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by

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SUMMARY

Single pilot instrument flight rule (SPIFR) operations have problem areas which may cause pilot errors that result in accidents. Problems and suggested research areas to solve these problems were determined by examining and analyzing the accident files of the National Transportation Safety Board for the years 1964 through 1975 inclusive.

The accident reports examined were restricted to instrument rated pilots flying in actual IFR weather. A brief examination was made of accidents which occurred during all phases of flight and which were due to all causes. A detailed examination was made of those accidents which involved a single pilot which occurred during the landing phase of flight, and were due to pilot error. It was found that there were 877 single-pilot pilot error accidents, 446 of which occurred during the landing phase, and 335 of the 446 had filed an IFR flight plan. The reports on these 335 accidents were examined in detail. It was found that the SPIFR pilot error landing accidents examined increased three times faster than the dual-pilot pilot error accidents during the same time period. Most pilots involved held commercial certificates and had an average of 3000 hours total flight time.

Problem areas were found to be pilot workload, low visibility at night due to fog and low ceilings, icing on aircraft not deicer equipped, imprecise navigation, failure to remain above minimum altitudes, mismanagement of fuel and low instrument time. Some suggested areas of research include new types of deicing or anti-icing equipment, standardized navigation instrument displays, improved fuel management systems and better methods for pilots to safely acquire experience and increase proficiency in SPIFR operations.

INTRODUCTION

As a whole, general aviation is safer now than in the past. This is evidenced by the fact that the total number of general aviation accidents had decreased over the past ten years while the activity has more than doubled. However, the number of

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accidents involving instrument rated pilots operating under instrument flight rules (IFR) and instrument meteorological conditions (IFR weather) had consistently increased and this is of great concern to the aviation community. The cause of these IFR accidents is usually attributed to pilot error rather than hardware failures.

A general consensus is that one of the problems related to pilot error is the high single pilot workload on an instrument flight. To determine if this consensus is true, to define other problem areas, and identify areas of research in single pilot IFR (SPIFR) operations, it was decided that the general aviation accident report files of the National Transportation Safety Board (NTSB) should be examined and analyzed.

The NTSB accident files were available on magnetic tape for the years 1964 through 1975. Each accident report contains as much information as available on the facts surrounding the accident, and the judgment of the NTSB as to the probable causes and factors contributing to the accident. Many accident reports have remarks included which give unusual information about the accident and insight not otherwise available in preformatted reports.

Prior to any examination of the accident data, it was decided that the data base would include only general aviation, fixed wing aircraft, and instrument rated pilots flying in actual IFR weather. Preliminary examination of the data using this criterion yielded over one-thousand accident reports. Over half of these accidents occurred during the landing phase of flight (the landing phase is defined as that portion of the flight from the initial approach fix inbound until the aircraft reaches the missed approach fix or taxis off the runway). The high percentage of accidents during the landing phase was felt to be significant due to the relatively short time span the landing phase occupies compared to the total duration of a flight. Because of the large number of accident reports and because so many occurred during the landing phase, it was decided that this report should emphasize this phase of flight. It was felt that for detailed examination, only those accidents where pilot error was involved should be used to give the best insight into the problems of SPIFR operations.

The accident reports were examined and the data were analyzed as twelve year totals. A detailed examination and analysis was made of reports of accidents which occurred during the landing phase. These landing phase accident reports were examined in terms of pilot error, the variables of flight, and the pilot's proficiency. The specific pilot errors are tabulated against other accident cause/factors to determine if certain pilot errors can be consistently associated with specific contributing cause/

factors. The different variables of a flight are cross referenced and examined quantitatively to discover any problem areas. Finally, the pilot's experience is examined with regard to total flight time, actual instrument time, time in last 90 days, and time in the type of aircraft to determine if the pilot's experience is a significant factor in SPIFR landing accidents. Information obtained from the "remarks" of the NTSB reports is included with other data as necessary.

Appendix A is a glossary which is included to help clarify many terms and phrases. Some terms used in the accide ' reports are defined slightly different or more specifically than the usual definition. Appendix B is a list of abbreviations used in this report.

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RESULTS AND DISCUSSION

Phase of Flight

Figure 1 shows the distribution of SPIFR pilot error accidents with respect to the phase of flight and a comparison between the total number of accidents and the number of fatal accidents. There were no fatal static or taxi accidents. These data include flights which were or were not on IFR flight plans. The data show that just over half the accidents occurred during the landing phase while the majority of the remainder occurred during the enroute phase.

Figure 2 shows the phase of flight data and the number of general aviation IFR approaches separated by year. The number of take off, enroute, and landing phase accidents have tended to increase over the time span while the number of static and taxi accidents have tended to remain constant. The top set of data in figure 2 shows how general aviation IFR activity has increased. These data are the number of general aviation instrument approaches handled by Federal Aviation Administration (FAA) facilities. (Ref. 1, and telephone conversations with the Information and Statistics Division at FAA Headquarters). The number of instrument approaches includes only aircraft on IFR flight plans making approaches during actual IFR weather. These data are considered to be the best available measure of activity during actual IFR weather.

