed-back.[2]

The point made about the urgent having priority is highly familiar to accident investigators, to safety directors, and to management by-and-large. Yet when this excuse is used by an accident investigator, we are most certainly not talking about "inadvertent omission," but rather, we have already started a series of trade–offs which mean that our effort when finally viewed has lost its momentum.

In a government or company investigation there are obvious financial limitations to the attention that can be directed towards an individual mishap, but my point—and it bothers me—is that we as a rule exercise more attention to severity than to frequency, thus generating for ourselves a vicious circle with too many "urgent matters" to attend to. If only this was fully understood and accepted by those directly involved with investigations, it would make for better conditions for those involved in devising and implementing loss control programs.

Oversight, Webster also says, is "management, supervision."

One still has to be rather careful with regard to reading cause determinations in the majority of published accident reports. Particularly when the sheer amount of information can easily saturate one's mind to the point where there are no reserves left for individual assessment of the presented facts. Consequently it becomes even easier for safety directors and the like to lulled into a complacent attitude towards how one's own business is run. Listen if you will:

Case No. 1: "(It was) determined that the probable cause of the accident was the failure of the pilot to maintain a positive rate of climb after a take-off toward an unlighted area in night, visual meteorological conditions. The failure to maintain a positive rate climb resulted in a collision with trees in the departure path. An overweight condition of the aircraft may have contributed to the pilot's actions."

Case No. 2: "The accident was caused by the misjudgment of the pilot in command in executing the landing."

In case no. 1, nowhere does the accident report show penetration into the "why" behind the overweight situation. For example, were loading instructions relevant for the aircraft version, was there a load control supervisor, and if so, why didn't he detect the situation. If there was no load control supervisor, why not?. . .and the like. In case no. 2, no study of the system that should have ensured adherence to detailed requirements for monitored approaches was carried out. Why was the policy not followed? Was it outdated? Was it not accepted by the pilots and thus only carried out sporadically? If so why had the situation gone undetected?

The common denominator in these cases appears to be the conviction that "the buck stops approximately three feet aft of the instrument panel." And the future looks rather gloomy, should one want to go along with Mr. Gerald Bruggink's statement[3] that, with regard to true human error, additional research will teach us nothing that we do not already know.

This is not so. Human errors in the *management* of ill–fated operations are seldom, if ever, subjected to the same microscopic analysis which is applied to the "whys" of a breakdown in crew behavior, a controller mistake, or a mechanic's error. Here again ample attention is given to the urgent, while follow-up and feed-back to the management level are neglected. Now, why this is true I don't know for certain, but I have a suspicion. An investigator primarily engaged in investigation has little or no room—and often no possibility—for staying adequately cognizant with the dynamics of management in a changing environment. No offense is intended here, because he has his hands full with his obligation to stay abreast with laws and regulations and the latest developments in investigative techniques, while constantly being haunted by the ghosts of litigation, paperwork, et cetera. The situation is reversed for those of us who are primarily engaged in before–the–fact activities such as lecturing and acting as management consultants. To him or her the task of assembling an aircraft that comes unglued against the side of a mountain would be a most disturbing experience. However, we are not here to make excuses for one another, so I shall concern myself with the management point of view and try to illustrate where future investigations can be of even greater assistance in timely implementation of safer operational procedures.

Every function in an organization must be managed. That is, action must be planned, organized, co-ordinated, and directed before it is taken, then controlled to ensure that what is done is both appropriate, timely, and within the economical constraints of the organization. Our function in loss control is to locate and define the operational errors that allow mishaps to occur, by asking why and by asking whether or not certain known effective controls are being utilized. Key words to expand upon are:

—objectives
—qualifications
—conditions.

Having been engaged in a development of new policy, how often have you not afterwards realized that the setting of superior objectives was lacking? The results of the resultant ad hoc planning are obvious, and are manifested, for example, in an increasing number of unscheduled events and mishaps throughout the system. To set objectives, managers rely upon external and internal resources. Ideally, additional internal resources in a typical flight operations department would preclude the need for "quick fixes." I fail to see this ideal situation in the future no matter how far I look.

The changes imposed by the working environment are well known to those present. Perhaps what is far less recognized is the impact of the changes in the social environment in our society. Once upon a time—which even I can remember—an order was an order and the employees would never question its validity. A co-pilot would not question his captain. Remnants of this attitude still come to light sometimes, and when it has been exercised in its extreme, accidents have followed. This division between the captain and his crew was maybe most recently exemplified as a cause factor in the Canary Islands tragedy. I take it that you already have sensed this speaker as an advocate of flight deck management that stimulates timely and free flow of information.

Getting back to flight operations management, there is no doubt that academic advice on employee involvement is relevant as long as it doesn't prohibit good and urgent decision–making, and as long as professional procrastination is eliminated. Actually it is not very mysterious that the highly permissive trend in our society, which manifests itself in finding excuses for most of the harmful behavior of individuals, should find its way into our professional sphere. The trend now is toward involvement of employees – through their associations – in the decisions-making process, often to the most minute details. But they cannot accept – and have no intention of accepting – responsibility. These new real-world day-to-day interactions in the employer-employee relationship must be known if one is to make a valid investigation and recommendation. But I caution both parties, the associations and the management: associations, against going further overboard with their hampering effects; and management, against using this changed situation as an easy excuse for faltering in decisions. The solution is modesty and honesty. On these terms it is possible to have both long-range objectives and prosperous group involvement.

Suppose that one long-range objective would be setting policies for the hiring of new personnel, specifically with regard to qualifications and terms of employment. Another could be an evaluation of current company policy, its effectiveness and feed-back to the individual when performance is in question. The logical steps here would be to look at the present and then determine the future. Reassessing qualifications and performance is highly relevant. For example, cockpit crew qualifications might be reassessed in some places because of dramatic increases in the number of mishaps, and in other places in order to be prepared for having to choose from a body of applicants which is totally different from those of the past. For whatever reasons, professional organizations and management are far from being in agreement on the issues. The dreamer would make quite a different statement.

It is a discouraging combination to be overly thrilled by the performance of our second-generation aircraft and their spin-offs, and simultaneously to witness a substantial lack of managerial abilities. When substandard performances are detected, we should ask if effective controls were being utilized. Why or why not? Specifically, are there appraisal systems that deliver honest feed-back for a given performance? The amount of deceptive evaluation that is currently being distributed can be verified by reading the analyses in recent and sometimes spectacular accident reports.

It is due time now, when areas such as underlying causes and character assurance have been covered, to concentrate on two key positions molding and measuring our end product – the positions of instructor and supervisor. Their managerial performance basically is dependent on three primary variables: abilities, role perception, and effort expended.[4]

Abilities
Selection
Individual characteristics
Sufficient knowledge
Ability to perform and control

Role Perception
Management blessing or directions
Alignment with the organization
Motivators
Training

Effort Expended
Is it worthwhile
Rewards after goal enrichment
Does the subject really need attention
Effective measurement of performance

All of these must be taken into account. How the individual will perform after fulfillment of these three variables then depends upon:

—his opinion of the value of the rewards (status, promotion, increased influence, etc.)
—the connection he sees between his effort and those rewards

Make a short mental review of the last time you investigated into the areas presented in this short overview of "musts" for managerial performance. Perhaps the closest we could come was when the paperwork showed "checks performed."

Very briefly, let's redirect our attention to the professional associations and their responsibility for a member's welfare. With the deficiencies just described, as association has rightful reasons to object to a member being axed all of a sudden because of lack of proficiency. Your prodding at this level of management will have a most positive effect — the only expense being your time.

Fallibility, says Webster, is "liability to err."

(Fallible – (1) liable to be erroneous; (2) capable of making a mistake).

Should you, on account to the above-mentioned definition of fallibility, already have decided to shut off your receivers — after all, "to err" is for everybody else — then try to recall the last time you filled out your income tax return. Those small mistakes are largely determined by three factors:

—knowledge
—proficiency
—attitude

Your *attitude* drove you to seek *knowledge* in order to perfect your *proficiency*. Precisely the same ingredients determine whether an individual is liable to err in his working environment. Since we earlier covered system deficiencies which, because of lack of effective measurements, invite substandard performances, it is adequate now to touch upon attitude only. To narrow it further down, let's discuss attitudes as a function of motivation. Let there be no doubt: I'm fully aware of the insignificant possibilities an investigator has to describe the climate of an organization in his accident-reporting procedures. The following is consequently merely intended as an aid in answering future questions where pure speculation would otherwise wise have been as far as we could have gone. This list[5] spells out climate factors as well as a number of formal programs for motivation.

Media for Motivation

Climate		*Formalized Programs*	
Expansion	Goal orientation	Planning	Attitude surveys
Delegation	Stability	Performance review	Work simplification
Innovation		Educational assistance	
Fluid communication		Compensation	

We will review a few.

Expansion. It is hard to be a bad anything if one is fortunate enough to work in a growth organization. Consequent changes even make it possible to live with, for example, a supervisor or a manager who is task-oriented rather than people-oriented. It won't last forever, changes will simply make him "go away." Expansion offers opportunities, a chance to grow professionally into new positions, acquire more responsibility if desired, and so on.

Innovation. Studies show that where there is a high rate of utilization of suggestions, the level of motivation is consistently high. Without getting into too many details it should be noted that a situation where management does *not* lend its ear to the employees would most likely indicate a system which hasn't been able to adapt to a change. For example, the addition of new equipment to the inventory almost always leaves somebody out and leaves teeth grinding at some point in the hierarchy. "Permissive innovation," such as suggestions for procedural changes, seems to vary linearly with the age of the new and interesting gadgets.

Goal orientation. This factor might warrant a little more attention. In passing, fluid communication depicted in a chart does *not* refer to indulging in the liquid temptations of life, but describes a state of communication which makes a point of doing away with as much inter-office paper work as possible. The task of establishing a common goal rightfully ranks very far up on the management's "must-have" list. Far enough up? I don't know, but what over the years has been called complacency, underlying causes, and latest, lack of character assurance, is perhaps only a symptom of conditions where we have not succeeded in establishing common goals. As a matter of fact it appears that we often succeed totally in establishing goals, outside the organization. For instance, as in the case of cockpit crews as evidenced by the individual's bidding for duty. In a very high percentage of cases, requests are determined by a diversity of outside interests.

If one would go along with this line of theorizing for cause determination after a breakdown in cockpit discipline, the next question should be: What can be done to assure the individual a higher degree of feeling part of, feeling appreciated – in short, job enrichment? Thoughts on discipline and motivation are readily available from numerous earlier discussions. Deducting from their fragmented use, apparently the information is considered invalid, impractical, too difficult, to academic, or whatever. Now is this really true? I don't think so, but loss control programs of this nature simply didn't fly for the same reasons a number of other programs didn't get airborne, *e.g.* they weren't production oriented, or were unrealistic in demands and recommendations — the list is long.

Two suggestions for consideration to be included in the next program: Maybe some sort of job rotation where practical would mean improvement, and maybe looking into the interaction between the social changes and the changes in working conditions could be advantageous. There are peaks in both areas and they seldom coincide. Just mind-triggers – starters, if you like – for the next company policy review.

In the field of human behavior, the ability for innovation being unlimited, we long ago invented redundancy in the hardware, and, similarly, bridged the gap between production and safety. Renewed interest for the system and its procedures – quality assurance – should be worthwhile.

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When Day Is Done And Shadows Fall, We Miss The Airport Most Of All

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ABSTRACT
Both the effectiveness of pilot training and the safety of flight can be influenced by the distribution of texture in the visual scene, the distance to which the eyes accommodate, and the associated shifts in the apparent size and distance of objects in central and peripheral vision. Results to date indicate that these factors are involved in various misjudgments and illusions experienced by pilots: (1) when searching for other airborne traffic or targets, (2) when making approaches to airports over water at night, (3) when breaking out of low clouds on a final approach to a landing by reference to head-up or head-down displays, and (4) when practicing simulated approaches and landings or air-to-surface weapon deliveries by reference to synthetically generated visual systems.

WHAT THIS TALK IS ABOUT

1. *Making landing approaches over water on a dark night toward a brightly lighted city.*
2. *Looking for intruding airplanes from the flight engineer's seat.*
3. *Sitting inside a screened porch and trying to read a NO FISHING sign down by the lake.*
4. *Projecting afterimages onto the walls of a football stadium.*
5. *Watching the moon rise over Miami.*

What do these seemingly unrelated activities have in common? And what does all this have to do with head-up flight displays, head-down imaging displays, helmet-mounted displays, and visual systems for contact flight simulators? In each case visual illusions occur: systematic misjudgments of size and distance relationships, departures by varying amounts from the so-called "size-distance invariance hypothesis."

Visual Illusions In Flight

When pilots make approaches and landings with any type of imaging flight display projected at unity magnification, they tend to come in fast and long, round out high, and touch down hard. On the final approach the runway appears smaller, farther away, and higher in the visual field than it does when viewed directly from the same flight path on a clear day. This finding has been obtained independently both with flight periscopes and with simulated contact visual systems (Roscoe, Hasler, and Dougherty, 1966; Palmer and Cronn, 1975; Roscoe, 1976).

In stark and tragic contrast, when pilots make approaches to landings over water on a dark night toward a brightly lighted city, the runway appears larger, nearer, and lower in the visual field than it does when viewed directly from the same flight path on a clear day. On several occasions in recent years, a commercial airliner has landed in the water short of the airport when making an approach at night. Kraft (1968; 1978) has shown that pilots will systematically misjudge the height and "tilt" of the runway and make low approaches under these conditions.

In another experiment by Kraft, Farrell, and Boucek (1970), a group of pilots judged the threat of midair collision with intruding airplanes at varying distances and angles, none of which represented an actual collision threat. The pilots were presented a series of pictures projected onto a screen viewed from a mocked up Boeing 737 cab. When the judgments were made from the flight engineer's seat, as opposed to the pilot's seat, the same pilots consistently judged the intruders to be a greater threat at all ranges out to 3500 feet. From the rear seat, the intruders appeared reliably larger and closer than from the front seat.

The viewpoint from the flight engineer's seat is nearly two meters from the windshield aperture; from the pilot's seat it is less than one meter. Furthermore, the view from the flight engineer's seat includes much of the instrument panel when searching for intruders. When searching head-up from the pilot's seat, the instrument panel appears in the dim periphery; the pilot sees mainly empty space through a windshield that reflects glare and may be dirty or scratched. These conditions suggest that pilots may unknowingly be subject to the "Mandelbaum Effect."

In 1960, Mandelbaum reported an informal experiment in which he asked subjects to read a distant sign from a screen-enclosed porch. For each observer he found a critical distance from the screen at which the sign could not be read, although it was clearly legible from other distances, either nearer or farther. Upon questioning, the subjects realized that they could not help focusing on the screen from the critical distance but could readily focus on the sign by moving either nearer or farther from the screen or by quick movements of the head from side to side. Mandelbaum concluded that the "effect" was due to involuntary accommodation.

It was noted that the critical distance from the screen varied from person to person, with an average distance of about one meter. In an ingenious series of experiments at Pennsylvania State University, Owens (in press) has subsequently determined that the critical distance is the distance of the individual's dark focus, or resting accommodation. For the young, healthy eyeball, that distance on average is slightly less than one meter (slightly more than one diopter in optical terms), the distance of the dirty windshield from the pilot. Almost any textured visual stimulus at that distance is a powerful involuntary "accommodation trap."

A Scientific Mystery

In addition to the misjudgments of size and distance discussed so far, bias errors in depth discrimination have been discovered independently by designers of submarine periscopes, tank periscopes, laboratory microscopes, "one-power" scopes for shotguns, and helmet-mounted CRT displays. All require some optical magnification to cause objects to appear at the same distances as when viewed by the naked eye. Furthermore all involve reductions in the field of view and in the textural gradient that serves as the stimulus for distant accommodation. These biased perceptions of size and distance are not fully explained, at least not sufficiently to give comfort to the pilots and passengers of airplanes.

The mystery manifests itself in many forms that have puzzled psychologists from Ptolemy, who tried to explain the "moon illusion," to Young (1952) who had subjects project visual afterimages onto the walls of the Ohio State football stadium from various distances across an open field. The farther the afterimage is projected, the larger it appears, but not in direct proportion as would be predicted by the size-distance invariance hypothesis. The "size" of the moon also varies with the extent of the visible textural gradient, appearing larger over a distant horizon than it does over a near horizon, as shown by Kaufman and Rock (1962).

Throughout the literature of vision research may be found additional examples of unexplained experimental findings and assorted "optical illusions" that may be related to the observations by Wheatstone (1852) and Helmholtz (1867/1962), and more recently verified experimentally by Biersdorf and Baird (1966), by Leibowitz, Shiina, and Hennessy (1972), and by Roscoe, Olzak, and Randle (1976), that the apparent size of an object changes with shifts in the distance to which the eye is accommodated. The phenomenon can be illustrated by any one of several simple experiments.

For example: close one eye, focus your open eye on your thumb held at arm's length, observe a more distant object such as a window or a picture on the wall, and while continuing to focus on you thumb, draw it toward you and observe the change in the size of the window or picture.

Better yet: look at the moon through a peekhole through your fist, alternately closing and opening the other eye. Not only can the moon on the horizon be made to appear smaller, but also the moon overhead can be made to vary in apparent size by a surprising amount.