In figure 3, the number of IFR accidents in each phase of flight has been divided by the number of instrument approaches to show how the number of accidents per IFR activity has changed over the years. A linear regression was used to obtain a rate of change on the number of accidents. This analysis shows that IFR landing phase accidents decreased at a rate of 4.4 accidents per 100,000 approaches per year and enroute phase accidents decreased at a rate of 6.7. A linear regression on the IFR taxi and takeoff data shows them to have decreased at one-tenth the rate of enroute accidents with poor correlation. A better approximation of taxi and takeoff accidents is a curve going asymptotically to a small number.

Pilot Error and Related Cause/Factors

Figure 4 presents data of accidents which occurred during the landing phase and shows that single-pilot pilot error accidents account for the majority. A linear regression was applied to the data to obtain straight line approximation. This analysis shows that single-pilot pilot error accidents increased at a rate of 3.5 accidents per year while dual-pilot pilot error accidents increased at less than one-third this rate. The single-pilot and dual-pilot accidents that were not caused by pilot error appears to vary about a mean. Single and dual-pilot not pilot error accidents both had means of 3.7 accidents per year with standard deviations of 1.8 and 2.5, respectively. It is thought that accidents not caused by pilot error remained steady while the total activity increased because improved aircraft equipment over the time period increased aircraft reliability.

Over the time period considered, 72 percent of the IFR landing phase accidents involved single pilot operations. Of these, 87 percent were attributed wholly or in part to pilot error. This is compared to the 28 percent which involved dual pilot operations, 75 percent of these were attributed to pilot error.

Table I gives the frequently cited cause/factors of SPIFR pilot error accidents which occurred while on IFR flight plans. Out of more than fifty possible specific pilot errors, those which occurred in at least ten accidents are listed across the top of the table. Out of approximately 95 nonpilot error cause/factors which were cited, only those which appeared in combination with the same specific pilot error in at least ten accidents are listed along the side. Since the NTSB can give each accident as many as ten probable cause/factors, the numbers in Table 1 can add to more than the number of accidents.

Improper IFR Operation

Table I shows that improper IFR operation was given as a probable cause/factor in 170 of the 335 SPIFR-pilot error landing accidents. Low ceiling and fog were also cited as cause/factors in many of these same accidents. In such cases, the accident usually was caused by the pilot being too low, off course, not executing a missed approach, or entering known or forecast moderate or severe icing.

Descending below minimums during an instrument approach and not executing a missed approach when required is an example of improper IFR operation. In many accident reports citing improper operations, additional cause/factors are given to explain why the pilot descended too low. These cause/factors include diverted attention from the operation of the aircraft, failed to follow approved procedures and directives, and misread or failed to read instruments.

Low ceilings were also a cause/factor in 68 of the 170 accidents where improper operation was a cause/factor. A low ceiling results in the pilot not being able to transition to visual flying until he is very low, and implies the presence of precipitation and possible icing if the temperature is below freezing. When low ceiling was cited as a cause/factor, the ceiling was usually below 500 feet. The minimum descent altitude or decision height (MDA or DH) for the approach was not reported for these accidents, so the difference between the ceiling and MDA or DH cannot be compared.

Fog was a cause/factor in 104 of the 170 accidents involving improper IFR operations. An example of improper IFR operation in this case would be the pilot descended too low or delayed executing a missed approach or both. As will be discussed later, fog and low ceilings usually occurred together.

Improper IFR operation was listed in conjunction with 10 of 15 accidents involving known pilot fatigue. Pilot fatigue was considered a cause/factor when it was known the pilot had been flying all day. It is impossible to know from the accidents reports how many other pilots were suffering from fatigue due to other activities. Fatigue decreases the workload the pilot can handle satisfactorily and increases the chances for improper IFR operation.

Icing

Table I shows that 56 accidents had icing conditions as a cause/factor, and 13 of these also had improper operations as a cause/factor. Icing conditions implies that the aircraft encountered aircraft ice or an icy runway. Aircraft ice includes airframe, windshield or propeller ice. Airframe ice was listed on 47 accidents, windshield ice on 20 accidents, and propeller ice on 2. Icy runway was listed on 14 accidents.