Investigating the Mystery

To investigate the possibility that shifts in apparent size are associated with shifts in visual accomodation distance, an experiment was conducted at NASA's Ames Research Center in which visual accommodation was measured continuously, using a Crane-Cornsweet infrared optometer, while subjects viewed discs that subtended a constant 3° angle at distances ranging from ¼ to 4 meters, with and without the distance cues provided by a sometimes visible textural gradient (Roscoe, et. al., 1976). Shifts from binocular to monocular viewing were accompanied by shifts in accommodation, both inware and outward, toward an intermediate distance of a little less than one meter (1.13 diopters on average).

The reliable inward shifts from the most distant targets at 4 meters were accompanied by reliable reductions in apparent size. A contingency analysis, summarized in Table 1, showed that the correlation between shifts in apparent size and shifts toward the resting accommodation distances of the individual subjects increased with target distance. At one meter there was a chance relationship, at 1½ meters the contingency was reliable at the $p < .01$ level, at two and four meters the p values were $< .002$ and $< .001$, respectively. At four meters the contingency was almost 2 to 1 greater than chance, which shows a highly likely relationship but still leaves a lot of variance unaccounted for.

To clarify the relationship between accommodation and apparent size, 12 of the original 16 subjects were tested on near (¼-meter) and far (4-meter) targets with a 1-mm diameter artificial pupil placed 8 cm from the entrance plane of the eye used for monocular viewing. An artificial pupil allows the eye to lapse farther toward its resting position without causing a blurred image (Hennessy and Leibowitz, 1975). In binocular viewing the second eye was unobstructed, thereby requiring more accurate accommodation to obtain a clear image of the target. The results of this comparison are shown in Table 2.

TABLE 1.

Summary of Contingent Probability Analysis of Predicted Judgments of Relative Size with Corresponding Shifts in Accommodation Size (Chance Probability of Contingency = 0.25).

	Distance to Target, Meters			
	1	1½	2	4.
Chance Contingency	.25	.25	.25	.25
Observed Contingency	.23	.36	.38	.45
Chi²	——	7.59	11.34	25.01
P	n.r.	< .01	<.002	.001

The arrows in Table 2 indicate the shifts in accommodation toward the resting position from binocular to monocular viewing, and the plus-signs indicate coincidence of positive accommodation shifts and "Monocular Smaller" judgments, or conversely, negative accommodation shifts and "Monocular Larger" judgments. The introduction of the artifical pupil clarifies the relationship: for the 4-meter target, the coincidence is virtually perfect, 23 of 24 cases in agreement for the ¼-meter target, accomodation shifted in the predicted direction 9 times in 12 under both light and dark ambient illumination, but only in the dark is there evidence of a trend toward "Monocular Larger" judgments with outward shifts in accommodation (9 of 12 cases, $p < .10$).

TABLE 2

Shifts in Measured Visual Accommodation and Judgments of the Relative Size of Three-Degree Discs, Viewed Monocularly (M) and Binocularly (B) at Distances of 25 cm (4.00 Diopters) and 4 m (0.25 Diopter) Under Normal Room Lighting (Light) and Reduced Illumination (Dark) with an Artificial Pupil in Front of the Left (Monocular) Eye

Distance to Target Disc

	25 cm (4.00 diopters)				4 m (0.25 diopter)			
	Dark		Light		Light		Dark	
S	B	M	B	M	M	B	M	B
1	2.64 →	2.07 +	3.07 →	2.27 +	0.69 ←	0.24 +	1.18 ←	0.28 +
2	3.70 →	2.81 +	3.88 →	2.50	1.06 ←	0.32 +	0.12 ←	− 0.43
3	3.86 →	2.86 +	4.42 →	1.78 +	0.87 ←	0.26 +	− 0.21 ←	− 0.78 +
4	0.26 →	0.17	0.49	0.79	− 0.15 ←	− 0.67 +	0.58 ←	− 0.97
5	1.86 →	1.51	2.18 →	1.06	− 0.12 ←	− 0.61 +	0.17 ←	− 0.33 +
6	4.13 →	2.86	4.40 →	3.38	0.07 ←	− 0.14 +	0.53 ←	− 0.56 +
7	3.04 →	1.76 +	3.75 →	2.14	1.02 ←	0.68 +	0.63 ←	0.39 +
8	4.30 →	2.66 +	4.66 →	4.12 +	0.26 ←	− 0.11 +	− 0.10 ←	−0.54 +
9	2.18 →	1.83 +	1.71 →	1.07 +	− 0.13 ←	1.02 +	0.08 ←	− 0.84 +
10	3.13 →	1.94 +	3.95 →	3.15 +	0.58 ←	0.06 +	0.22 ←	0.02 +
11	2.58 →	2.24 +	3.12 →	2.51	1.73 ←	0.35 +	1.25 ←	0.45 +
12	3.32 →	1.98 +	3.08 →	1.54 +	0.18 ←	0.05 +	− 0.33 ←	−0.41 +
Mean	2.92	2.06	3.23	2.19	0.51	− 0.05	0.23	− 0.31

Legend: Arrow indicates that shift from binocular to monocular accommodation is toward intermediate distance. + indicates that a positive shift in accommodation is accompanied by a judgment of "Monocular Smaller" or, conversely, a negative shift by "Monocular Larger."

In addition to the fact that correlations do not guarantee causal relationships, these findings are equivocal because of the confounding of shifts in accommodation, which were measured, with shifts in convergence between binocular and monocular viewing, which were not measured. Furthermore, the accommodation data are not sufficiently clean for comfort, and a few individual data are suspect by inspection. Nevertheless, neither the data nor their implications can be discounted as completely spurious in the absence of better data. In any case, the mystery is not so much how we judge the size and distance of near objects that afford binocular cues as it is how we judge distant objects that provide only monocular cues.

To gain a better understanding of the effects of visual accommodation upon judgments in tasks involving complex dynamic visual scenes, another experiment was recently conducted at Ames Research Center using the Crane-Cornsweet infrared optometer and experimental night-landing visual display generated by a digital computer (Randle, Roscoe, and Petitt, in press). Professional pilots made judgments of whether they would undershoot or overshoot their landing aimpoint as the computer flew their simulated jet transport on final approaches to the computer-generated airport scene.

Experimental variables included: (1) the magnification of the visual scene, which was varied in five steps between 0.83 and 1.67, (2) the visual accommodation distance induced by five sets of ophthalmic lenses with dioptric powers ranging from zero to three, (3) the actual descent path of the simulated airplane, which included overshoots and undershoots as well as correct landing approaches, and finally, (4) whether the landing scene was presented as a real image viewed directly on a TV monitor or a virtual image produced by a collimating field lens mounted between the monitor and the pilot.

The first finding was that the eye does not respond obediently to the accommodation distances called for by ophthalmic lenses; the eye is lazy and reluctant to be drawn away from its intermediate resting position. The brain, in turn, seems happy to accept an amazingly out-of-focus image uncritically and, in fact, without conscious recognition that it is out of focus. In response to ophthalmic lenses covering the range from zero to three diopters, the pilot's eyes, on average, accommodated to the virtual and real images over ranges of only 1.27 and 1.46 D, respectively.

Despite the relatively small shifts in accommodation "induced" by the ophthalmic lenses, there were statistically reliable interactions in the predicted directions between actual accommodation levels and the pilot's judgments of whether they would overshoot or undershoot their landings. There is now little doubt that such judgments are related in some complicated way to visual accommodation distance, which, in turn, is affected far more by the various viewing conditions encountered in the spectrum of normal flight operations than it was by the ophthalmic lenses used.

An experiment typically raises more questions than it answers, and this one was no exception. The pilots made two judgments along the final approach, the first at 20 seconds, or 4000 feet, before passing the runway aimpoint and the second at 10 seconds, or 2000 feet. With unity image magnification, they predominantly indicated an overshoot on the first judgment and an undershoot on the second. If they had been flying manually, they would have tended to overshoot. Veridical judgments were obtained at the nearer distance with an image magnification of 1.25, as has been found with flight periscopes (Roscoe, et al., 1966).

The possible explanations for this curious reversal in judgments are infinite. Of course, the finding might be unique to the particular computer-generated night visual scene used. However, based in Kraft's findings, it could be that the pilots habitually make low approaches at night to avoid overshooting and, when they are still 4000 feet out, "expect" the runway to appear as it does from a position below the 3-degree approach path. At 2000 feet out, they can see their position better and maintain thrust to carry them to the touchdown.

At 4000 feet out the dominant cues for accommodation, namely, the airport lighting system and the lighted city beyond, appear as a thin horizontal band of point sources at a relatively great distance; far accommodation is required to resolve the scene. As the airplane approaches the runway, the band deepens and comes nearer; the runway lights are more easily resolved, and accommodation drifts inward from its distant "trap." The so-called "size constancy" of the runway is not maintained; in effect it shrinks a little, and pilots tend to overshoot their aimpoint once they have safely crossed the threshold.

To test this wild speculation, two experiments have just been conducted at the University of Illinois (Iavecchia, 1978). A ½-degree collimated disc of light, simulating the moon, was projected onto a 45-degree combining glass so that it appeared as a virtual image superposed on the outside visual scene (a la Kaufman and Rock). A second, comparison "moon" of adjustable diameter was presented as a real image at a distance of one meter in an otherwise dark surround. The two views were presented alternately in the same visual position by means of a sliding mirror arrangement, and the subject adjusted the diameter of the comparison until a satisfactory apparent-size match was obtained.

In the first experiment, conducted in clear daylight, subjects viewed the collimated moon against the scene visible from corresponding windows of the third to the eighth floors of the Psychology Building overlooking the Urbana campus and residential area. On the third floor the moon was projected against the roof of a nearby sorority house, and on successively higher floors against successively more distant rooftops and large trees. At the fifth and sixth floors it appeared just above the horizon, and on the seventh and eighth, higher and higher above the horizon. The apparent size of the moon increased from the third to the sixth floors and then reversed itself as it rose above the horizon.

The mean apparent size ratios of the moon, relative to its apparent size when projected onto a newspaper viewed from one meter, were (3rd floor) 1.143, (4th) 1.250, (5th) 1.311, (6th) 1.364, (7th) 1.330, (8th) 1.282. These means differed reliably ($p < .05$). As the moon was projected against increasingly distant surfaces from the 3rd through the 6th floors, its apparent size increased monotonically. From the 6th floor, the moon was projected against the sky just above the most distant surface texture. From 7th and 8th floors, it was projected against the sky higher and higher above the horizon.

In the second experiment the distance and vertical position of visible texture was manipulated more systematically by viewing the scene from the fifth floor through a series of masks. Four of the masks revealed horizonal bands of texture in the Near, Intermediate, Far, and Very Far visual fields. Another mask obscured all surface texture in the visual field so that the moon was projected against the open sky just above the "horizon" formed by the mask. Finally, a clear mask revealed the entire scene. The results of these tests clarify the situation.

When viewing the moon against the "unmasked" background scene (clear-mask control condition), its apparent size ratio was 1.369. With the mask that revealed only Near texture, it was 1.225; for Intermediate texture, 1.235; for Far texture, 1.289; and for Very Far texture, 1.395. With the mask that obscured all surface texture below the horizon (similar to a view of the moon overhead), the apparent size ratio dropped abrupt to 1.136, only slightly large than its apparent size when projected onto the newspaper viewed from a distance of one meter.

What these two experiments show is that the apparent size of objects well beyond the 6-meter, or 20-foot, distance to "optical infinity" change reliably with the changes in the spatial distribution of textural stimuli to accommodation in the background visual scene. The greater the distance through empty space to resolvable texture, the larger the apparent size of centrally fixated objects, such as the moon or an airport runway. As the textural pattern extends downward or moves nearer, the central object fails to maintain a constant "apparent size." As the pilot approaches a runway over water at night, his visual image of the runway grows, but not in perfectly inverse proportion to distance remaining.

When no resolvable background texture is present, as when viewing the moon against a clear sky, the textureless moon provides an inadequate stimulus to distant accommodation and shrinks in size, as do the symbols of a head-up display when flying in clouds. Even a partially clouded sky apparently cannot hold distant accommodation to a textureless collimated moon or display symbols. Thus, the "moon illusion" is not manifested by a spuriously large moon on the horizon but rather by a perceptually shrunken moon overhead.

Implications For Flight Safety

For years Kraft, Hennessy, and several other investigators have recommended that pilots routinely wear bifocal lenses at night and when making IFR approaches in daylight conditions. The lower section would optimize their vision for instrument panel and chart viewing distances. The upper section would provide negative correction to distant accommodation for outside viewing. Owens and Leibowitz (1976) have shown that, if night drivers with normal vision are asked to select the lenses that allow them to see best, they will choose those with a negative correction halfway between their dark focus and optical infinity.

To combat the possible underaccommodation experienced by some pilots while making "black hole" approaches over water at night, lead-in light buoys should be considered and tested for use at major airports. Although no specific data are available, it would be expected that, in the absence of visible texture in the near field, pilots with extremely distant dark focus would be the ones who tend to make low approaches at night and occasionally land in the ocean. Perhaps they should wear positive corrective lenses at night, but evidently no such tests have been made.

The use of head-up displays for night and IFR approaches warrants further investigation. It has been tacitly assumed and strongly asserted by the advocates of such displays that the collimated presentation prepares the eyes to resolve immediately whatever is out there to be seen. Available experimental evidence does not support the assertion. The CIG/NVS landing approach study at Ames (Randle, et al.) and the moon-illusion studies at Illinois (Iavecchia) clearly show that collimating bold, well defined symbology, whether viewed directly or reflected from a combining glass, does not necessarily call the eyes to a far accommodation distance. When the pilot breaks out of the clouds, rapid negative accommodation is required, and the scene "explodes."

Implications For Pilot Selection And Training

The evidence presented suggests that dark focus, or resting accommodation distance, in addition to basic visual acuity and color vision, should be taken into account in pilot selection and assignment. Having a far resting accommodation distance might be one basis for assigning military pilots to air combat duty; they should be less troubled by empty-field myopia. Those with a nearer resting position might benefit from negative lenses, as in the case of civilian pilots watching for intruders. As pilots get older their resting accommodation may retreat into the distance, occasionally to a point at which they could have serious problems making "black hole" approaches.

There is ample empirical evidence that pilots learn to compensate for the biased distance judgments they experience at night with flight periscopes and the visual systems used in flight simulators. Specific training in the relationships between viewing conditions and the direction and magnitude of the associated visual biases would expedite learning the appropriate compensations. Providing variable magnification in computer-generated night visual systems as a function of the variations in visibility and illumination simulated would give the manufacturer another training feature to sell – one that might be worth its cost.

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Prater Hogue (l.) and Don Hawley

"Tina, do they ever *stop talking about flying?"*

FLIGHT SIMULATOR USE IN ACCIDENT INVESTIGATIONS

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A recent example of the use of flight simulators in accident investigations is the Allegheny Airlines accident at Philadelphia in 1976. The National Transportation Safety Board requested that the Douglas Aircraft Company conduct a flight simulator investigation of the critical factors in this accident. The critical factors of interest in this particular accident included the interactions of the relatively unknown windshear profile, the aircraft performance capabilities under the probable existing conditions, and the impact of various piloting techniques for coping with a situation of this type.

The Douglas Aircraft Company decided to use two of the available simulators for this investigation. One was a part task simulator called the DETAC (Digital Equipment and Technology Analysis Center Equipment) and the other was the Flight Development Motion Base Simulator. The DETAC was used for a quick look at the equations that were being programmed into the motion base simulator. Using large–flight–envelope longitudinal equations of motion, tailored aerodynamic data and key cockpit equipment control capability, the DETAC provided a check on equipment, aerodynamic data and calculated winds. It also provided a check on the trajectory analysis that was performed for the NTSB as well as a quick check on what to expect from the motion base simulator. The conclusions from this simulation was that the DETAC simulator data closely matched the trajectory analysis and the motion base simulator equations and aerodynamic data inputs were verified.

The motion base simulator cockpit was modified to simulate the Allegheny flight director system, the Captain's flight instruments, the control wheel forces and the glareshield shape. It was programmed with the appropriate equations for the DC-9-30 aircraft and with four wind shear models that had been developed during the analyses phase and were considered to be the most probable of the various wind shear models considered.

The motion base simulator investigations had the following objectives:

- Substantiate the correlation between the Allegheny Flight 121 profile and the wind models developed in the analytical performance study.
- Investigate the interaction of the various go-around techniques and speed command system indications in minimizing an altitude loss.
- Develop and verify a probable wind condition profile.
- Develop and verify a probable flight path profile.

The investigation in the simulator involved seven pilots in three test series. Five pilots were airline pilots, one an FAA representative and one a Douglas test pilot. After a no–wind familiarization approach and go–around trial, each pilot flew at least one approach for each wind model. The trials were designed to duplicate the known elements and to sample the spectrum of probable, but unknown, elements of the accident. The impact of a critical instrument failure was explored as well as the impact of varying specific pilot techniques.

The pilot comments written up after the simulator runs included the following:

- Must be flown to max aircraft performance
- Being forewarned helps
- Call outs after go-around helps
- A/S went to 110 knots
- Accidently hit palm switch at 200 feet. Continued approach—Go around at 100 feet. Hit ground! A/S went to 110 knots.
- 65 feet, 110 knots, Recovered. Trimmed as pull up performed.
- Lot of yoke movement (above command bar)
- On recovery command, had to move yoke considerably forward to keep from going above V bars
- Impact 118 knots, 8° pitch angle. Even though losing altitude, speed command directed to lower nose—couldn't arrest sink
- Came high into "Delta" to decrease descent rate
- Tight Flight Director, descended to 30 feet.
- Speed command is programmed much like real aircraft
- At 112 knots speed, would not exceed 15° pitch angle
- Difficult to hold in slot. Used trim—finally got it
- Hard to hold—tendency to go over speed command bars, typical of airplane
- Held close to groove—still sunk out from under—hard to hold—used trim
- Very severe–crash

As a result of the simulator investigation, information not available from the analysis was developed. This information included the probable wind profile encountered, the probable aircraft flight profile, the probable piloting technique employed and the probable aircraft performance capabilities in this situation. The results of the simulator investigation were provided to the NTSB.

The following suggestions for planning simulator investigations of aircraft accidents and incidents are based on human factor considerations:

- Ensure that the piloting background of some of the simulator pilots is similar to pilots involved in the accident or incident.
- Plan the experimental design to minimize as much as possible the following:

  Pilots' knowledge of the exact conditions planned for a run.
  Pilots' exchanging information on the conditions or how they handled a particular run.
  Practice effects on specific unusual conditions.

- Ensure that simulator features critical to the investigation are tailored to the subject aircraft
- Ensure that all information inputs to the pilots are as identical as possible to the accident or incident being investigated.
- Very carefully prepare, dry run and evaluate the pilot question-naires.
- Dry run all procedures before trying them out on the pilots in-volved in the investigation.
- Obtain subject and simulator pilots' critical anthropometric measurements.

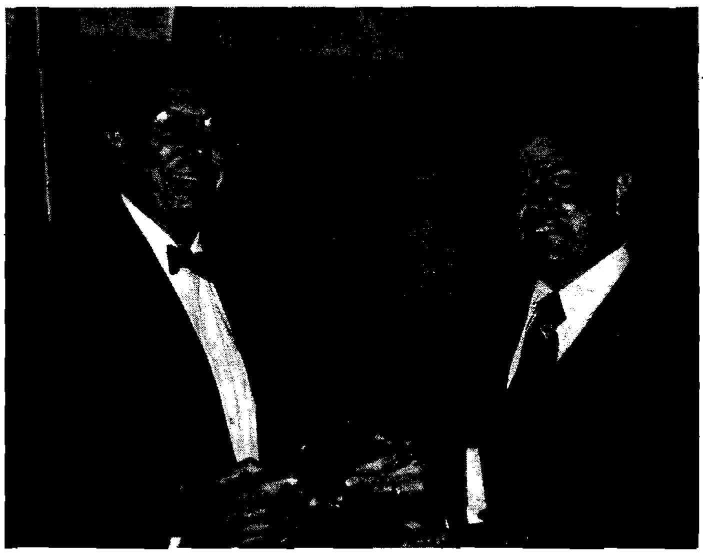
- Determine subject and simulator pilots usual seat and rudder bar positions.
- When analyzing the results of the investigation, don't overlook possible interactions of anthropometric measurements, seat and rudder bar positions with cockpit geometry.

CONCLUSIONS

Flight simulators have demonstrated their usefulness in accident and incident investigations. Their strongest point seems to be the capability for exploring interactions of piloting technique and a range of unknowns. Flight simulators are very helpful in sorting out low probability and high probability events. Flight simulators have also demonstrated their usefulness in developing new procedures to ensure that the lessons learned from the accident and incident investigations are passed on to the appropriate pilot population.

Captain Otto Hohn, Andy Yates

Bill McArthur, Jim Leggett



ASSESSING THE ROLE OF HUMAN PERFORMANCE IN AIRCRAFT ACCIDENTS

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The views expressed by the writer do not necessarily reflect those of the NTSB

Seven years ago, the theme of our Society's annual seminar was identical to this year's: Human Factors in Aircraft Accident Investigation. What progress have we made in the intervening years?

While the application of human factors knowhow found its peak in man's exploration of the moon and scheduled, supersonic passenger service, our credibility as human factors investigators became a subject of public criticism. Regardless of the extent to which this criticism may have been promoted by ulterior motives, frustration, or misinterpretation of human factors concepts, some of it may be deserved. However, even our most vociferous detractors cannot claim that the problems in the investigation of the human factors aspects of an accident are caused by unwillingness on our part to try our best.

Despite continuing efforts to develop a protocol for human factors investigation that satisfies conflicting interests as well as the need for practical conclusions with accident prevention potential, in civil aviation we are still at the point we were seven years ago. It is unlikely that a breakthrough will be made unless the objectives and limitations of the human factors investigation are better defined and understood. The first three sections of this paper are devoted to that purpose. The final section presents a new method for a structured approach to the investigation of the role of human performance in aircraft accidents.

Various Concepts of Human Factors

The basic idea behind human factors is simple: fitting the task to the worker. This concept is probably as old as human evaluation itself because its application was–and still is–part of our mechanism of self preservation and adaptation. The flattering inference can be made that the prototype of the modern human engineer was the first individual with the courage to give up his sheltered life in the trees so that he might enjoy greater but riskier freedom on the ground. To survive, he had to devise a tool that would expand his limited reach and hitting power and exploit the weak spots of his adversaries. Thus, aspiration, ingenuity, and need brought about the creation of what has been the basic empirebuilder ever since: the custom–made club. Ironically, war and the threat of war have been the great stimuli in establishing human factors as a career field.

Although human factors concepts have been applied since time immemorial, the term itself did not become a household word until the late forties, at least in this country. The British did not care for the ambiguity implied in the related term 'human engineering' and chose the more descriptive word ergonomics (ergon–work; nomos–division, law). Human factors has also been equated with engineering psychology and industrial psychology. Some representative definitions:

"Human factors technology is the art and science of designing compatible if not optimum relationships between man and the complex systems in which he must function and the equipment with which he must work." (Rappaport, 1970).

"Ergonomics can be taken to involve the study of man/machine relations, or, in some circles, its meaning may be expanded to include the study of such areas as selection and training." (Seminara, 1975).

"Engineering psychology — is specifically concerned with the discovery and application of information about human behavior and its relation to machines, tools, and jobs so that their design may best match the abilities and limitations of their human users." (Chapanis, 1968).

It takes experts in many sciences and disciplines to develop and apply pertinent human factors data. To mention a few: physiology, biology, medicine, anthropology, sociology, engineering, design and management. Considering the diversity of the talent that governs the activities in the human factors field, it is easy to agree with McCormick's (1969) position that "The human factors area is of course not a separate discipline in its own right but is itself an interface; it is the busy crossroad of several disciplines—."

Since psychologists present the largest number of human factors practitioners it may be well to sound a precautionary note with regard to their utilization in accident investigation. As Meister (1977) explains it, psychological research is mainly concerned with the study of the individual in an non–system context, whereas the behavior of an individual who operates within a man–machine system is modified by his interaction with various systems elements. Specifically, Meister believes that "Because of their psychological training most human factors researchers pursue research topics more appropriate to a purely individual orientation. Lacking the system context, this research cannot be readily applied to system development problems." Since behavioral analysis in accidents requires a thorough understanding of the total context in which individual actions occur, it is unlikely that there is room, in the early phases of an investigation, for the interpretive talent of indepth but narrow human factors expertise. With regard to the initial identification of raw data with human factors implications we should rely on investigators who know first–hand what makes people tick – and stop ticking – in a specific, real–world, operational environment.

Before we select human factors as the flag around which to gather our forces on the march to the Why of an accident, we should consider the appropriateness of our choice. The scope of human factors may eventually encompass every facet of the human condition. McCormick (1970) senses the emergence of a new philosophy in human factors which goes beyond the immediate man–machine compatibility and addresses and wider aspects of basic human values. Fraser (1978) expresses a similar view in his discussion of job satisfaction and work humanization.

Parsons (1970) goes one step further and suggests that human factors might get involved in such global activities as the prevention of war, population control, investigating the parameters of death and, in general, a system analysis of mankind.

This brief overview suffices to show that an infinite number of concepts, goals, and activities can be made to fit under the human factors flag. However, as fact–finders at the scene of an accident we can hardly pretend to be concerned with the grand design of human society. Therefore, we need a more modest and practical statement of purpose for the human factors portion of an investigation. In essence, that purpose is to find an answer to the following questions:

Under the existing operational, environmental, and equipment conditions, what were the controllable elements in the role of human characteristics, limitations, and behavior in:

(1) The development of the accident or incident (Accident causation) and

(2) The survivability aspects of the occurrence (Injury causation)

Although injury causation, conceptually, belongs under human factors, we should avoid ambiguity with regard to accident investigation priorities by using the human factors label only in connection with accident causation. In that case, we can formulate a straightforward working definition of the investigative activities dealing with the human role in accident causation:

> ***The systematic search for the probable reasons why personnel directly involved in the operation of a flight did not, or could not, interrupt the event sequence that terminated in the accident or incident.***

Human Factors and Investigative Responsibilities

The complexity of a major accident brings with it the need to organize all available investigative talent into task forces, or groups, during the field phase of an investigation. These groups derive their designation from the specialty area involved, such as: structures, powerplants, aircraft systems, operations, air traffic control, weather, witnesses, and flight recorders. The validity of this systematic approach to a large–scale, fact–finding task cannot be questioned. However, we made an overkill when we assigned the responsibility for the investigation of the "people aspects" at the scene of a catastrophic accident to one group, conveniently labeled the human factors group. The term is too encompassing in its connotations to apply it to the group's immediate tasks which are predominantly aeromedical in nature: pathology, toxicology, identification, crash injury correlation, all aspects of pre-accident fitness, and physiological and psychological conditions.

Another reason to shy away from terminology that associates all responsibility for the human factors portion of an investigation with the group by that name is that it ignores the identical responsibilities of team members in other groups. In the proposed working definition of the investigative activities dealing with the human role in accident causation, the term "personnel directly involved in the operation of a flight" refers to mechanics, dispatchers, air traffic controllers, and flight crew. It would be totally inconsistent to imply that the different investigative groups who probe the activities of these personnel can ignore human factors aspects because it is another group's specialty. As stated earlier, the identification of raw human factors data during the field phase of an investigation should be entrusted to the members of the various groups who are intimately familiar with the job responsibilities, practices, and procedures of the activity being investigated. For example, if a maintenance discrepancy contributed to an accident, any error-inducing factor in the work environment is best identified by an investigator with a thorough maintenance background. Furthermore, it is easier to give an experienced maintenance investigator a basic background in the recognition of error-provoking situations than to make a mechanic out of a human factors professional. Unfortunately, failure to apply this concept to the training of all air safety investigators is one of the main reasons for the sterility of the total human factors endeavor at the scene.

An even stronger reason to change the current label of the human factors group is that the use of this identifier during the field phase is premature. Most of the critical elements for the evaluation of the human role in the accident mechanism are not even ready for discussion until long after the human factors group has completed its task at the scene and ceases to be a cohesive team. Typically, the expertise of several other groups is required to reconstruct an event sequence complete enough to begin to hypothesize on the Why of accident-related behavior. And even then, the expert examination of these critical elements is not necessarily the monopoly of the originally established human factors group, or any other group.

In summary, the term human factors is too non-specific and all-inclusive to use in the exacting art of accident investigation. If we want to preserve the term, we should use it only as a broad reference to the human role in accident causation, but not to lump together several traditional activities at the accident scene. We need more precise task identifiers before we can stress the neglected concept that the initial gathering of pertinent human factors data is every team member's business, not just that of the human factors group as we know it. Once this is recognized, the need for an important change in protocol becomes evident, the inclusion of a human factors section in the reports of all groups who identified discrepancies that affected the performance of the principals involved.

The Medical Group

As alluded to earlier, we should put a more descriptive label on the group that handles the "people aspects" at the scene by calling it the medical group. In the next section it will be explained how a comprehensive evaluation of the human factors aspects of an accident is to be developed by a group with that specific purpose: the human performance group.

When circumstances dictate it, the medical group can be further broken down into functional sections such as: pathology, crash survival, and identification. The remarks that follow are limited to the group's on-site responsibility for developing aeromedical evidence – positive as well as negative – with a bearing on the human role in the event sequence.

To maintain the proper perspective we should first dispense with the popular notion that accident causation is determined during the most conspicuous part of the evidence-gathering process: the on-scene investigation. This is only true in the rare case where a single, catastrophic, and easily identifiable, technical failure occurred independently of any action of the part of the crew. In all other cases, the What and Why of the occurrence do not come into focus until long after the news media stopped speculating on it. And if the accident mechanism has human factors aspects, these are always the last pieces of the puzzle to be put into place.

The urgency and complexity of the medical group's task is apparent when we consider the group's principal handicaps:

1. The removal from the scene of human remains before the team arrives.
2. The requirements in most jurisdictions that human remains be processed and released to next of kin in a very short time.
3. Legal and other obstacles in securing thorough postmortem examinations or, with regard to survivors, appropriate medical tests.

Since human remains may yield more reliable indication of certain pre-impact conditions and aircraft attitude at principal impact than aircraft structure, it is vitally important to keep the medical group informed of pertinent findings and conjectures in other groups, and vice versa. Nothing would be more embarrassing than to have to admit that lack of coordination between the different groups resulted in the delayed formulation of critical questions that can no longer be answered because the human remains that could have provided the answer are no longer available. Of special significance in this regard is crash injury correlation with a bearing on the individual's position and activity at impact.

The medical group's responsibilities concerning the pre-crash fitness of the flight crew are so well established that any elaboration on this point seems redundant. This leaves the handling of survivors as a discussion item.

Almost every investigative group has reasons to be interested in survivor recollections concerning its specialty area, be it weather, ATC handling, engine operation, aircraft configuration, inflight conditions, and so on. Therefore, the question arises, who should interview the survivors?

With regard to the initial interviews of surviving cockpit occupants, it seems logical that these be conducted by the operations group with proper representation of those groups whose area is a "prime suspect" in the accident sequence. The medical group should always be represented, preferably by an aeromedically qualified person. When the physical condition of the survivor is questionable, the interview should be controlled by the aeromedical specialist or the treating physician. Under no condition should the value of these initial interviews in governing the scope and direction of the investigation be diluted by undue or out-of-context emphasis on crash survival aspects. Needless to say, having preliminary readouts of inflight recorders and ATC tapes available during these interviews makes the dialogue more meaningful.

The interviews of surviving cabin occupants should be conducted by crash injury experts, because most of the obtainable evidence involves the specialized fields of crash rescue, firefighting, evacuation, injury correlation, and survivability. However, this emphasis is not an excuse to ignore the potential contribution these interviews can make in the reconstruction of pre-impact flight conditions and sequence of events. Therefore, these interviewers must be knowledgeable of the operational aspects of the aircraft involved and be fully aware of the specific interests and concerns of other investigative groups. If they identify survivors whose recollections – often in conjunction with an aviation background – may shed considerable light on operational and environmental aspects of the flight, the appropriate investigative groups should also be given the opportunity to question these survivors.

The Human Performance Group

Usually, it is not until well after the field phase of the investigation is completed that the results of less visible – but not less critical– activities become available: laboratory tests, teardown inspections, bench tests, CVR and flight recorder correlation, aircraft performance studies, simulator tests, design and certification reviews, background interviews, and so on. Once the accuracy and reliability of these inputs are established, the investigation reaches the point where the chronology of What happened can be worked out in detail and we can begin to look for the "connective tissue" between the different events and conditions insofar as the human element is concerned.

Regrettably, it is also by this time that the investigation may have lost much of its original impetus. The technical specialists of interested parties, who played such a vital role in the initial fact-gathering process, have returned to their normal duties. The cooperative spirit that characterized the work at the scene can no longer be relied upon to overcome the defensive bias generated by the realization in which direction the preponderance of evidence begins to point. Lastly, there is a general tendency to equate the hypothesis-generation and testing process with cause determination or blame assignment; this creates reluctance to treat the final interpretive process with the openness it deserves.

As can be expected, investigations that suffer most from the gradual narrowing of analytical dialogue are those with operational or traffic control overtones. Although the retrospective assessment of human performance of complex tasks in a dynamic setting is a subjective and tenuous exercise at best, the confidence in its outcome can be enhanced by scrupulous use of all required skills and knowledges in this process. Therefore, whenever the characteristics of an accident demand it, we should establish a human performance group using the same principles we used in organizing the other groups with one important difference: the composition of this group is governed by the nature of the problem areas it has to address. As a result, this group cannot begin to function until after a fully developed flow chart of What happened allows identification of the Whys that have to be answered.

The human performance group should be chaired by a representative of the investigative authority, preferably the one who, during the field phase of the investigation, headed the group most closely associated with the basic accident mechanism; for instance, the operational, ATC, or medical group chairman. Interested parties should be allowed to contribute the required specialization to this group but only with the understanding that scientific integrity will not suffer from loyalties– lofty or otherwise. If there is any doubt, the investigative authority should not hesitate to enlist the services of independent agencies or individuals. For the same reasons, we should challenge the suitability of a human factors specialist whose approach to human error mishaps centers exclusively on the concept that every accident-involved individual was victimized by the system in which he operated.

A task overview of the human performance group has to suffice at this time. To judge the actions and the decision-making process of the principals involved, this group has to evaluate the adequacy of available information as well as the individual's selective or conditioned perception of this information at each critical turn of the accident development sequence. The evaluation must take into account identifiable forms of stress, transient distractions, and other forms of enabling conditions that may have affected individual and collective behavior. In short, the human performance group integrates and interprets all the human factors data gathered by the various investigative groups. When dealing with unexplored areas, the group should secure answers by arranging for appropriate tests or short-term research. Detailed suggestions for a possible work methodology for this group may be found in papers by Cornthwaite (1975) and Barnhart *et al* (1975).