FAR 91.209 for large and turbine-powered multiengine aircraft states that a pilot may not intentionally fly into forecast or known icing or moderate or severe intensity without proper deicing/anti-icing equipment. In accidents where the pilot flew into known icing, the cause.factors were considered to be combinations of improper IFR operation, attempted operation with known deficiencies in equipment, and improper preflight preparation or planning. In several accidents, improper IFR operation was cited for descending too low, or failing to execute a missed approach. Pilots may have intentionally descended too low in hopes of getting out of icing conditions or may not have executed a missed approach because of poor climb performance and the danger of increased ice. In some cases, icing caused deterioration in the aircrafts' performance and control to the point where the pilot lost control of the aircraft. These accidents were controlled or uncontrolled collisions with the ground.

All pilots that encountered icing did not necessarily violate IFR procedures. In cases where they did not, the cause of the accident was failure to obtain/maintain flying speed, or improper level off and mechanical overload failure. In these accidents, the aircraft was controllable but suffered from some deterioration in performance which the pilot did not compensate for properly. Icing conditions was not given as a cause/factor in some accidents with windshield ice. This implies the windshield may have frosted over when the aircraft descended from freezing temperatures into clouds above freezing temperatures. The primary cause of such accidents usually was given as misalignment with the runway or intended landing area.

The problem of icing is important in SPIFR operations because many of the types of aircraft involved are the smaller aircraft which are not deicing/anti-icing equipped. Many small aircraft do not have the power available to drive deicing/anti-icing equipment. The situations where icing is encountered are infrequent and usually avoidable in SPIFR operations, therefore, deicing/anti-icing equipment is not considered cost effective. Suggested areas of research are the development of a low-power cost-effective deicing/anti-icing system for small aircrafts and improved icing forecasting/detection techniques.

Fuel Exhaustion

Table I shows 18 accidents has mismanagement of fuel as a cause/factor and 14 of these experienced fuel exhaustion. The FAR's state that if the intended destination's weather is forecast to be below certain minimums, the pilot must start out with enough fuel to complete the flight to the first airport of intended landing, fly from that airport to an alternate airport and fly thereafter for 45 minutes. In the accidents caused by fuel exhaustion, the data do not show if the pilot ran out of fuel at his first intended destination or at his alternate destination. In six of the 14 accidents where fuel exhaustion was a cause/factor, the pilots were cited for inadequate preflight preparation or planning.

Many small aircrafts do not have fuel flow gauges, therefore, it is impossible to accurately know how fast fuel is being burned. Generally, the pilot estimates the endurance time based on the fuel aboard using the average fuel consumption of his aircraft. The actual fuel consumption will be somwhat different, depending on gross weight, engine conditions, leaning procedures, and other factors. Many aircraft fuel quantity gauges do not give accurate readings of the fuel remaining. In addition to this, the gauges are small and are marked only to give approximately values. Therefore, unless the pilot suspects a large error, he is not likely to reestimate the fuel consumption in flight because of the increase in workload it causes. A possible area of study is accuracy of present day gauges and fuel management instruments which give accurate information on fuel remaining and flying time remaining based on the present fuel flow.

Mission Variables

Mission variables are the different conditions surrounding the flights and subsequent accidents. These variables are examined to determine what conditions complicate a landing approach and to determine if the accidents were due to improper aircraft control or to imprecise navigation.

The NTSB accident analysis computer program was used to tabulate the number of accidents in terms of certain values or ranges of user selected pairs of mission variables. Table II is a matrix of the different variables it is possible to tabulate. The X's and O's indicate which pairs of variables were examined during this study. The O's indicate either that one or both of the variables were not recorded on the majority of the accident reports, or that the variables did not show interesting trends. The X's indicate combinations of variables which were available on a sufficient number of reports and exhibited interesting trends. This information is presented in Tables III through X and discussed in this section.

At the top of each table is tabulated the most serious injury which occurred in each accident. Injury can be used to measure the severity of an accident. It is felt to be a better indicator than damage since in virtually all the accidents where there was a fatality, the aircraft was destroyed but in accidents where there were no injuries, the aircraft still was destroyed or substantially damaged. Some of the data presented in the tables are included for completeness and will not be discussed in the text. Data on pilot's certificate, occupation, and ratings will be discussed in the section on pilot's experience.

Flight Purpose

Table III presents the flight purpose in terms of selected mission variables. Pleasure flying was the most common flight purpose, followed by business, corporate/executive and air taxi. The percent of accidents in below IFR minimums weather and the percent of fatal accidents vary as a function of flight purpose. Pleasure flights had the lowest percentage of accidents in below minimum weather with 14 percent. Air taxi-cargo operations had 17 percent while business and corporate flights each had 18 percent in below minimum weather. However, air taxi-passenger operations had 30 percent of their accidents occur in below minimum weather and ferry operations had the highest percentage of below minimums accidents at 45 percent. For pleasure, air taxi-cargo, and corporate flights an average of 37 percent of accidents were fatal while for business flights and air taxi-passenger operations, 49 percent of the accidents were fatal. These distributions probably reflect the psychological pressure on the pilot under different types of operations.

Weather Briefing

Table IV presents the type of weather briefing received by the pilot. The accidents of pilots briefed in person involved fewer injuries and occurred less often in below minimum weather. For the pilots briefed in person, 40 percent of their accidents had no injuries and 15 percent occurred in below minimum weather. Whereas, pilots briefed by phone had 28 percent with no injuries and 18 percent in below minimums and pilots briefed by radio had only 20 percent with no injuries and 32 percent below minimums. It is thought that the pilot who gets an in-person briefing realizes the value of indepth weather information more than the pilot who spends less time and effort on his briefing. Since pilots briefed in person do not have as many accidents in low IFR and below minimum weather, it is though that these pilots are deciding not to fly in these weather conditions.

The in-person interview is the only type of briefing where the pilot can view the weather charts and form a good mental picture of the location, extent and movement of significant weather. The in-person briefing is less convenient but is usually more complete. During an in-person or a telephone briefing, the pilot can usually give more attention to the briefing than if it was a radio briefing. A briefing by radio would tend to contain only the essentials in order to minimize transmission time, and the pilot would also retain less since he is concerned with other cockpit duties at the same time. Any weather briefing received while in flight would certainly increase pilot workload more than if the briefing had been done prior to take off. It may be more current, however.

Obstruction to Vision

Table V presents the obstructions to vision at the accident. The table shows that fog was the overwhelming cause of poor visibility in the accidents here. In over half the accidents, fog occurred in conjunction with precipitation. This further hampers vision by blurring the view and suggests that the fog existed below a more solid cloud layer. The presence of low ceilings and fog together is substantiated by the information in the briefs No obstruction to vision was given in 40 percent of the accidents. However, 65 percent of these accidents had precipitation and associated cloud ceilings which would restrict cockpit visibility. An area of research is in alternate methods for removing water from general aviation windshields.

The accidents in the mountains tended to have generally better weather than in other terrains. Only 28 percent of the night accidents occurred in the mountains compared to 61 percent on level land. Also, 39 percent of the mountain accidents occurred in visibility of one mile or less while 58 percent of the accidents on level land had comparable visibility. It appears that pilots flew less or were more cautious about flying in mountains when the visibility is poor, especially at night.

Condition of Light

Table VI gives the condition of light at the time of the accident. There were 180 accidents at night and 132 during daylight hours. The total number of night operations is not known, but it is thought to be less than the number of daylight operations. If this is true, then the number of accidents per operation is even greater at night.

Already existent problems seem to be magnified at night. Most fatal and serious injuries occurred at night. Most of the accidents where the visibility was one mile or less, where fog existed and precipitation existed, occurred at night. A variable ceiling also presented more of a problem at night. The variable ceiling at night would cause difficulty in determining when the aircraft broke out of the overcast. All of these are visibility restrictions which would cause the pilot to be distracted from the control panel to look for lights before he had any possibility of seeing them. Because of this, the pilot might not notice altitude, course, or attitude deviation until it was too late.

This suggests the need for new warning devices and improved stability and control.

Most of the controlled collisions with a stationary object occurred at night. At night, the pilot is dependent on ground lights to see the ground and airport, but restricted visibility reduces the light which can reach the aircraft and increases the reflection of aircraft rotating lights back at the pilot. The high number of accidents in terrain which is dense with trees indicates a problem in unpopulated areas at night. There are few ground lights to cue the pilot on his clearance between the ground or tree tops.

It is also more difficult to notice ice forming on an aircraft at night than during the day. If the pilot uses a flashlight to check the wings for ice, he has not only introduced a very attention consuming task into his workload, but he has increased the possibility of spatial disorientation because he must turn his head through large angles. Accidents where freezing temperatures were given in the data occurred more often during the day, but freezing precipitation was most often present in accidents at night. The briefs indicate that spatial disorientation usually occurred at night.

Phase of Landing

Table VII gives the particular phase of landing the aircraft was in when the accidents took place. Over twice as many accidents occurred during the final approach as occurred during either the initial approach or level off/touchdown. The final approach and missed approach phase accidents are strongly related to low visibility. The number of accidents which occurred on final doubled for each one mile decrease in visibility. Many of these accidents occurred in what is considered to be very low visibility. Almost 30 percent of the final approach and 35 percent of the missed approach accidents had visibility of one-half mile or less at the accident site. In 30 percent of the final and 15 percent of the missed approach accidents, the weather was below landing minimums. The cause of the low visibility was fog in over 80 percent of the accidents.

During the final approach the pilot must transition from instruments to visual and see the airport without descending below the minimum altitude. If the pilot is not able to make visual contact by the time he reaches the missed approach point he is required to execute a missed approach.

In weather which is near or below landing minimums, the pilot probably knew apriori he would not be able to complete the approach. If the pilot was psychologically conditioned that the normal procedure was a missed approach rather than the landing, then he would react quickly and properly if the runway is not sighted.