The findings of the human performance group should be summarized and explained in a factual report. To alleviate unnecessary fears it must be emphasized that it is not this group's task to determine the probable cause of the accident but to explain the probable How and Why of specific individual and team behavior at specific times in the accident sequence. Dissenting views should be freely offered and discussed in the report. Only in this manner can the investigating authority be assured that its final deliberation will take into account the best available interpretation of the human factors aspects of an accident.

Conclusion

Although human factors, as a philosophy, may hold the key to universal contentment, we, as air safety investigators, should realize that aviation's low tolerance to human error requires a Why-oriented investigation aimed at undiluted answers to frank questions. The formation of a human performance group along the suggested lines would be a step in the desired direction.

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Human Factors Aspects In Aircraft Accident Investigation

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Introduction:

Hq TAC/SE requested various organizations throughout the Air Force involved with human factor related problems regarding major aircraft mishaps to attend a meeting at Langley AFB, Virginia, on 20-21 July 1977. The purpose of this meeting was to outline specific short–and long–term actions to reduce TAC human factor mishaps. TAC/SE suggested the use of human factors specialists on aircraft mishap investigation boards when human factors appear to be a significant cause. USAFSAM/VN, Dr. Bryce O. Hartman, offered one manyear and TDY funds to study six selected TAC mishaps.

Accident Investigation Background:

This human factors accident investigation program is not unique within USAFSAM. During the late sixties a human factors program was established and supported the FAA and NTSB in fixed and rotary winged aircraft accidents; however, the program was discontinued in the early seventies. This effort has now been revived to support TAC/SE and AFISC in major aircraft mishaps.

USAFSAM Objective:

To provide operational commands with recommendations and procedures designed to reduce aircraft accidents where human factors is a primary or contributing cause. The total number of aircraft accidents has significantly declined in the past two decades; however, human factors continues to be the prominent problem in these accidents. The most significant increases in major aircraft accidents continue to occur from pilot induced control losses, collision with the ground and engine related mishaps. These operator caused mishaps have increased significantly from 1 July 1976 to 28 January 1978, specifically involving fighter/attack aircraft colliding with the ground during low altitude maneuvering. Operational commanders are concerned with this trend and have requested augmented technology development and applications from life sciences, biotechnology and accident prevention organizations to provide greater visibility in resolving this problem in the human factors arena.

Approach:

1. USAFSAM will provide human factors expertise on six selected TAC mishaps.
2. USAFSAM will support five selected AFISC TAC accidents as human factors advisor.
3. USAFSAM is the process of developing a study kit for USAF Flight Surgeons.
4. Establish collaborative programs with the Aerospace Medical Research Laboratory (AMRL) in future mishap efforts.
5. Develop a human factors data base compatible with AFISC/SEL.
6. Modeling efforts to provide operational commanders long–term work–load requirements to reduce human factors involvement for air/ground crews in sortie surge operations.

Accidents Supported by USAFSAM:

Accident participation began in July 1977 and terminated in August 1978. A total of 18 aircraft mishaps were evaluated during this time frame. Eleven mishaps were on scene investigations and seven were by consultation. The six TAC accidents resulted from collision with the ground during combat exercises following air–to–ground operations, air combat maneuvering (ACM) after bomb delivery and training exercises on a tactical gunnery range.

Air Force Inspection Safety Center (AFISC)

Approach:

The Air Force Inspection Safety Center (AFISC) is concerned with the predominance of air–to–ground mishaps. As of this date, a corporate memory program is being developed to evaluate human factors involvement in major aircraft mishaps. An investigation team was established to evaluate the effectiveness of a permanent investigative team concept, and their points of interest involved the following human factors area:

1. Pilot attention
2. Motivation
   Peer pressure
   Supervisor pressure
3. Cockpit design
   Span of attention
4. Crew coordination
5. Psychological Autopsy

Description of Accidents:

USAFSAM's goal which supports R&D efforts is to establish a computer retrieval system in order to obtain a reduced narrative description of particular accident for possible use in this program. *These accident descriptions do not reflect accident findings or cause factors resulting in the major aircraft mishaps.*

Investigation Findings:

Eighteen accidents were reviewed utilizing the standard Air Force form 711 GA and a human factors profile developed from common findings or causal factors during the investigation series.

In order to develop a data base for the SAM matrix, ten factors were evaluated on each mishap. If a factor was not resolvable, a question mark will appear in that particular space. These results do not necessarily reflect the accident board's findings.

Supervisory, experience/training, radio communications and psychophysiological factors were not prominent indicators in these mishaps.

Environmental factors involve weather problems, night flying, wind shear and sunglare. Six cases were considered as environmental problems and three were questionable. The 72-hour history is normally prepared by the flight surgeon; however, on the six TAC accidents, the human factors advisor assisted in this endeavor. Although this does not appear to be a significant factor in these accidents, the immediate importance of obtaining vital information regarding fatigue, nutrition, life–style changes and stress (physical and mental) may determine the whole investigative approach. The interviews performed during the 72-hour workup were very significant in resolving four of the major mishaps.

The term, other factors, implies that the nature of the problem is variable and has no common thread with the other categories. Seven problem areas surfaced in this category. They are ranked as follows:

1. Command and control
2. Motivation
3. Pilot induced error
4. Situational awareness
5. Violation of directives
6. Aircrew discipline
7. Task saturation

Command and control is a very broad and encompassing factor which involves judgment, crew coordination and flight coordination. Due to the complex and demanding mission profiles, coordination efforts between flights including communication within a dual seat aircraft, specifically in a high intensity environment, is very demanding. Combat training and noncombat training appear to be the most demanding whether at home base or during special exercises. Air combat maneuvering (ACM) and low altitude bomb runs including egress were the most difficult areas.

Motivation was experienced in over half of the mishaps. Peer pressure, supervisor pressure and the will to succeed were the most predominant factors. Combat training indicates much higher levels than noncombat training which would be expected.

Pilot induced error is defined as a pilot placing himself in a position "knowing" that it may be marginal for recovery. His options should be obvious; however, ability, ego, supervisory pressure, peer pressure or pilot error are dominant factors to stimulate the pilot to recover the aircraft at all costs. This factor was higher during combat training versus noncombat training.

Situational awareness is defined as knowing and computing the various factors that exist in the dynamic envelope surrounding the pilot. In other words, know what is going on at all times. During ACM whether at low or medium altitude aircrew members became over–encumbered with the situation at hand and made a critical error.

Violation of directives occurred only during combat training. The motto "train as you fight" fueled with motivation are the principal factors for this statistic. It did not appear that aircrew members were violating rules at will.

Aircrew discipline is defined as how an individual governs his/her profile in following regulations and directives so as to maintain a mental and physical state at a qualified level to meet mission requirements. This includes the aircrew members' conduct on the ground and in flight. For example, obtaining the proper crew rest, alcoholic consumption, etc. This factor occurred only during combat training and was considered at the 3% level.

Task saturation occurred in three cases. One involved cockpit design creating pilot distraction with subsequent aircraft loss.

Accident Investigation: *USAFSAM HF Support*

The future concepts and potential achievements in establishing a human factors aircraft accident investigation program within USAFSAM will provide the following expertise to accident investigation teams:

1. Offer immediate assistance to the board president through a team of human factors specialists.

2. Provide an interface between the board members (operations) and medical investigation.

3. Assist the board members and medical investigator during interviews for human factors involvement in i.e., psychological autopsy.

4. Consultant to the medical investigator in resolving questionable psychophysiological factors.

5. Evaluate cockpit design for task saturation and span of attention.

6. Analyze all psychophysiological factors and other factors to include a report which will provide accident board member solutions in resolving the findings and cause factors in the mishap.

7. Provide assistance to the medical investigator in preparing and analyzing the 72-hour history.

Accident Investigation: *Recommendations*

This program will require intensive study and review before future commitments will be allocated. General recommendations for future evaluations regarding human factors aspects in aircraft accident investigation are:

1. Develop a permanent accident investigation team program.

2. Identify human factors investigators with a specialty code.

3. Upgrade human factors training for medical investigators.

4. Provide a human factors training to operational/maintenance crews.

ACCIDENT INVESTIGATION: FINDINGS-SAM MATRIX

Other Factors	Combat Tng		Non-Combat Tng	
	Home	Exercise	Home	Exercise
Command & Control	5	4	5	2
Motivation	3	3	2	1
Pilot Ind. Error	3	2	1	1
Sit. Awareness	1	3	1	—
Violation Directives	2	2	—	—
Aircrew Discipline	2	1	—	—
Task Evaluation	2	—	1	—

HUMAN FACTORS EVALUATION ON EIGHTEEN
MAJOR AIRCRAFT ACCIDENTS

72 Hour Prior History
- Fatigue
  - Cumulative
  - Insidious
- Nutrition
- Life style
  - Marked deviation from normal habit pattern, i.e., very early morning missions.
- Stress
  - Mental/physical

Psychophysiological Factors
- Biochemical analysis
  - Blood alcohol
  - Glucose
  - Lactic acid
  - Carbon monoxide
- Psychological autopsy
- Mental/physical stress
- Fatigue
- Hypoglycemia
- Spatial disorientation
- Biological rhythm

INVESTIGATION: FINDINGS AF 711 GA/USAFSAM-HF

FACTORS	T-38A	F-100D	F-4E	EC135	T-37B	RF-4E	F-111A	F-4C	T-38A
Supervisory	?	?	—	X	—	?	—	X	—
Exp/TNG	—	—	—	—	X	—	—	—	?
Radio comm	—	X	X	—	X	—	—	—	—
Psychophys	—	—	?	—	X	X	—	?	?
Environmental	X	—	—	X	X	X	—	X	—
Other factors	X	X	X	X	X	X	X	X	—
Command cont	X	X	X	X	—	X	X	X	—
Motivation	X	X	X	X	X	X	X	—	X
Pilot ind. error	X	X	—	?	X	—	X	—	X
Sit. awareness	X	X	X	?	—	—	—	—	X
72-hour history	?	X	?	X	—	X	—	—	—

Legend:
X Positive
— Negative
? Questionable

INVESTIGATION: FINDINGS AF-711GA/USAFSAM-HF

FACTORS	F-106A	F-100D	A-7D	A-7D	F-100D	T-37B	F-105D	F-4D	A-10
Supervisory	?	X	—	—	—	X	?	—	X
Exp/Tng	X	X	—	—	—	—	X	—	X
Radio comm	X	X	?	?	—	—	—	—	—
Psychophys	X	—	—	?	—	—	—	X	—
Environmental	?	?	—	?	—	X	—	—	—
Other factors	X	X	X	?	—	X	—	X	X
Command & cont	—	X	—	—	X	X	X	X	—
Motivation	—	—	X	—	—	X	—	—	—
Pilot ind. error	X	X	—	?	—	X	—	—	X
Sit. awareness	—	—	—	—	X	—	—	—	—
72-hour history	—	—	—	X	—	—	—	X	—

Legend:
X Positive
— Negative
? Questionable

An Analysis of Pilot Error In General Aviation Aircraft Accidents

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The views expressed in this paper are solely those of the author and do not reflect the opinions of the National Transportation Safety Board.

Introduction

National Transportation Safety Board (NTSB) statistics reveal that pilot error or pilot involvement virtually monopolizes the "top ten" list of the most frequently cited cause/factors of general aviation aircraft accidents in the United States. It is therefore quite obvious that pilot (human) factors are the key issues to be considered in aircraft accident prevention efforts. Prior to launching a program to prevent pilot error or human failure type accidents, one must understand what type of pilot errors or failures actually occur. Moreover, the means by which the facts, conditions, and circumstances of pilot error accidents are collected and reported, and how the probable cause and factors of such accidents are determined and recorded must be understood to use them effectively for accident prevention purposes.

This paper discusses the investigation of selected general aviation accidents in which the NTSB has found the pilot to be directly involved in the cause of the accident. The discussion is directed to the nonprofessional pilot. Varying degrees of pilot involvement in the accident cause are described. For example, the case where the pilot is imprudent, careless or reckless, as compared to the case where the pilot is victimized or lured into an "error," is discussed. The method by which the NTSB investigates accidents and reports accident data is explained to illustrate how the data may contain variable amounts of pilot involvement under one probable cause or factor designation.

The purpose of this discussion is to enlighten those persons who use NTSB accident data for the analysis of pilot error accidents, so their conclusions will be as valid and useful as possible. Additionally, a challenge is presented to those of us who investigate aircraft accidents to investigate and evaluate underlying human factors aspects, which may be the key to effective accident prevention efforts.

Background

The NTSB is charged by an Act of Congress with the investigation of civil aviation aircraft accidents to determine the probable cause of such accidents. The Safety Board is also charged with making safety recommendations to appropriate authorities for the purpose of preventing future accidents. To comply with its mandate, the NTSB has developed investigative procedures for the collection of the facts, conditions, and circumstances of general aviation accidents. These data are generally collected by a single NTSB field investigator with the assistance of various interested parties. To assist the investigator, the NTSB has developed forms and guidelines to collect specific data. The International Civil Aviation Organization report format is used by the NTSB investigator to organize his narrative factual report.

The NTSB investigator is responsible for collecting and recording sufficient data to enable the 5-Member Safety Board to determine the probable cause of the subject accident. Factors which contributed to the cause of the accident are also determined by the Safety Board. Unsafe conditions detected as a result of the investigation, whether related to the probable cause or not, are documented to generate safety recommendations issued by the Safety Board.

Over the past 10 years, there has been an average of over 4,000 accidents per year involving U.S. general aviation aircraft. In order to efficiently fulfill its mandate, the NTSB has implemented electronic data processing techniques to store factual and cause/factor accident data. Computer briefs of accidents containing key information are issued to the public with the factual data to support the probable cause and factors. The cause/factors are also published in the computer briefs.

Since the Safety Board also has the responsibility to improve aviation safety through accident prevention efforts, computer stored accident data are retrieved, analyzed, and published in annual reviews of general aviation accidents. The reviews contain numerous tables, charts, and graphs to illustrate trends in accident rates, etc. Periodically, special studies of specific safety problems are conducted by the NTSB using multiple years of data to support safety recommendations to alleviate the problems. The data are also used by many facets of the aviation industry for their specific needs.

Accident Data Collection

The recording of the facts, conditions, and circumstances of aircraft accidents in a standardized manner is extremely important, especially for trend analysis. This task is simplified by use of the computer. Factual data are coded for computer entry by means of "direct entry" or pre-selected codes. Facts, such as temperature, wind information, aircraft make and model, injuries, etc., can easily be standardized by this method. Virtually all the essential information to support the Board's probable cause are entered into the computer by this method.

The standardization of cause factor data for trend analysis is equally as important. It is generally recognized that it is often impossible to ascribe one single cause to an aircraft accident. Frequently there are numerous factors or causes which lead to an accident. In many cases, each accident is unique and the cause/factors may never have occurred previously and may never be expected to occur again. Therefore, to report realistically the cause of aircraft accidents, a separate unique cause should be written for each case. This is not difficult to accomplish; however, it precludes systematic collection and electronic storage of accident cause/factor data. Analysis of causal trends would have to be done manually.

In order to standardize its accident cause/factor data, the NTSB uses coded causes and factors for computer entry. In special rare cases, a unique "written cause" may be used, when none from the list are appropriate. The list of coded causes and factors is extensive and includes virtually all the commonly found cause/factors of aircraft accidents. The cause/factors are grouped in broad categories, such as "pilot, other persons, powerplant, weather, miscellaneous, etc." In most cases, the NTSB uses multiple causes and factors to more accurately describe the accident. By using this method, the NTSB is able to standardize causal data for electronic retrieval, data analyses and accident prevention purposes. Additionally, the NTSB is able to more efficiently make public its findings. The above information must be kept in mind when using the NTSB causal data.

Pilot Error Defined

In order to discuss and analyze pilot error accidents, one must understand what the term "pilot error" means. Webster discusses the term "error" as "(1) the state of believing what is untrue, incorrect or wrong; (2) a wrong belief or an incorrect opinion; (3) something incorrectly done through ignorance, carelessness or mistake; (4) the difference between a computed or estimated result and the actual value, as in mathematics." Webster continues by stating that "an error implies deviation from truth, acccuracy, correctness, right, etc., and is the broadest term in the comparison, i.e., an error in judgment, in computation, etc. A mistake suggests an error resulting from carelessness, inattention, misunderstanding, etc., and does not in itself carry a strong implication of criticism."

It is apparent from the above definition that the term "pilot error," as used in the title of this paper, is used to describe the entire spectrum of inappropriate actions by a pilot which lead to an accident. The inappropriate action can be the result of overt intentional actions by a pilot, or it can be the result of subtle or underlying forces affecting the pilot's performance. These subtle or underlying factors are the key aspects about which this paper is concerned.

A "pilot error" or pilot "involvement" in an accident cause can carry the implication of little or no blame; or, at the other end of the spectrum, considerable fault may be placed on the pilot. The broad category of pilot cause/factors used by the NTSB is designed to cover the entire spectrum of pilot involvement in accident causation. Additionally, there are numerous pilot involved causes under a broad category of miscellaneous cause/factors. A few of the cause/factors are the obvious areas for accident prevention activities.

The Top Ten Most Frequently Cited Cause/Factors

Information from the 1976 "Annual Review of Aircraft Accident Data" for U.S. General Aviation (NTSB-ARG-78-1) was used for this paper because it was the most recent complete annual review. The trends and the top ten list have not changed significantly over the past few years.