The number of accidents during the initial approach did not vary substantially as a function of visibility or condition of light. This is probably because the pilot's attention is concentrated in the cockpit during this phase of the approach. The fatality rate for initial approach accidents was higher than the other phases, .63 fatal accidents per accident whereas final approach had .53 and level off/touchdown had zero. This variation is attributed to the difference in airspeed, aircraft configuration, and attitude of impact between the different phases. The initial approach accidents occurred more often in the mountains in contrast to final approach accidents which occurred more often in nonmountainous areas. This tends to indicate the initial approach was being flown with insufficient position and attitude precision. The procedure turn is part of the initial approach segment and the pilot usually does not know if he is staying within the prescribed area for obstruction clearance while executing the procedure turn. In the mountains, staying within the prescribed area is obviously more crucial than in flat lands, since the ground clearance can go to zero quickly outside the prescribed area.

Accidents which occurred during the level off/touchdown or roll phase of landing generally occurred during the daylight and in better visibility than accidents which occurred in other places. This would be expected since the pilot had already transitioned to visual flight and flown to the runway before the accident occurred.

Type of Instrument Approach

Table VIII presents the type of instrument approaches the aircraft was executing when the accidents occurred. The approaches have been separated into precision and nonprecision, straight-in and circling. The type of approach was not given on 59 of the 335 accidents examined. Generally, these accidents occurred at the airport and in such cases the type of approach was not considered to be important.

The ILS and VOR were the most frequent types of approach listed in the accident reports. The ILS approaches are separated into those with and without advisories from approach surveillance radar (ASR). Of the accidents where ASR was available, 55 percent occurred on final approach, and 18 percent occurred during initial approach. This is compared to the accidents where ASR was not available in which case 46 percent of the accidents occurred on final and 24 percent occurred on initial. It is felt that the increase in initial approach accidents on ILS without ASR is due to pilot workload, the lack of precise position information, and that many pilots have become accustomed to ASR service. Without ASR, the pilot must, in most cases, fly outbound from the locator outer marker along the localizer, do a procedure turn and then intercept the localizer inbound for the approach. This involves four major heading changes, altitude changes, timing of the segments flown, and making wind corrections. With ASR, the pilot is instructed by a radar controller what heading and altitude to fly until he intercepts the localizer inbound. In this case, there is no timing, no procedure turn, and not as much cognitive workload required. It is hypothesized that the reduced workload for the pilot on the ILS and ASR and the accurate position information available to the controller, accounts for the difference in accidents on initial approach.

The NDB approach had the highest percentage of accidents during initial approach, 37 percent. The NDB approach was the only frequently used instrument approach where over half the accidents were fatal. The topography at the accident site was most often mountainous, whereas, on most other type approach accidents, the topography was level.

The NDB has the advantage of providing approaches to airports in mountains where the terrain prevents the use of VHF radio equipment for instrument approaches. Its disadvantages lie with the airborne equipment, the automatic direction finder (ADF), which receives the NDB signal. The display readout is often of poor accuracy and the display can give only indirect position information and does not give on-course information. A possible area of research would be designing a low/medium frequency receiver which gives position and on-course information more accurately and directly than the present day ADF.

The localizer back course type of approach had the lowest percentage of fatal accidents of the different instrument approaches. The ASR only approach had the highest percentage of fatal accidents with 60 percent. This high percentage of fatal accidents could be due to the relatively low precision of ASR approaches. However, the low number of samples in both these cases make the statistical validity low.

The visibility was generally poorer on the ILS approach accidents than on other types of precision and nonprecision approach accidents. The median visibility at the ILS accidents was between 3/4 and 1 mile and the mean was 1.3 miles. These low values are thought to be due to the lower landing minimums allowed on an ILS approach. The VOR and NDB approaches have higher landing minimums and, as expected, the accidents tended to occur in slightly better visibilities. The VOR and NDB accidents both had a median visibility between 1 and 2 miles while the VOR had a mean visibility of 1.9 miles and the NDB had a mean of 1.6 miles.

It appears that night accidents vary more as a function of MDA than visibility. The pilot is allowed to descend lower on an

ILS than he can on a VOR or NDB approach, and straight-in minimums are lower than circling minimums. There were over three times as many night as day accidents on ILS approaches. On NDB straight-in approaches there was exactly twice as many accidents at night, and on the VOR straight-in and LOC approaches there was slightly less than twice as many at night. There were more VOR circling, NDB circling and LOC back course accidents during the day.

The current procedure allows the same landing minimums for an airport whether it is day or night. A study should be done to determine if certain types of approach procedures should have a different minimum descent altitude for day and night.

Type of Accident

Table IX gives the type of accident. From the type of accident it can be determined if the accident was due to aircraft control or imprecise navigation (including altitude deviation).