In 1976, the 10 most frequently cited cause/factors in 670 *fatal* general aviation accidents were as follows:

Cause/Factors	Frequency of Occurrence	Percent of Occurrence
Pilot-failed to obtain/maintain flying speed.	185	27.61
Terrain–high obstructions.	143	21.34
Weather–low ceilings.	137	20.45
Pilot–continued VFR flight into adverse weather conditions.	100	14.93
Weather–Fog.	95	14.18
Pilot–improper inflight decisions or planning.	93	13.88
Pilot–inadequate preflight preparation or planning	82	12.24
Pilot–spatial disorientation.	80	11.94
Miscellaneous–unwarranted low flying.	66	9.85
Pilot–improper use of flight controls.	53	7.91
Total Accidents	670	

The 10 most frequently cited cause/factors in 3,470 *nonfatal* general aviation accidents in 1976 were as follows:

Cause/Factors	Frequency of Occurrence	Percent of Occurrence
Miscellaneous act, conditions–overload failure.	542	15.62
Pilot–inadequate preflight preparation or planning.	488	14.06
Terrain–high obstructions.	476	13.72
Pilot–failed to maintain directional control	385	9.94
Pilot–failed to obtain/maintain flying speed.	330	9.51
Terrain–rough/uneven.	313	9.02
Weather–unfavorable wind conditions.	303	8.73
Pilot–improper level off.	302	8.70
Pilot–mismanagement of fuel.	240	6.92
Pilot–misjudged distance and speed.	229	6.60
Total Accidents	3,470	

The 1976 data show that the pilot was cited as a causal factor in 89 percent of the fatal and 83 percent of the nonfatal accidents. The percentage figures shown in the above tables total more than 100 percent. That is accounted for by the fact that more than one cause/factor was cited in many cases.

It is interesting to note that "Pilot–failed to obtain/maintain flying speed" was cited in 1976 in 27.61 percent of the fatal and 9.51 percent of the nonfatal accidents. This cause/factor is generally cited by the NTSB in stall/spin or "mush" type accidents. On the surface, it would appear that more stall and spin training of pilots might alleviate this problem. In fact, the Safety Board has most recently issued a safety recommendation to the FAA on the subject of stall/spin training.

"Terrain-high obstructions" is cited in 21.34 percent of the fatal and 13.72 percent of the nonfatal accidents. This cause/factor is generally associated with takeoff or landing accidents when an aircraft strikes a tree or similar obstruction. Therefore, this code is usually a factor in the accident rather than the primary cause. It necessarily follows that another cause must be associated with the "high obstructions." "Inadequate pre-flight preparation of planning" or "improper inflight decisions or planning" are obvious pilot causes, which may be cited by the NTSB in these accidents.

It is possible to associate "pilot involvement" with nearly every cause/factor in the top ten list. That fact would seem to indicate that accident prevention efforts should be concentrated on those particular pilot cause/factors to improve aviation safety. However, an indepth study of certain cases reveals that there are often underlying human factors, which may be the true culprits in the accident causation. These less frequently cited causes or factors may be the more productive areas to be studied for accident prevention efforts. To illustrate this view, a few case histories are presented for consideration. The case histories are directed towards the top ten list of fatal accident cause/factors although a similar analysis of nonfatal cases could be accomplished.

Case Histories

To evaluate the human factors involved in the top ten list of cause/factors, the coded causes must be related to facts from actual cases. In that manner, the key aspects and the underlying factors can be compared with the coded cause/factors assigned by the NTSB. The cases presented illustrate pilot involvement at various levels of "blame" or "pilot error." That is, the case where the pilot is imprudent, careless or reckless, such as buzzing, flying with a known medical deficiency, or initiating flight into known adverse weather. At the other end of the spectrum, cases are presented where the pilot is victimized or lured into an error. Examples of these include inadequate weather forecasts and pilot briefing, poor flight instruction, inadequate maps, etc.

The four cases presented are actual accidents investigated by the undersigned. The facts, conditions, and circumstances, as well as the probable cause and factors assigned by the NTSB are true; however, identifying information is deleted. The actual identity of the accidents is not important for this discussion.

Case History No. 1

A 35-year old pilot took his 10-year old son for a local pleasure flight from their ranch airstrip. The pilot had over 600 hours total flying time and nearly 100 hours in the acrobatic aircraft which he flew on the accident flight. Weather was excellent. Witnesses, who knew the pilot, saw the aircraft flying over their house at approximately 75 feet A.G.L. The aircraft made three passes over the house below 100 feet A.G.L. On the last pass, witnesses stated that the aircraft flaps were down. They said that the aircraft was seen to make a rapid pull-up, after passing the house. They said the left wing then dropped and then the nose dropped. The aircraft rotated to the left and crashed onto its nose. Both occupants were killed instantly.

Examination of the wreckage revealed that there were no airframe or engine malfunctions prior to impact. The flaps were found "up" in the wreckage. The pilot apparently retracted the flaps during the pull-up, thus aggravating the stall. During the examination of the aircraft records, it was learned that there had been propeller and landing gear damage a few months previously. It was learned that the dead pilot had groundlooped the aircraft during a landing. The damage did not meet the NTSB criteria for an accident, so was not investigated.

The above two short paragraphs are sufficient to place this accident in the top ten list of cause/factors three times for fatal accidents. That is, "Pilot – failed to obtain/maintain flying speed, miscellaneous – unwarranted low flying, and pilot – improper use of flight controls." Buzzing and low altitude acrobatics are careless and reckless actions, which are very difficult to police or prevent. This accident could easily be placed at one extreme on the spectrum for pilot involvement or "error." If one looks at this case for possible accident prevention information, based on the cause/factors from the top ten list, better training in stall/spin avoidance is an obvious possibility. Since judgment cannot be regulated, perhaps acrobatic flight training should be required. Such possibilities can be readily supported by the statistics on the top ten list.

Additional facts discovered during the investigation of this case warrant consideration to truly understand this accident. The pilot's father was interviewed and he said that the minor groundloop incident a few months previous was caused when the pilot's feet went numb and he couldn't feel the rudder pedals. Additional interviews and examination of medical records revealed that the dead pilot had had a degenerative central nervous system disease. The pilot had been hospitalized at least twice for symptoms such as numbness in his extremities, double vision, staggering gait, slurred speech, etc.

During the period that the pilot was under treatment for his disease, he received an examination by an Aviation Medical Examiner (AME) for a Third Class Medical Certificate. The pilot did not reveal the existence of his disease and the AME apparently did not detect the symptoms. The pilot's father was a long-time aviator, who admitted that his son wanted to fly, regardless of his disease. It was not determined why the AME failed to detect the existence of the pilot's disease. An examination of the pilot's medical records by an FAA physician revealed that the disease had progressed considerably at the time of the AME's examination.

Another interesting aspect of this case is the fact that the pilot had just received a gift of a radio headset for his aircraft. The accident flight was the first time that the pilot had worn it. The headset was a muff-type, which completely covers the ears to reduce engine and airstream noise. The accident aircraft did not have an artificial stall warning system. Moreover, the aircraft has insidious stall characteristics. That is, it doesn't buffet or shake prior to a stall. The "grandfather clause" for FAA type certification did not require inherent or artificial stall warning. Therefore, other than his airspeed indicator, the pilot must rely on engine and airstream noise and other aircraft characteristics to warn of an impending stall. The muff-type headset may have masked some of the peripheral noise normally available to alert the pilot to an approaching stall. The loss of these important cues may have been one of the underlying human factors which caused the accident.

This case illustrates obvious careless and reckless actions by a pilot. However, there are also underlying factors in this case which may have been the more important causal factors. By looking at the top ten list of cause/factors, one may miss the important accident prevention potential. Perhaps the AME could have prevented the accident by conducting a more thorough examination and by refusing to issue a Medical Certificate to the pilot. Or perhaps the minimum standards for a Third Class Medical exam should be revised. Lastly, perhaps there should be more information directed to pilots regarding items which may destroy important cues for safe flight.

Case History No. 2

A man in his 50's and his wife rented an aircraft from an aircraft sales and rental firm for a flight to a city 200 miles away. The pilot received a checkout at the rental firm, prior to being allowed to rent the aircraft. His wife was not a pilot. The following day, a VFR flight was planned to return home. The pilot received a weather briefing from a Flight Service Station (FSS) briefer for the return flight. He was given VFR conditions for his proposed flight and he filed a VFR flight plan.

Approximately one-half way to his destination, the pilot radioed to a distant control tower that he was "in clouds and lost." After numerous attempts to assist the pilot to gain access to visual conditions, the aircraft stalled and crashed out of control. Both occupants were killed.

The investigation revealed that the pilot had 200 hours total flying time. He had not received actual or simulated instrument flight training for several years since his private pilot's license was acquired. The investigation further revealed that a mild cold front extended across the pilot's proposed route of flight. The pilot had encountered clouds, became disoriented and eventually lost aircraft control. Transcripts of radio communications with the pilot revealed that he was extremely confused and did not understand such items as a directional finding (DF) steer or VOR radial, etc.

This case has as many as five cause/factors from the top ten list. That is, "pilot – failed to obtain/maintain flying speed, weather – low ceiling, pilot – improper inflight decisions or planning, pilot – continued VFR into adverse weather conditions, and pilot – spatial disorientation." These cause/factors describe considerable pilot involvement in the accident cause.

Additional facts learned during the investigation revealed that, previous to the first flight in the accident aircraft, the pilot received one hour of flight in the aircraft. The flight was a checkout by a certified flight instructor at the aircraft sales/rental facility. The instructor stated after the accident that the one hour flight was to comply with the rental firm's insurance requirements. The instructor stated that the checkout consisted of takeoffs and landings, climbs and turns, and approaches to stalls. He said that the pilot "handled the aircraft okay." No simulated instrument flight was practiced, no unusual attitudes, and no VOR or other type of tracking was performed. The possibility of inadvertent encounters with clouds was not even discussed with the pilot. The pilot's logbook was not reviewed by the instructor.

Further investigation revealed that the existence of the mild cold front along the proposed route of flight was not discussed with the pilot during his weather briefing. It was a weak front which had passed the destination airport without dropping ceilings and visibilities below VFR. Additionally, there were no weather reporting facilities in the vicinity of the front at the time of the accident and no inflight weather advisories had been issued. Nevertheless, it was depicted on the weather charts available to the FSS briefer. Based on existing criteria, the existence of the weak front was not required to be briefed to the pilot. Therefore, the pilot initiated his flight with the impression that the weather was good. Granted, when he encountered the clouds, he should have been able to turn back or circumnavigate; however, it is also very possible that he may never have initiated the flight, if he had been aware of the existence of the cold front.

An important aspect of this case is that a more thorough checkout by the certified flight instructor may have identified the pilot's lack of ability. The instructor may have been able to better prepare the pilot for the cloud encounter. This pilot's knowlege was extremely lacking; however, the FAA certified instructor failed to detect or improve his ability. Since it was only a "checkout," the instructor had no mandatory obligation to do this; however, the certification as an instructor would seem to indicate that he would have a moral obligation in this matter. One "human factor" to keep in mind is that if the flight instructor pressures a prospective customer to acquire additional flight instruction, or dissuades the pilot from taking the trip, the customer may go elsewhere to rent an aircraft.

Both the flight instructor and the FSS weather briefer complied with existing regulations governing their actions. Nevertheless, they had an excellent opportunity to prevent an accident. Again, this case shows up in the top ten list of cause/factors; however, the true accident prevention potential may lie in other areas.

CASE HISTORY NO. 3

The third case involves a law firm employee who was the company pilot for a 6-place light twin-engined aircraft. The aircraft departed a high altitude airport with the pilot and 5 passengers aboard. During the takeoff roll, the aft baggage door opened and items began spilling onto the runway. Shortly after takeoff, the airport Unicom operator advised the pilot about the items spilling on the runway. The pilot acknowledged and said that he was going to turn around and land immediately. The aircraft began a shallow right turn for about 30 degrees change of heading. The aircraft then began a left turn. The angle of bank gradually steepened to at least 60 degrees of bank and the aircraft stalled and crashed. All six occupants were killed. It was apparent that the pilot attempted a partial "90-270" type turn to land opposite to his takeoff direction, since the winds were light and variable. The aircraft fuselage came to rest aligned with the runway heading, approximately ½ mile from the extended runway centerline.

Examination of the wreckage revealed that the aft baggage door was open at impact. Fire damage precluded the determination of why the door came open. No pre-impact airframe or engine malfunctions were discovered. Extensive flight testing revealed that the open door had no adverse effect on the aircraft performance. In fact, when the door was forcibly held open at various positions, no adverse flight characteristics were apparent.

This accident has three cause/factors from the top ten list. That is, "pilot — failed to obtain/maintain flying speed, pilot — improper inflight decisions or planning, and pilot — improper use of flight controls." All three carry the connotation of "error" or involvement on the part of the pilot.

The pilot was found to be highly qualified in multi-engine aircraft and he also had considerable experience in operations from high altitude airports. It is difficult to pinpoint a possible accident prevention avenue in this case except possible "more" training in stall/spin avoidance. The statistics on the top ten list would obviously support this effort.

A few other facts gathered during the investigation may shed a slightly different light on this case. Among the items falling from the aircraft were original signed transcripts of depositions taken by the law firm employees aboard the aircraft. The "one-of-a-kind" documents constituted many weeks of depositions in a very expensive law suit. One of the company's senior law partners was riding in front right seat of the aircraft, during the takeoff. He held a private pilot's license and had flown the accident aircraft on numerous occasions with no passengers aboard. He was not an experienced pilot. Friends and associates of the man in the front right seat stated that he had an extremely violent temper. He was intolerate of mistakes or incompetence by his staff. The friends and associates said that the man would probably have been screaming viciously because of the impending delay and the loss of the valuable papers from the aircraft. He may have ordered the pilot to land immediately. Lastly, the company pilot was also the law firm's office manager and was well aware of the importance of the documents.

In this case, "pilot error," as previously discussed, was the cause of the accident. However, the extent of distraction or even actual interference with the operation of the aircraft by the right front seat passenger must be considered. The cause/factors from the top ten list must be tempered with the "underlying" human factors, if one is to properly evaluate this case for accident prevention purposes. The aspect of "pressure" or subtle influence must be considered in corporate/executive accident investigations because the pilot's livelihood depends a great deal on satisfying his employer.

CASE HISTORY NO. 4

The last case involves a pilot who planned a flight to a high altitude airport (8700 feet) at a resort area. The resort operator had a Unicom radio. The pilot radioed that he was inbound for landing and that he wanted ground transportation and tie-down for his aircraft. The pilot was advised that the terrain surrounding the airport required landing to the south. The winds were reported as light and variable.

Witnesses stated that they saw the aircraft make an approach to the south. The aircraft was seen to be high on final and overshoot the landing. The pilot radioed that he would go down the valley and turn around for another landing try. The aircraft was seen to continue southerly down the valley, which had very steep, high, and narrow walls. The terrain began to rise rapidly as the valley progressed southerly. Twenty-four miles "up" the valley, the aircraft was seen extremely low and then it stalled and crashed into a ravine, after maneuvering to avoid trees and rocks. The elevation at the crash site was 11,300 feet. Density altitude was approximately 13,800 feet — very close to the service ceiling of the aircraft. All five occupants, including two adults and three children, were killed. The aircraft was a 4-place 180 horsepower model.

This case involves four items from the top ten list of cause/factors. That is, "pilot – failed to obtain/maintain flying speed, terrain – high obstructions, pilot – improper inflight decisions or planning, and pilot – inadequate preflight preparation or planning." The pilot "erred" and was directly involved in the cause of this accident. But, how could the accident have been prevented? Perhaps, better training in preflight, map reading, and stall/spin avoidance. That seems reason-able, if the top ten list cause/factors are considered.

The investigation revealed that the valley, in which the airport is located, becomes very narrow after about three miles south of the airport. A review of the current aviation charts did not readily highlight the hazardous conditions at this airport. Terrain features require landing to the south and takeoffs to the north. The pilot had a sectional chart in his aircraft open to the airport area. The chart depicts the valley; however, one must study it carefully to realize the hazard of flying south "up" the valley past the airport. After approximately three miles from the airport, a safe turn-around or a climb-out is not very likely in an aircraft or the accident type. The airport is adequately depicted on the charts; however, there is no warning about the hazardous terrain features.

The extent of this pilot's map reading ability was not determined. He was a private pilot with approximately 400 hours of flying time. The adequacy of his training in preflight and planning could not be established. The pilot was from California, so he had some mountain flying experience. The aircraft Unicom operator could possibly have prevented this accident. He was also a pilot and obviously aware of the hazardous terrain features. Perhaps he could have radioed a warning to the pilot to turn shortly after missing his approach. Moreover, upon initial contact, he could have briefed the pilot about the airport conditions.

The pilot's knowledge of his aircraft's performance capability is subject to question. Where did he get the notion that he could safely fly this model aircraft into such a hazardous area? Did he realize the narrow margin of performance available or did he believe that he could "fill the seats, fuel tanks, and baggage area" and safely fly into this area? Did an aircraft salesman tell him he could? Was his flight instruction such that he had such erroneous beliefs? These are important human factors to be considered.

Another interesting aspect of this accident is that it probably should not have been fatal to the occupants. There were numerous areas along the last 24 miles of flight where a successful forced landing could have been accomplished. Of course, the aircraft most likely would have been damaged; however, no lives should have been lost. The extent of the pilot's training in this area is a factor to be considered. In this case, the stall (failure to maintain flying speed) is to "blame" for the cause of the accident and the death of the occupants. In numerous cases, when a pilot gets "boxed in," if the stall is prevented, the fatal injuries may be prevented. The human factors which cause a pilot to try to prevent damage to his aircraft and which lead to an out-of-control accident are a wide open field for prevention of needless deaths. The survivability potential of this accident is not obvious from its status on the top ten list of cause/factors.

SUMMARY

The intention of this paper was not to attempt to dissect or solve the human factors causes of aircraft accidents. Rather, the intention was first to enlighten those persons, who use NTSB accident data, about the development and presentation of the data, and secondly, to alert those persons to the necessity to "look beyond" the statistics for the important underlying human factors. Lastly, those of us, who investigate aircraft accidents, must be aware of the underlying human factors, and we must investigate and document those factors. In that manner, more productive accident prevention programs may be forthcoming. We will always have a top ten list; however, perhaps some of the needless accidents on the list can be eliminated.

Air Force Application of Simulators to Assist in Accident Investigations

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The application of a simulator to assist an accident investigation resulted from the crash of an Air Force training aircraft (T-37) during a dual undergraduate pilot training mission.

The student pilot had received only one prior training flight – he safely ejected from the aircraft, however, the instructor pilot was killed.

The accident investigation board was unable to determine what transpired after the IP took control of the aircraft during a power-on stall recovery.

The board was not able to determine what caused the crew to get into the situation. Nor could it be determined what the fatal maneuver was. The student was able to provide only sketchy impressions of the events leading to his ejection.

The board members felt that if the possible events could be simulated it could possibly aid the student to recall details.

The Flying Training Division of the Air Force Human Resources Laboratory worked with the Board in providing resources which included a Research Instructor Pilot and the Advanced Simulator for Pilot Training (ASPT).

6° Motion System (Synergistic)
Full Mission
Visual Scenes Generated by Computers
300° × 150° Field-of-view

ASPT is the world's most advanced flying research device.

APPROACH:

1. Attempt to create events leading to crash.

2. Allow the maneuver to develop following several hypothetical sequences which could have led to the aircraft configuration and the attitude at impact.

3. Have student fly ASPT observing the various sequences to see if he could identify which one approximated what he experienced in the aircraft.

4. If the student could isolate a sequence, perhaps it would refresh his memory and allow a recall of definite details.

PROCEDURE:

A. Preliminary:

Board members flew initial maneuvers considered as likely candidates based upon student comments, crash evidence, and the experience of board pilots.

It was generally accepted that the accident probably occurred as a result of some type of inadvertent spin or high speed spiral followed by a "too late" recovery. A number of these maneuvers were flown in the simulator.

When the analysis of the wreckage revealed that the elevator trim motor was driven to the full nose down trim position power-on stalls were again flown in the simulator but this time as the nose was raised to the desired 40° of pitch, the elevator trim was run full nose down.

No unusual stick pressure was noticed because the airspeed bleeds off rapidly.

As the stall was reached the nose was lowered to 30-40° below the horizon and power increased to 90-100% RPM. However, our experienced pilots tended to go beyond the 40° pitch and with full power combined with the full nose down trim, the situation rapidly progressed to an uncontrollable maneuver.

B. Student.

The student received a regular pre-flight briefing. With conditional provisions that if he did not feel well or if at any point he desired to discontinue, the effort would cease.

Video and voice recordings were made of the flight in addition to flight dynamics. Freeze provisions were extensively used.

". . . O.K. let's freeze here once . . . the nose I think was a little bit lower than this (55° nose down) (incremental freeze steps followed).

. . . About right there you say? That looks about right?

. . . Seems about right." (62 degrees nose low, airspeed 120KIAS).

DISCUSSION:

*The Board was able to rule out the possibility of a spin.

*Student's description verified the hypothesized sequence of events leading to crash.

*Visual scene was realistic enough to allow student to orient himself geographically.

*Student recalled sequence of events leading to the last power-on stall.

*Review of the video tape and observations by the Research Instructor Pilot revealed student habitually grasped the stick with his thumb resting on the trim button.

*Data record features were extremely valuable.

*Problem freeze enhanced the investigation.

*Flying the accident maneuver in the simulator dramatically illustrated the insidious danger of full nose down trim in power-on stall recoveries.

*Without the simulation the pilots involved would likely never have been convinced that these circumstances represented a danger of any significance.

*Duplicating flight in the safe arena of simulation allows experimentation/investigation in flight conditions that would otherwise be impossible.

CONCLUSION:

Simulation made a significant impact on the proceedings and findings of the accident investigation. Without the simulation it would have been difficult to rule out the possibility of a spin or to draw anything but speculative conclusions.

"*Use of the Advanced Simulator for Undergraduate Pilot Training (ASUPT) in an Accident Investigation,*" Rust, Steven K. and Fuller, Robert R.

(Maj. Robert R. Fuller may be contacted at Holloman, AFB, NM Autovon 867-4434)

DIFFICULTIES IN HUMAN FACTORS INVESTIGATIONS

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The views expressed herein are those of the author and do not necessarily reflect the views of the US Air Force or the Department of Defense.

In the real world of aircraft accident investigation, the human factors specialist faces enormous difficulties. In spite of the progress made in recognizing the need for human factors investigation and in spite of progress made in developing some methodology for investigation, the actual practice has not yet lived up to its potential.

The United States Air Force has experimented on a small scale with using a human factors specialist on selected accidents. He participated in the investigation from start to finish and fully contributed his ideas. From our point of view at the Air Force Inspection and Safety Center, the results were not all we wished for. That is not to say that there were not plenty of possibilities about human factors involvement; there were.

At the end of the investigations, though, the degree of confidence in the level of involvement was only slightly above what it would have been without the human factors investigation. Let me cite two examples.

Case #1. This particular pilot had recently undergone a rather traumatic change in jobs and had not been sleeping well. Because he had relatives visiting him, he tried to get excused from this particular duty period but was turned down because of the importance of the missions. As a concession to his visitors, he was offered his choice of which sortie he wanted to fly. He picked a 0400 takeoff for a tactical reconnaissance mission.

The evening before the mission, he was mildly sick with nausea, vomiting, and a headache. He took two aspirin and got about 5 hours sleep before reporting for duty.

He apparently felt good as he didn't complain or exhibit any signs of stress or illness prior to the mission.

He flew the plane into the ground during entry into a low–level reconnaissance route.

Here was a case where the human factors investigator learned a great deal about the pilot and his habits. As the proximate cause, you could hypothesize that the pilot misread an altimeter or encountered some degree of spatial disorientation. You could even support a conclusion that this probably resulted from a combination of fatigue, hypoglycemia, and stress from a number of factors.

Carrying this one step further, though, a lot of us feel that there is another factor present – implied pressure resulting from his rejected request to be excused in the first place. Once that happened, any subsequent reason for not flying might appear contrived. Under the circumstances, we think it unlikely that the pilot would have voluntarily grounded himself unless he was visibly sick or injured. But how do you prove that to the satisfaction of the people who review and approve accident reports?

Case #2. This pilot, although an experienced pilot, was fairly new to this aircraft. He had a slight near–vision impairment which, coupled with his low experience in the aircraft, might have increased the time it took him to locate a correct switch or instrument in the cockpit. He lost control of the aircraft during a very demanding low–altitude tactical maneuver and crashed. Based on the evidence, we might intuitively feel that he was task–saturated. But what is task saturation? How do we measure it?

We've done some soul searching in an effort to discover what we are doing wrong in our investigations. The answer, I think, is that we have not fully credited the difficulties facing the human factors investigator, and we may be expecting more than we are realistically going to get. We may, in fact, have misjudged the contribution a human factors specialist can make to our overall accident prevention program. That point will be addressed later in the paper.

As I see it, the human factors investigator encounters some problems not shared by the rest of the investigation team. For purposes of discussion, I would like to separate these into people problems, paper problems, and investigation problems.

Foremost among the people problems is the perception that if a person has a human factors problem of some sort and is permitted to operate an aircraft, it is a supervisory deficiency. I think the clearest expression of this perception is the supervisor who, immediately after the accident says, "I just can't believe it. He was my best pilot." In all my years of investigating accidents, I have never had anyone tell me that the pilot who got killed was not one of the best pilots. Intuitively we know that just isn't true. Not everyone is "best:" The "best" do not always have the accidents, and no one is "best" at all things at all times. Nevertheless, the human factors investigator faces an almost impenetrable wall. The fact that a supervisor will not realistically admit that a particular pilot might have been anything less than perfect is in itself a human factors problem.

Another problem faced by the human factors investigator is probably built into our cultural mores. We do not like to speak ill of the dead. It is very difficult for the human factors investigator to find anyone who will say anything that's not good about a fatally injured pilot. Here, our practice of granting immunity or anonymity doesn't seem to help us much. We are up against a basic moral problem as there are many people who cannot in good conscience speak ill of the dead regardless of the circumstances.

Turning to the "paper problems" facing the human factors investigator, his biggest problem is that written records rarely reflect human deficiencies. As long as a pilot can recover from his mistakes, meet the standards, and pass the evaluations, his difficulties with training are rarely documented. This probably comes from use of training records for some purpose other than training. There was a period of time in the Air Force, for example, when an officer's annual report card – his Efficiency Report – contained an obligatory comment about how well he had done on his flying evaluations and flying training. This was probably well–intentioned, but the long–range effect of it was to turn entries on flying evaluation records from training devices to career devices. A pilot, for example, who had difficulty learning night refueling – but still learned it – might find himself having difficulty getting promoted to the next rank. That procedure has been terminated in the Air Force, but the effect lingers on. It is very difficult to audit a pilot's records and discover what his real training problems were.

In addition to the lack of critical comments from the records, we are not sophisticated enough to track a pilot's previous experiences. I think we would all accept the proposition that we are all products of our previous experience. We tend to react to situations based on some learned response; and that response may have been learned in actual experience or in training. We will not all necessarily respond in the same manner to the same situation because we have not all had identical experiences. Even though we might agree with that as a proposition, we do little to document that and prepare ourselves to predict future responses based on past experiences.

Let me cite an example.

In the late 1950s and early 1960s, the principal source of B-52 pilots in the Air Force was the B-47. The B-52 was being phased in while the B-47 was being phased out, and the two had a lot in common in terms of mission, configuration, systems, and so on. Training a B-47 pilot to fly a B-52 was a relatively simple matter, except for one small item. I happen to be one of those B-47 pilots – I had flown the B-47 for about 5 years – and I brought a potentially lethal habit with me.

The B-47 had a manual trim system on all axes so there was no need for a trim button. On the control yoke under the pilot's left thumb, Boeing had put a rocker switch which worked the microphone. If you pushed it forward, you were on interphone; if you rocked it back, you transmitted to the world on whatever radio you had selected. I didn't have any trouble with this arrangement until I got to the B-52. As you can probably guess, Boeing had now managed to sell the Government an electric trim system, and a very effective one at that. Under the pilot's left thumb on that control yoke was the standard 4–way trim switch. I think you can see the problem. B-47 pilots in the B-52 spent a considerable amount of their time trying to talk on the trim switch. I can remember one early flight during refueling where I suddenly ripped off my oxygen mask and yelled to the instructor, "Hey, I just lost my interphone and–whoops–we've got a runaway elevator trim, too." In my case, I would say that it took most of the year to completely eliminate the habit of trying to talk on the trim switch. During that time, I would revert to form just often enough to scare myself, particularly during some low–level, high–speed maneuver where a little bit of unwanted nosedown trim could be fatal.

The point of all this is that we do not specifically maintain records on B-52 pilots that would give us some insight into what their experience had been or what they had flown immediately before the B-52. The information is there, to be sure, but you have to intuitively know that there is a habit transference problem between the B-47 and the B-52, and this is not documented anywhere. Of all the B-52 accidents wherein the B-52 collided with the ground for no discernible reason, we have never, to my knowledge, asked ourselves if we had a B-47 pilot who merely trimmed himself into the ground. We simply don't keep records in a fashion that enables the human factor investigator to readily trace that kind of history.

I know of at least one attempt to do that, and it occured when I was a flying instructor in the Air Training Command. In those days, we were teaching students fresh out of civilian life to fly tail draggers. The thing a tail dragger did best was groundloop. It was completely unstable on the ground. Once it started turning, the natural tendency of the airplane was to continue turning at an even faster rate. If no one stopped it, it would eventually wind itself into a very tight circle and probably tip over and damage the wingtip on the outside of the turn. That was a groundloop.

We had one student who got into a classic goundloop and tore up the airplane pretty badly. An investigation showed that his recovery actions had been exactly incorrect. He was groundlooping to the left, and he added full left rudder and brake instead of right rudder and right brake. When asked why, he had a simple explanation. His most recent experience in steering anything with his feet had been in the 1952 Olympics. He was a bobsled driver, and bobsleds are steered exactly backwards from an airplane. If you want to make a bobsled go to the right, you push it with your left foot. From then on, we added a new question to the questionnaire that we gave every student who showed up at flying school. We'd ask for his name, rank, part number, age, previous flying experience, and so on, but then suddenly we'd ask him if he'd ever driven a bobsled. Most students thought it was a joke – or that we were trying to trick them – or that we'd gotten our questionnaire mixed up with something else, but our intentions were pure. We were trying to identify those students whom we could expect to groundloop an aircraft based on their previous experience. To my knowledge, no one ever answered "yes" to that question, and I'm not sure that I know what we would have done if one had. Nevertheless, there was an honest attempt to bring human factors into the accident prevention business.

The third area where human factors investigators run into trouble is in the basic accident investigation mechanism. Our system encourages the conclusion that can be substantiated, and inhibits the one that is merely a strong possibility. In spite of our directives on objectivity of investigation, we do not see very many minority or dissenting opinions. With some experience in investigation of military accidents, I can tell you that there are very few investigations ever conducted which result in completely unanimous opinions on the conclusions. There are always different ways to interpret the facts of the matter; but for some reason, these other opinions seldom show up in the report – even though some of them contain some very good ideas. I believe the human factors investigator chronically finds himself in this area. He has some good ideas, but he cannot substantiate them; so his opinions don't carry much weight in the final report. His problem is that it is basically difficult to measure such human factors areas as stress, fatigue, or proficiency. Even though we suspect that any number of psychological or psycho-social or even physiological phenomena may be present, it is very difficult for the human factors investigator to substantiate them to the satisfaction of the investigative authority. Even in the military, where we restrict the use of our accident reports and do not release them to the public, we are not collecting very much of this kind of data. In the civil world, it is rare to read an accident report that contains any mention of it at all.

In seeking solutions to the human factors investigation problem, I have some suggestions which ought to make life a litle easier for the investigator. I also have one fairly radical idea which the human factor specialists might seriously consider. I'll get to that in a moment.

First, I don't think we're going to get very far in this business without some means of measurement other than just gut feeling.

Take crew rest, or more properly "crew fatigue." I don't think we know what constitutes fatigue. I am fairly familiar with most of the ground rules on crew rest, and I have also flown numerous long missions in Strategic Air Command bombers. Until someone comes up with a scheme for objectively measuring fatigue, I believe that the items which principally define crew rest are the requirements of the mission. You take the length of the mission that has to be flown and decide that anything longer than that constitutes fatigue. We know that's wrong, but as investigators, we tend to look at an accident and decide that anyone who hadn't worked any longer than that wasn't tired. Anyone who did work longer than that was, by definition, fatigued. I personally find that argument very fatiguing. I just don't believe it.

Second, I suggest to you that there has to be a better scheme for keeping records on the history of individual experience than there is now. Granted, that the first efforts at this will be rudimentary; we need to start somewhere. We need to document the fact that a person's past experiences and past performances will influence his future performance.

Third, I think that the military's scheme of collecting information in confidence is essential to the human factors investigator. He is not going to get candid information from people if he cannot assure them that the information will be held in confidence. Unfortunately, the trend in our society is not in that direction. The only thing we have going for us in the civil world is the national Aviation Safety Reporting System run by NASA. This system takes a very shallow cut at the problem because the data submitted are never investigated, or verified, or followed up. Nevertheless, it clearly demonstrates the amount of information available if the people who know it elect to talk about it. Without belaboring the issue, I can tell the human factors investigator that he is just not going to get much information unless he can show the person who knows it that the information will not be used in a manner embarrassing to him in the future. The NTSB can't do that; the lawyers won't do that; and the three military services are having a tough time in holding the line on what we consider to be privileged information.

Fourth, I suggest to you that if you want speculative and possibility type opinions in your accident reports, you have to write the report rules in such a manner as to encourage them and accept them for what they are.

Finally, I would like to suggest something which may be fairly radical. Considering all the problems faced by the human factors investigator, I believe that we may be wasting our time in trying to use him in trying to solve a specific accident. I mentioned earlier the problem of habit transference between the B-47 and the B-52 interphone switch. Even if we were perceptive enough in the Air Force to identify that as a problem, I do not believe that the knowledge of it would have led us to modify any of our accident reports. On an accident-by-accident basis, we just can't substantiate what the pilot did or did not do with his left thumb. Nevertheless, I believe that we could have collected data over the years which, taken as a whole, might support a human factors judgment. If, for example, we could say that one factor shared by all of a certain type of B-52 accidents was that the pilot had previously flown B-47s and had less than "X" amount of time in the B-52, where would we be then? Would we have enough to make a judgment? Would we change our training? Perhaps; I don't know.