The types of accidents categorized as controlled collisions with ground/water, trees, wires, poles or towers have been grouped together as controlled collisions with a stationary object because it is felt that these types of accidents are basically similar. This group accounts for 45 percent of the landing phase accidents, and includes 81 collisions with trees, 61 collisions with the ground/water, and 10 collisions with wires, poles or towers. Controlled collisions with a stationary object occurred in very poor visibility more often than any other type of accident. The visibility at the accident site ranged from zero to one mile in 95 accidents. Fog was responsible for the reduced visibility in most of these accidents. This group of accidents occurred three times more often at night than during the day. In 54 percent of these accidents there was some form of precipitation present which indicates a cloud ceiling was also present.

In almost all of the accidents which were controlled collisions with a stationary object, the pilots' navigation was imprecise and it is assumed they either did not see the impending collision or saw it too late to avoid the accident. At night, especially, with reduced visibility, it would be nearly impossible to see the ground, trees, or unlit objects in time to avoid a collision. With a low ceiling, even in good visibility, the accidents could occur while the aircraft was still in the clouds, or immediately after breaking out of the clouds. In these cases, transition from instrument to visual flying probably never occurred. When the visibility is better, especially during the day, the pilot has more time to transition and react so that a collision can usually be avoided.

Accidents which were controlled collisions with a stationary object varied as a function of the phase of landing, the type of approach, and the terrain. Colliding with trees was the most common type of accidents on final approach. Together with colliding with the ground, these account for 85 of the 139 final approach accidents. From the remarks included in the accident briefs, it was found that the pilot descended below the legal minimum IFR altitude in half the accidents which involved controlled collisions while on final approach. Over half of the controlled collisions occurred during nonprecision* approaches where there was no vertical course guidance. The number of these collision accidents which occurred in mountains is almost equal to the number which occurred on level ground. Many in the aviation community have the opinion that a pilot is more likely to collide with a mountainside than level ground during instrument weather. If the supposition that there are less approaches attempted in the mountains is true, then there are more collision accidents per approach in the mountains.

The second most frequently occurring types of accidents happened when the aircraft flared and touched down. This group accounts for 49 of the 335 landing phase accidents and includes 25 hard landings, 14 wheel-up landings, 6 gear retracted and 4 gear collapsed. These accidents caused extensive damage to the aircraft but did not cause any fatalities or serious injuries because of the low airspeed and low vertical descent rate at touchdown. One problem these accidents indicate is with the pilot controlling the aircraft when airframe ice is present. From the accident briefs it was found that hard landings were usually due to the pilot not compensating properly for airframe ice. Another problem on touchdown is the pilot not having the gear down and locked. The remarks indicate that wheels-up and gear retracted accidents generally occurred as a result of the pilot not following his usual prelanding routine due to high workload.

Overshoot accidents include aircraft which touched down but were going too fast and were too far down the runway to stop before the end of the runway. One way this type accident could occur is if the pilot had spotted the airport in front of him on final approach and tried to land but was too close to the runway for a normal descent. The visual-descent-point markers currently being installed at some nonprecision approach airports should help in this situation. Another way this type of accident could occur is if the runway is icy or if the pilot compensated for airframe ice by coming in faster than usual.

Other frequently occurring types of accidents include stalls, uncontrolled collisions with the ground and engine failures. The 28 stall accidents include 17 regular stalls, 7 mushes, and 4

*In the data, the accidents which stated the aircraft was on an ILS approach, but the aircraft was not glideslope equipped, have been separated and grouped as nonprecision approaches.

spins. All of the spin accidents were fatal and 54 percent of the other stalls were fatal. Most of the stall accidents occurred in relatively good weather. The accidents occurred over three times more often during the day than at night, and 24 of the 28 accidents had one mile visibility or better. This type of accident indicates a control problem when the aircraft performance has deteriorated. Information from the briefs and remarks indicate that airframe ice and low ceilings are prevalent factors in stall accidents. In cases with light icing, the stall usually occurs after the pilot made visual contact with the airport at low altitude but was not in a position to land and tried to maneuver into landing position. In heavier icing, the pilots often lost control on initial or final approach. This accounts for the majority of stall accidents in daylight and relatively good visibility.

Uncontrolled collisions with the ground were 82 percent fatal. This is the highest fatality rate of all of the different types of accidents. The number of accidents is distributed evenly with respect to visibility. In low visibility outside of clouds, a pilot can usually see ground directly below him and therefore maintain spatial orientation. However, flying in clouds or darkness does not afford the pilot outside orientation as evidenced by the fact that more than half the accidents occurred at night. The briefs indicate that both the day and night accidents had low ceilings but the cause at night was usually spatial disorientation whereas the cause during the day was usually loss of aircraft control due to aircraft icing or turbulence.