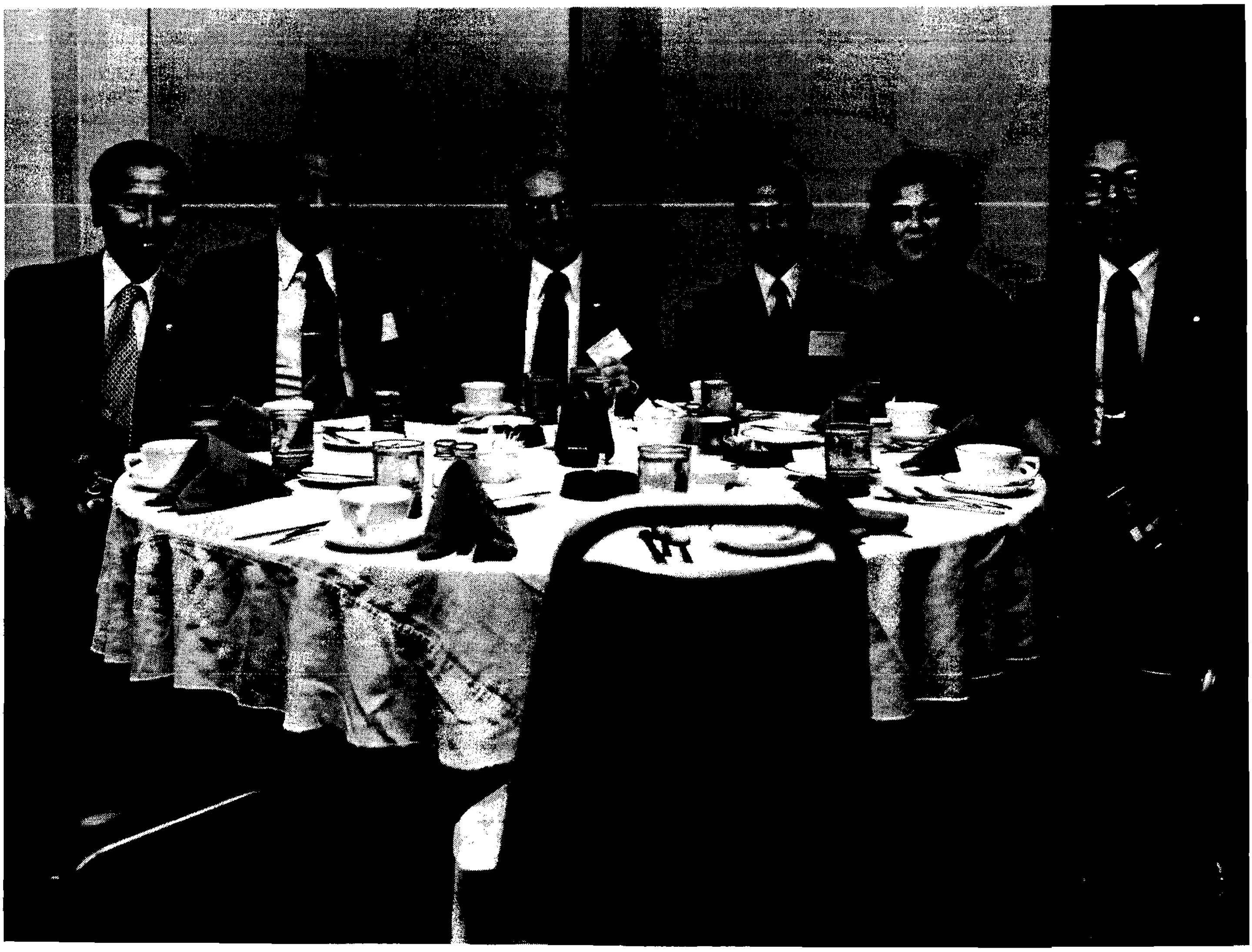
Suppose, going back to the case cited earlier, instead of trying to prove something about that accident, we merely logged the fact that fatigue, stress, hypoglycemia, and peer pressure were all present.

If we do this often enough, I believe, over time, that we would be in a position to say that these factors present in these combinations and quantities will produce accidents. I believe that is a more practical approach than trying to say that this factor produced that accident.

This, of course, would require a data collection and automation system more advanced than any of us now have. It would require us to keep and update records on pilots' background, training, and experience. It would require us to routinely collect certain elements of information on all accidents, regardless of the circumstances. It would require us to train all accident investigators on the concept and the importance of gathering the human factors data.

While we're doing this, it would be helpful if we all agreed on the data elements and the terminology. Perhaps it is time to seriously consider national or international standards on definitions of human factors terms.

It's a big job. Nevertheless, if we agree that the chief value of human factors investigation is in the collection and correlation of factors from a large number of accidents, we might as well get started on it.



DRUG AND ALCOHOL FINDINGS AND EFFECTS IN CIVIL AVIATION: 1978 UPDATE

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Studies in 1912 and 1915 determined that pilot failure caused 90 percent of aircraft accidents. We still find pilot or other personnel causes or causal factors in about 90 percent of general aviation aircraft accidents, both fatal and nonfatal.

This afternoon I will be discussing the effects of alcohol and (other) drugs on performance, 11 years of experience of the Civil Aeromedical Institute's (CAMI) Forensic Toxicology Research Unit, and recent CAMI research on drug and alcohol effects on performance. The importance of looking for the presence of alcohol and drugs to help determine accident cause and the existence of possible accident–causing diseases and symptoms, and the interpretation of reports rendered to you, will be my main theme. Other aspects of human factors accidents, medical conditions, and toxicological data regarding pesticide poisoning and fire will not be discussed.

Annual drug consumption in the United States is measured in tons (over 5,000 tons of aspirin) to billions of pills and capsules for some psychoactive drugs. In 1970 there were an estimated 214,000,000 prescriptions written for psychopharmaceuticals (for 4,000,000,000 of one popular tablet) including antianxiety, hypnotic, stimulant, antipsychotic, sedative, and antidepressant agents. Estimates of the number of products on the market range from 50,000 (probably prescription items only) to "250,000 to 500,000" over-the-counter drug products. It can be stated that we do not know within 250,000 the exact number of drug products currently on the market. Even though one-third of them are probably laxatives, it still can be said that none of them is totally safe for use while flying, and pilots have many of the same motivations to use medication as others.

We are frequently requested to provide a list of "safe" drugs to take while flying. With the huge and largely unknown list of eligibles, consideration of the medical condition for which a drug is taken, individual variation (in which one drug can have "side effects" ranging from stimulation to sedation), the dose taken, body weight, age, other physical and mental conditions, environmental factors, combinations of drugs and drugs and alcohol interaction, and findings that up to 64 percent of patients do not take drugs as prescribed, you can hopefully see the near–impossibility of such a list. The best advice for an airman then is to (1) preflight yourself and don't fly when you are not mentally and physically up to par, (2) don't take any drug just prior to or during flight, (3) obtain advice from physicians who are designated FAA Aviation Medical Examiners and/or pilots, and (4) if you are going to ignore this advice and use a drug preparation and fly, *never* take the *first* dose during or just before a flight.

Drugs have been identified in two (1.1 percent) of 174 fatal agricultural aviation accidents and in 120 (4.9 percent) of 2,449 other general aviation fatal accidents in which samples were submitted to CAMI for analysis between 1968 and 1978. About three-fourths of these were found in pockets and in the wreckage rather than in tissue and fluid sample. Barbiturates, antihistamines, tranquilizers, and salicylates are the most frequently encountered drugs. This data does not include drugs found at the scenes of accidents which were readily identified nor drug levels found in samples sent to other laboratories for analysis. The percentage of fatal accidents in which samples are sent to CAMI has increased gradually over the past 10 years and is now approximately 60 percent.

In several cases the presence of drugs has pointed to significant diseases which could have caused the accidents. This is the main reason to have "carried" drugs identified, for presence *on* the body frequently does not correlate with ingestion and possible drug effects on performance.

There is very little information on the anticipated effects on performance of a given tissue or fluid drug level – of any drug. Known toxic levels are rarely found. The individual variations, diseases, and other factors previously mentioned further complicate conclusions in these investigations. Testing by pharmaceutical companies and government agencies does determine toxicities, some drug interactions, effectiveness, and "side effects" of new drugs prior to approval and they update this information thereafter. No one routinely checks on drug effects on performance of complex tasks, particularly at altitude, under stress, with angular acceleration, with low humidity, etc. The military services have rarely approved drug usage by pilots and, therefore, have not had problems to study.

Therefore, it has been necessary for the FAA to perform its own studies on several drugs of importance for medical standards, certification policy, or airman education purposes.

Of particular interest and concern have been psychoactive ("mind altering") drugs with regard to judgment, alertness, memory, etc.; muscle relaxants which can affect coordination and increase reaction time; and sedatives which include several antihistamines for allergies in addition to preparations for sleep, high blood pressure, and ulcer and other gastrointestinal disturbances. Several products sold over–the–counter to assist sleep are in fact antihistamines and contain warnings about sedation, sleepiness, dizziness, and disturbed coordination.

CAMI studies on d-amphetamine when it was commonly used to aid weight reduction and to reduce fatigue determined that it did delay the onset of fatigue and moderate the degradation of performance due to fatigue but gave a false sense of performance capacity and had effects lasting for 8-48 hours. Secobarbital, like alcohol, interfered with smooth muscle tracking movements of the eye and visual fixation and caused blurred vision.

Dimenhydrinate and promethazine, drugs taken for motion sickness, had no demonstrated effects in a static environment but caused total blurring of the instruments in dynamic tracking. Promethazine with d-amphetamine was best for motion sickness and performance but is recommended only for nonpilot personnel.

The antihistamine chlorpheniramine was demonstrated to activate sleep mechanisms; the psychotropic drug chlorpramazine was found to adversely affect motor coordination for over 48 hours; the antihypertensive clonidine was shown to have less and shorter coordination effects; atropine, scopolamine, pralidoxime, and eserine disturbed visual attention to the point of apparent transient blindness in monkeys; lithium carbonate decreased short term memory; propranolol decreased the time of useful function at altitude in rats; and there were changes in the levels of effort and attention devoted to different tasks with Dristan® and Actifed® in recent CAMI studies.

CAMI does not yet have the capability to detect marihuana (or LSD) at the effective levels in body tissues and fluids; therefore, we do not know if it is a problem and, if so, the magnitude in civil aviation. Even if identified as a problem it is not feasible for the FAA to study the effects of marihuana on pilot performance. In one CAMI study on baboons, work output was reduced at higher doses at altitudes of 2,438 and 3,658 m. A university study of 10 pilots who smoked a social dose of marihuana and flew a flight simulator were reported to have "a gross decrement in flying performance, with increased prevalence of major errors, minor errors, altitude deviations, heading deviations, and radio navigation errors" which persisted for 2-6 hours after administration.

By comparison, ethyl alcohol has been identified as a significant safety problem in general aviation, the effects on pilot and other complex performance have been relatively extensively studied, additional effects at altitude are usually reported, and interactions with drugs are well documented.

Left to be discussed are findings in accident investigation, trends, causal blood alcohol levels, duration of effects, congener effect, the 8–hour rule, postmortem production of ethyl alcohol, the relationship between alcoholism and alcohol–related accidents, and the detection of alcoholism.

Blood alcohol levels above 0.05 percent have been found in 226 of the 2,623 pilots killed in general aviation accidents since 1968 whose samples were sent to CAMI. This approximately 8.5 percent incidence has been fairly constant since 1974 after drops from 12.8 percent (1971) to 10.2 percent (1972) to 4.9 percent (1973) following adoption of the 8-hour alcohol rule December 5, 1970.

Despite studies which have clearly demonstrated effects of alcohol on pilot performance in a moving environment at 0.026 to 0.040 percent, and consideration of altitude and a more complicated machine, determination of causal roles in accident causation have been tied to various state levels for operating motor vehicles. Until relatively recently this permitted legal flight with blood alcohol levels up to 0.150 percent. Billings *et al.* showed dramatically that this was not realistic in 1972. Most states now permit 0.100 percent and two have 0.080 limits. The NTSB has unofficially used 0.050-0.100 percent as contributory and over 0.100 as causal for the past few years. They are presently reviewing existing data and a revision by NTSB and a rule by FAA are possible.

Discussion of the effectiveness of education to encourage pilots not to drink and fly, the 8–hour rule, determining the relationship between alcoholism and alcohol–related accidents, detections of alcoholism including legislation to permit access to the National Driver Registry, and medical investigation of nonfatal accidents are beyond the scope of this paper.

Despite interesting theories on the role of congeners in some alcoholic beverages on acute and hangover effects of alcohol, no differences in ataxia, nystagmus, coriolis effect, or subjective symptoms of hangover have been found after ingesting congener and non–congener beverages in CAMI studies.

Alcohol has been reported to have long–term (12-37 hours) effects on some aspect of the vestibular system but no effects on nystagmus responses, responses to angular accelerations, or performance have been demonstrated during hangover stages in CAMI studies.

No effects of drinking history on alcohol tolerance have been observed in the young subjects used in our studies.

Effects of alcohol on visual functions in pigeons at the equivalent of 10 to 40 grams of whiskey for an 80 kg human have been detected in a recent study. These effects are at lower alcohol levels than those where performance decrements have been detected for pilots with angular stimulation to the vestibular area. The practical significance is uncertain at this time.

Although ethyl alcohol has been found in 29 percent of over 4,000 victims of general aviation aircraft accidents, less than half of the positive findings could be attributed to ingestion of alcohol. Fifty-five percent of the samples have contained microorganisms capable of producing ethanol from body substrate. The procedure of culturing samples to identify these organisms and interpretation of the results are of considerable current interest.

(left to right) Ted Ferry, Marty Speiser, Charles Garber

HUMAN FACTORS ENGINEERING CHALLENGED: THE DESIGN OF ACCIDENTS AND ACCIDENTS IN DESIGN

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I've been concerned for some time with the organization of the field of Human Factors Engineering and with providing some meaningful and useful definitions. Within the Air Force Human Factors Engineering community I'm trying to initiate some R&D which interrelates our areas. I present this to get you to think about this design area, some definitions and future relationships with safety.

The Air Force human factors engineering community again is beginning to pick up its ears and wants to pay more attention to the challenges of aircraft accidents. Why? What are the trends and challenges ahead for the design community? We are faced with designing for worldwide operations against dense, mobile threats and targets. Demanding, all-weather day and night combat operations are necessary. The complexity of the threat scenarios requires additional systems and subsystems to be added to the crew stations. We are not building as many new aircraft systems as before, but we do continue to add to and modify the avionics and weapon delivery subsystems. These add up to more sophistication and perhaps complexity for the crew to manage; potentially more workload. But the bottom line is that we are or should be designing for tough combat conditions.

What do we know about accidents under combat conditions? Not a lot but we do have some data under near combat: our operational exercises. During recent exercises the rate was 19/100,000 flying hours, or about six-fold increase over recent year's rate. Perhaps a nine- to ten-fold increase over our low normal operational rate of 3/100,000 flying hours would be a best but wild guess for combat conditions. Some researchers in our lab have analyzed fighter aircraft accident summaries for human factors involvement. They found distraction to be a major contributing element. A more recent analysis of eighteen months of Air Force accident experience revealed similar human factors involvment in about 50% of our cases.[1] The Strategic Air Command's recent accident experience includes six out of nine involving controlled flight into the ground; these are obvious human factors involvements.

What's "human factors" and "human factors engineering?" What more could the latter contibute to the safety/accident prevention business? Human factors is a broad term referring to many areas. Human factors engineering is an emerging design discipline which applies man-machine integration technology. The areas in Figure 1 can be thought of as categories of research or as factors which bear on doing a job, or on an accident on the job.

Let's think about an individual and an accident which is hypothetically going to happen today. Let's back off from combat to "flying the line" in any commercial operation. Our individual – a pilot, the company operations officer, got the job through medical selection. Of course this person brings a state of health to today's job and accident. There are environmental factors which affect the man and machine. They are brought about by the time, place and requirements of the mission. Personnel selection likewise got our pilot into the cockpit today. So did training selection. Our pilot brings trained skills, knowledge of procedures, subsystems functions and expectancies to the flight. The individual also carries many private concepts; the flight today is just part of the job. After all he is head of company operations – and don't you forget it! No one on today's crew will. Nor will his supervisor forget it. The entire organizational structure is a part of him whether he likes it or not. (It's like the cucumber in the pickle brine, the person's a part of the organization and so it is a part of the person.) Additionally, there are also the real bosses, the spouse, and kids. Although the person is full of needs, struggles, goals, etc., these are individual factors not depicted in the figure. When it comes to flying, it's all business, all professional. Off our crew goes concentrating on the mission and tasks at hand. It is the mission, the man-machine interfaces and the aviation system that determines the range of acceptable tasks and paces the tasks. But you say "that interface is frozen, fixes by the design, . . . somewhat predictable." Right, relatively so. But what went into freezing it? Or what should have, or will in the future? That's where the man-machine integration technology can play a role in safety. Our pilot had better hope that whoever did the design thought about what is going to happen to today's flight. Better yet, hope that there are designed-in tasks for recovery. "If not I'll sue 'em," the pilot says; or on second thought you, the accident investigators might sue 'em. Sue whom? The designers? The human factors engineers? Product liability concerns are not the only place where our two specialties challenge each other.

Another challenge is: What can man-machine integration information developed in design say about today's accident–some today but tomorrow a great deal. What technology am I talking about? Data bases, methods, tools, system representation and simulations. In the future we should be able to systematically access these data bases.

Let's get back to today's flight of the ops officer. The first officer is frightened ashen grey at his unlucky choice (if it was luck) for today's substitute captain. Flight attendants say "sir" or "ma'am" twice in each sentence to passengers, knowing his telepathic mind will catch the first omission. Out they climb, all concentrating on the tasks at hand and on who's behind the wheel. Nothing could go wrong, something going wrong is not in anyone's mind. A profound law, "the unexpected happens when least anticipated" takes over. It does and there you are investigating. The crew knew what happened but now it's up to you to find out.