The accidents involving engine failures were almost all due to fuel exhaustion. This accident usually occurred after the first approach, either on the missed approach or on subsequent approaches. Engine failure due to fuel exhaustion was the single most often cited type of accident on missed approaches.

Pilot Experience

Table X presents the type of certificate held by the pilot in SPIFR pilot error landing accidents in terms of selected mission variables. Of the 335 accidents examined, 187 involved commercial pilots of which 69 had instructor ratings. It appears that commercial pilots had accidents in worse weather than private or air transport pilots. The visibility was one mile or less in 53 percent of the accidents involving commercial pilots compared to 39 percent for all other pilots. It was dark in 64 percent of the accidents involving commercial pilots compared to about 50 percent for all other pilots. The higher level of confidence displayed by the commercial pilots may have been a causal factor in their accidents.

Professional pilots were involved in almost half of the accidents examined. These pilots were well qualified. Two-thirds of the professional pilots had a commercial certificate while all but one of the remaining one-third had an air transport certificate. The nonprofessional pilots were also well qualified. Over half of these pilots had commercial air transport certificates.

Commercial pilots accounted for the majority of the accidents, but private pilots had a higher accident rate. In 1973, the instrument rated private pilots accounted for 10 percent of the instrument rated pilots (ref. 1). This figure appears to be representative of other years. However, private pilots accounted for 25 percent of the SPIFR-pilot error landing accidents. Commercial pilots accounted for 69 percent of the instrument rated pilots but only 56 percent of the accidents. This indicates that, in this case the private pilot accident rate was three times higher than the commercial pilot rate. This is probably because the flying skills of the private pilot are not necessarily as well-developed or maintained as those of commercial pilots.

Tables XI, XII, and XIII present data on pilots' total time, instrument time, and time in last 90 days. The tables contain the number of accidents and an estimate of the number of instrument rated private and commercial pilots in the U.S. in the 1968 time period. The estimate of the pilot population was calculated by multiplying statistical data, from a private and commercial pilot survey by Ohio State University, (ref. 2), by the total number of active* private and commercial pilots in 1968. The survey did not include air transport certificated pilots so the accident data in tables XI, XII, and XIII were adjusted for this for comparison purposes. The resulting number of accidents in each hourly range was divided by the estimated number of pilots in each range and by 12 years to obtain an estimated number of accidents per pilot per year. These values are compared to determine how the accident rates vary with pilot experience. This analysis assumes that the distribution of pilots with respect to flight time did not vary over the twelve year period and it does not take into account that all pilots do not fly in single pilot operations.

Table XI shows the distribution of pilots' total time. The average total time is about 3000 hours. The accident rate is the highest for pilots with less than 300 hours and it decreases for pilots with between 300 and 3000 hours. The rate increases for pilots with between 3000 and 7000 hours and then decreases beyond 7000 hours to the lowest level. It is thought that this trend indicates that experience is an important factor below several thousand hours total time. Between 3000 and 7000 hours over confidence may have a negative effect, and beyond 7000 hours an

*Pilots who were issued medical certificates in the 30 months prior to the survey.

attitude change toward increased safety may be the key factor.

Table XII shows the distribution of pilots' actual instrument time. Pilots with less than 20 hours of actual instrument time had a slightly higher accident rate than pilots with 20 to 100 hours. Pilots with over 100 hours of actual instrument time had accidents twice as often as pilots with less hours. Again, it is thought that higher rate for pilots with low actual instrument time is due to lack of experience and the rate for pilots with large amounts of actual instrument time is due to over confidence which resulted from previous successes.

Table XIII gives the data on pilots' time in the 90 days prior to the accident. The accident rate was lowest for pilots with less than 24 hours in the last 90 days, approximately the same for pilots with 25 to 200 hours and highest for pilots with over 200 hours. This trend is difficult to explain in view of the trend shown in Table XI. It would seem that the pilots with the most time in the last 90 days would be the safest and vice versa, however, just the opposite is true. One possible explanation is that the pilots that are flying a lot are becoming over-confident and are flying in low IFR weather whereas the pilots at the other end of the spectrum are much more cautious and don't fly if the weather is forecast to be low IFR.

Table XIV gives the number of pilots involved in accidents grouped according to time in type. The pilots with 0 to 50 hours in type had 53 accidents while pilot with 50 to 100 hours had half as many accidents. This same trend is true on a larger scale. Pilots with between 0 to 300 hours in type had 148 accidents while pilots with 300 to 600 hours in type had 73 accidents. Again, this supports the need for methods to increase pilot proficiency. Also, it indicates that pilots should adjust their personal weather minimums according to their time in type.