How do you organize the information you collect to get at the human factors; the man-machine design factors? Of course there are approaches, information, and data bases in all areas which might contribute to a different organization of the data. Psychometric techniques could contribute to improvements in reliability of the judged information. I am suggesting that the man-man-machine, man-machine system organization may better organize what you collect. What data you collect is dependent upon your purposes. I feel like I'm humming to the philharmonic on the first of these. How about the man-machine integration area? Recently, there are Dieterly's analysis[3] and Barnart *et al* with a human factors interview checklist.[2] In the future we will look at interface design and task data to trace omissions and commissions.

One approach to task data is illustrated by Dieterly's decision analysis. In Figure 2 each crew position is analyzed in terms of input information, decisions, actions, and expectancy outcomes. This is very similar to task analyses used in the design process which may get down to the stimulus-response level. The closed loop analysis is an analogue of manual control work. Unfortunately much of the design data is not now thorough or accessable. If you were an Air Force investigator, Figure 3 shows what you would collect at the present time.[4]. This is not organized yet as I'm suggesting, but does contain valuable information. Other speakers will address this form.

Of course one purpose is affixing responsibility. Perhaps by the time the crew knew the problems, there were no provisions designed-in for solution, or no designed-in provisions to help the crew to know the problems while they were solvable. Is this the crew's fault? Or is it the designers' fault? The courts are pointing at design more often and human factors engineering input is needed often as an expert testimony.

The main human factors engineering interest is in how the data can lead to prevention. Prevention may depend upon more than the individual accident case. It involves the collation, analysis, and factor extraction of data across accident circumstances. Let's explain the human factors engineering interest by looking at hypotheses about accident circumstances. If accidents have prescriptions (i.e., setups of antecedent events) then the "root causes"[5] of omission or commission may cluster or have commonalities or common factors. Some of these omissions or commission clusters may go as far back as the designer. Also accidents only represent nonrecoverable prescriptions which may be a function of mission circumstances. How often do similar prescriptions occur where the root factors are present but recovery as far as catastrophe is concerned was effected? These factors may very well still be influencing mission outcomes or mission effectiveness. If we consider distractions and spatial geographic awareness as human factors, then it may very well be worthwhile, cost effective to do research, sophisticated exploration of the root factors to determine their nature and range of effects and to suggest/evaluate alternative design solutions. I'm talking about research on man's properties, man–machine interfaces and man–machine systems factors specifically aimed at prevention of accidents and improved mission effectiveness. Design solutions must still be creative processes but the same kinds of research that are used to manipulate complex man–machine systems can contribute to evaluations of alternative design solutions. Here I'm referring to systems analytic tools like the SAINT fast time computerized system description language, and complex, multivariate, multiman, real-time engineering design simulations. (These are distinct from training and training research simulations).

For design research purposes and in order to organize the Human Factors Engineering area we note that there are three kinds of information which build upon each other and which form the design related data base of Man–Machine Integration Technology — information related to man's properties, information related to man–machine interfaces and information about man–machine contribution to mission performance. Independent and dependent variables differ in each of these data base content categories. Data collected relevant to these categories will add to the data base and this categorization may simplify access to the data base.

We already addressed the problem of what to collect and ask about what human factors engineering methods could bear upon the purpose of description. But here we are asking what additionally do we collect to contribute to potential design, safety and effectiveness criteria? Again we should collect human factors engineering information centered about the specific man-machine tasks. What do we collate and how do we extract factors across accidents to get at clusters of root omissions and commissions? There are no special tricks here—or in closely related areas for applying techniques — subjective through objective. There already are clusters begging for design solution — mid–air collisions and controlled flight into ground. But what are root causes in such man–man–machine or man–machine systems areas? Some factors should be systematically subjected to research manipulations to prevent their occurrence in disastrous circumstances, for example: distraction of attention, spatial geographic awareness/orientation and heavy crew workloads. Such a research process is analogous to looking for how widespread is the structural crack. Simulations can look at design alternative evaluations. What to design remains a creative process. Voice warning interfaces may work some places. Tests can be assisted by simulations which look at mission effectiveness.

Let's momentarily get back to our ops officer and the accident investigation. I'll give you one more clue, this one includes human factors engineering design related factors. Hopefully you can suggest to me many such instances. We'll solve this next time perhaps within five years by dipping into the man–machine integration data base and tools.

How can we be sure that design or other solutions will apply to the combat situations with accompanying tendency for accident circumstances? In combat we find pressing workloads, a need to throw out the rules and to accept risk. What design approaches may help alleviate these in the future? I suggest: display integration; mission segment designed–in tolerance criteria; training of the mission and malfunctions — decision making; displayed energy maneuvering envelopes, weapons envelopes; instant, easy mission replanning and easy interfaces. In combat accidents, who's liable? Is the designer still involved? Yes, combat is the design purpose. Accident losses and combat losses add up to mission losses. Accident circumstances to mission effects. In summary, what are the challenges: design for combat, collection and extraction of root factors and factor research for design solutions.

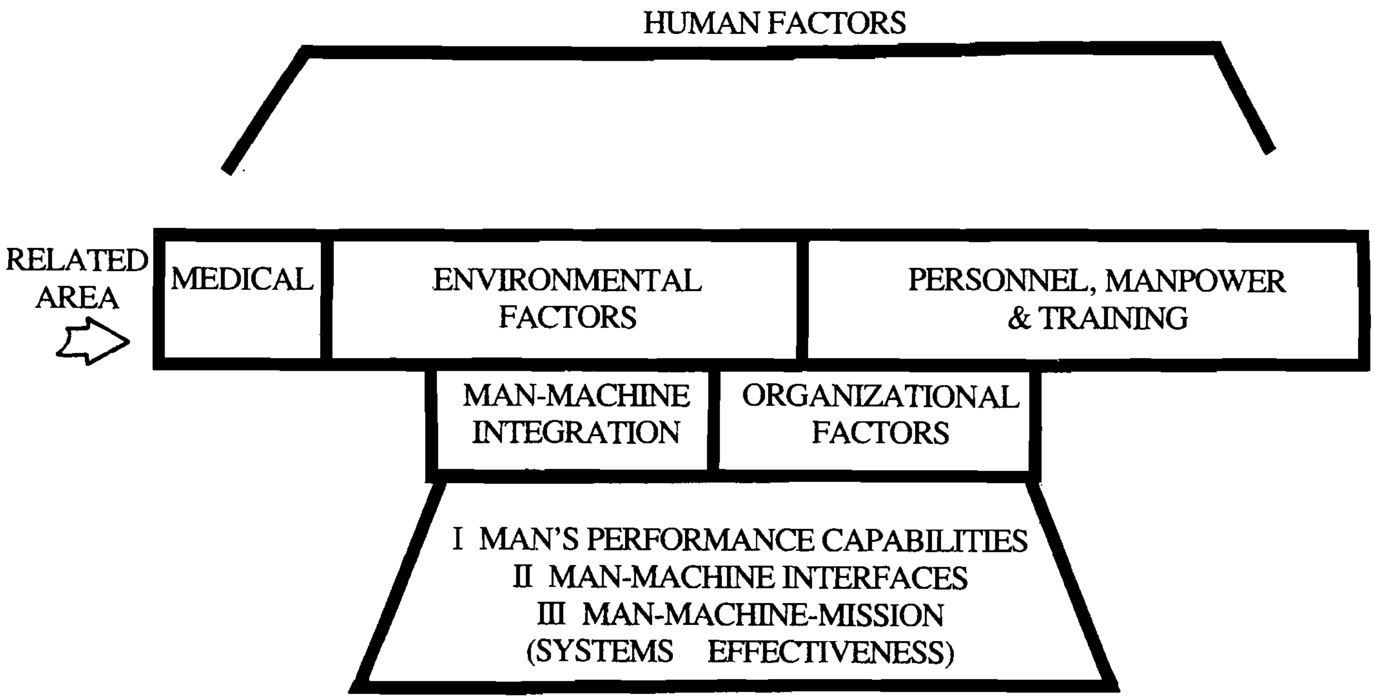

Figure 1

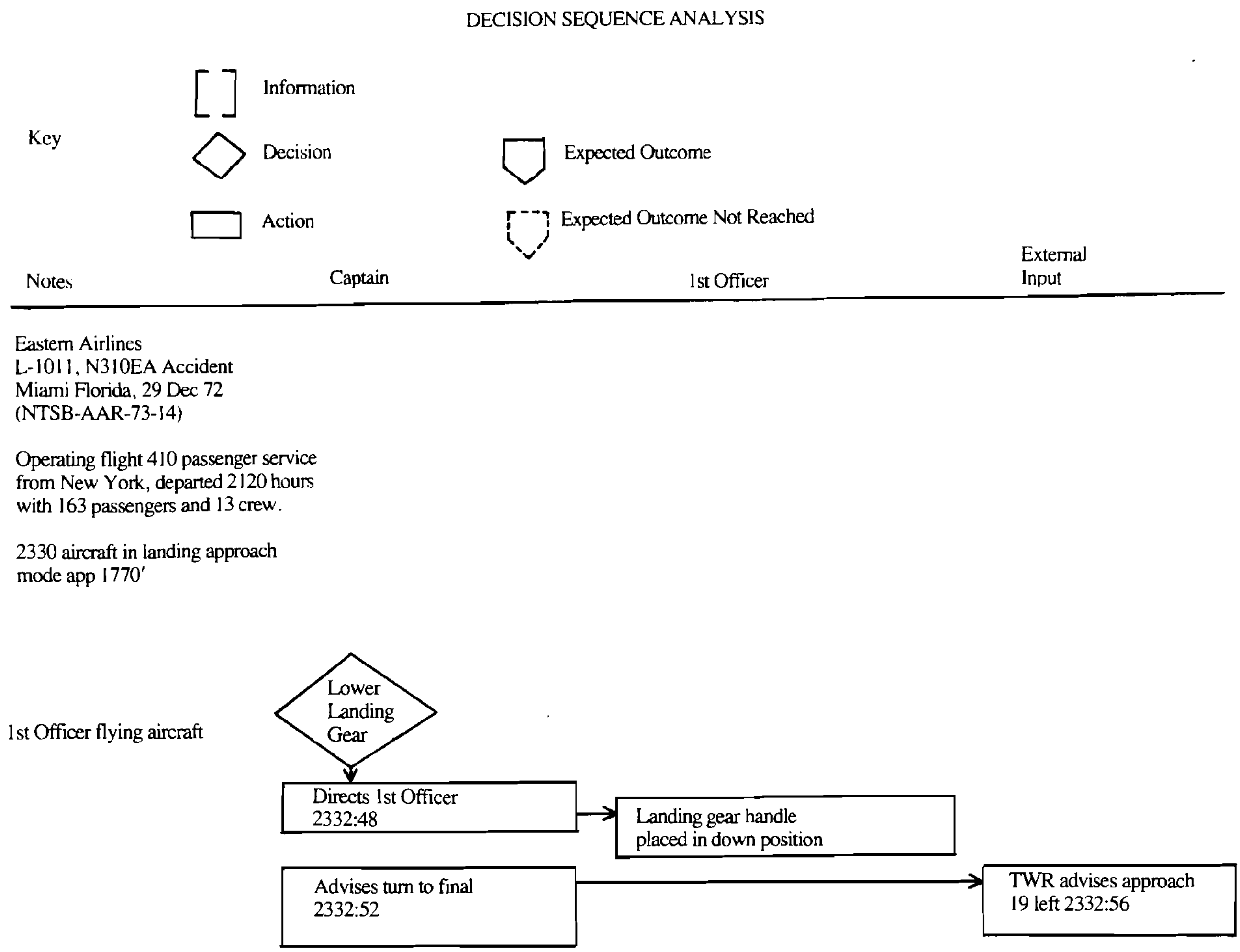

Figure 2

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FIGURE 1

III. PSYCHOPHYSIOLOGICAL AND ENVIRONMENTAL FACTORS

INSTRUCTIONS: Complete on all occupants of aircraft, all injured persons, and all persons possibly contributing to the cause of the mishap. Supervisory factors attributed to persons not in the aircraft and such factors as design or weather should be reported only for the person in primary control of the aircraft. Factors contributing to injury during mid-air collisions, crash landings, ditchings, etc., are to be considered part of survival phase. Use codes at right to show only those factors present or contributing in each phase.

PHASES OF MISHAP
- A - ACCIDENT
- E - ESCAPE
- L - LANDING
- S - SURVIVAL (*Includes parachute landings*)
- R - RESCUE

FACTOR IMPORTANCE
- D - DEFINITELY CONTRIBUTED
- S - SUSPECTED FACTOR
- P - CONDITION PRESENT, BUT DID NOT CONTRIBUTE TO ACCIDENT OR INJURY.

FACTORS		A	E	L	S	R
1. SUPERVISORY FACTORS						
INADEQUATE BRIEFING	101					
ORDERED/LED ON FLIGHT BEYOND CAPABILITY	102					
POOR CREW COORDINATION	103					
OTHER (*Specify*)	199					
2. PRE-FLIGHT FACTORS						
FAULTY FLIGHT PLAN	201					
FAULTY PRE-FLIGHT OF AIRCRAFT	202					
FAULTY PREPARATION OF PERSONAL EQUIP.	203					
HURRIED DEPARTURE	204					
DELAYED DEPARTURE	205					
INADEQUATE WEATHER ANALYSIS	206					
OTHER (*Specify*)	299					
3. EXPERIENCE/TRAINING FACTORS						
INADEQUATE TRANSITION	301					
LIMITED TOTAL EXPERIENCE	302					
LIMITED RECENT EXPERIENCE	303					
FAILURE TO USE ACCEPTED PROCEDURES	304					
OTHER (*Specify*)	399					
4. DESIGN FACTORS						
DESIGN OF INSTRUMENTS, CONTROLS	401					
LOCATION OF INSTRUMENTS, CONTROLS	402					
FAILURE OF INSTRUMENTS, CONTROLS	403					
COCKPIT LIGHTING	404					
RUNWAY LIGHTING	405					
LIGHTING OF OTHER AIRCRAFT	406					
PERSONAL EQUIPMENT INTERFERENCE	407					
WORKSPACE INCOMPATIBLE WITH MAN	408					
OTHER (*Specify*)	499					
5. COMMUNICATIONS PROBLEMS						
MISINTERPRETED COMMUNICATIONS	501					
DISRUPTED COMMUNICATIONS	502					
LANGUAGE BARRIER	503					
NOISE INTERFERENCE	504					
OTHER (*Specify*)	599					
6. PSYCHOPHYSIOLOGICAL FACTORS						
FOOD POISONING	601					
MOTION SICKNESS	602					
OTHER ACUTE ILLNESS	603					
OTHER PRE-EXISTING DISEASE/DEFECT	604					
GET-HOMEITIS	605					
HANGOVER	606					
SLEEP DEPRIVATION, FATIGUE	807					
FATIGUE, OTHER	808					
MISSED MEALS	809					
DRUGS PRESCRIBED BY MEDICAL OFFICER	610					
DRUGS, OTHER	611					
ALCOHOL	612					
NAME OF INDIVIDUAL						

FACTORS		A	E	L	S	R
VISUAL ILLUSIONS	613					
UNCONSCIOUSNESS	614					
DISORIENTATION/VERTIGO	615					
HYPOXIA	616					
HYPERVENTILATION	617					
DYSBARISM	618					
CARBON MONOXIDE POISONING	619					
BOREDOM	620					
INATTENTION	621					
CHANNELIZED ATTENTION	622					
DISTRACTION	623					
PREOCCUPATION WITH PERSONAL PROBLEMS	624					
EXCESSIVE MOTIVATION TO SUCCEED	625					
OVERCONFIDENCE	626					
LACK OF SELF-CONFIDENCE	627					
LACK OF CONFIDENCE IN EQUIPMENT	626					
APPREHENSION	629					
PANIC	630					
OTHER (*Specify*)	699					
7. ENVIRONMENTAL FACTORS						
ACCELERATION FORCES, IN-FLIGHT	701					
ACCELERATION FORCES, IMPACT	702					
DECOMPRESSION	703					
VIBRATION	704					
GLARE	705					
SMOKE, FUMES, ETC.	706					
HEAT	707					
COLD	708					
WIND BLAST	709					
VIS.RESTR.-WEATHER, HAZE, DARKNESS	710					
VIS.RESTR.-ICING, WINDOWS FOGGED, ETC.	711					
VIS.RESTR.-DUST, SMOKE, ETC., IN ACFT.	712					
WEATHER, OTHER THAN VISIBILITY RESTR.	713					
OTHER (*Specify*)	799					
8. OTHER FACTORS TO BE CONSIDERED						
HABIT INTERFER., USED WRONG CONTROL	801					
CONFUSION OF CONTROLS, OTHER	802					
MISREAD INSTRUMENT(S)	803					
MISINTERPRETED INSTRUMENT READING	804					
MISLED BY FAULTY INSTRUMENT	805					
VISUAL RESTR. BY EQUIP. STRUCTURES	806					
TASK OVERSATURATION	807					
INADEQUATE COORDINATION OR TIMING	809					
MISJUDGED SPEED OR DISTANCE	809					
SELECTED WRONG COURSE OF ACTION	810					
DELAY IN TAKING NECESSARY ACTION	811					
VIOLATION OF FLIGHT DISCIPLINE	812					
NAVIGATIONAL ERROR	813					
INADVERTENT OPER, SELF INDUCED	814					
INADVERTENT OPER, MECHANICALLY INDUC.	815					
OTHER (*Specify*)	899					
SSAN						

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