The accident data showed that 272 of the 335 pilots involved in theSPIFR accidents had a multi-engine rating. Further, 211 of the 335 accidents were in twin engine aircraft. Reference 2 shows that of the private and commercial pilots surveyed in 1968, 45 percent conducted their IFR operations in twin engine aircraft. The accident data showed that of the 211 twin engine aircraft accidents 159 pilots had private or commercial certificates, and of the 124 single engine aircraft accidents 116 had private or commercial licenses. Thus, 58 percent of the SPIFR accidents, where the pilot had a private or commercial license, occurred in twin engine aircraft. Hence, based on the 1968 survey, it can be seen that even though 45 percent of the IFR operations were conducted in twins 58 percent of the SPIFR accidents occurred in twins. This indicates that the higher workload involved in flying a twin and the higher level of pilots' confidence inherent in flying with two engines may be a causal factor in SPIFR accidents.

CONCLUDING REMARKS

An examination and analysis of the single pilot instrument flight rule (SPIFR) accident data for the years 1964-1975, compiled by the National Transportation Safety Board, was made for the purpose of identifying critical problem areas in SPIFR operations. The accident reports examined were restricted to instrument rated pilots flying IFR weather. A brief examination was made of accidents which occurred during all phases of flight and which were due to all causes. A detailed examination was made of those accidents which involved a single pilot, which occurred during the landing phase of flight, and were due to pilot error. The landing phase was selected because of the large number of accidents that occurred in this phase. From these data, the following information was found.

- o Single-pilot pilot error accidents are increasing at a rate of 3.5 accidents per year. This rate is three times the dual-pilot pilot error rate. There were 877 single-pilot pilot error accidents, 446 of which occurred during the landing phase. Of the 446, there were 335 on IFR flight plan.

- o Improper IFR operations were given as a cause/factor in 170 of the 335 SPIFR accidents. In 104 of the improper IFR operations accidents fog was also a cause/factor and in 68 low ceiling was a cause/factor. Icing was a cause/factor in 56 accidents and fuel exhaustion was a cause/factor in 14.

- o There were 152 SPIFR accidents where the aircraft collided wings level with trees or with the ground. In 63 percent of these the visibility was one mile or less and in 70 percent it was dark.

- o Of the 335 SPIFR accidents there were 96 which occurred while the pilot was executing an ILS approach and 90 while executing a VOR approach. In general, the approaches which allowed lower descents had a higher percentage of accidents at night.

- o There were 139 SPIFR accidents which occurred during final approach. In these cases, the number of accidents doubled for every mile decrease in visibility. The initial approach phase had the highest fatality rate with .63 fatal accidents per accident. There were no fatalities in the leveloff/touchdown or rollout accidents.

- o There were 240 SPIFR accidents which occurred in fog, 180 in the dark, and 62 in below minimums weather. Air taxi-passenger and ferry operations had the highest below minimums accident rates.

- Commercial pilots were involved in 56 percent of the 335 accidents, however, the number of accidents per 100,000 private pilots was three times that of commercial pilots. Forty-six of the accidents involved professional pilots.

- The pilots in the 335 accidents had an average of 3000 hours total pilot time. The pilots with less than 300 hours total time had the highest estimated accident rate and pilots with more than 7000 hours had the lowest. The accident rate for pilots with less than 100 hours of actual instrument time was one-half that of pilots with more instrument time. The accident rate was lowest for pilots with less than 25 hours in 90 days and highest for pilots with more than 200 hours.

- Fifty-eight percent of the SPIFR accidents occurred in twin engine aircraft whereas an estimated 45 percent of the IFR operations were conducted in twins.

After analyzing the accident data, the following problem areas were identified.

- Landing phase operations, especially on the final approach segment

- Low visibility operations at night due to fog and low ceilings

- Flight in icing conditions when the aircraft is not deicing or anti-icing equipped

- Imprecise IFR navigation

- Below minimums approaches

- Weather data dissemination techniques and pilot understanding

- Fuel mismanagement and inadequate fuel quantity information

- Pilot overconfidence due to high instrument time and time in last 90 days

- Low pilot time in aircraft type

- High workload, especially in twin engine aircraft

Research aimed at solving these problems must emphasize low cost, low volume, low weight equipment, and human factors considerations. The following are suggested areas of research.

- o Cockpit displays of aircraft position on area mapping
- o New types of deicing or anti-icing equipment
- o Low/medium frequency receivers which can give on-course information
- o Standardized and human factors designed navigation instrument displays
- o Improved fuel management systems
- o Better methods for pilots to safely acquire experience and increase proficiency
- o Better cockpit displays of weather information
- o Improved air-to-ground communications which would reduce pilot workload
- o Improved basic aircraft stability and control
- o Low-altitude warning systems
- o More effective pilot training methods

APPENDIX A

Glossary

The following terms are used in this report and the general definitions given are intended to help the reader comprehend the data presented. Technical detail has been omitted from these definitions. (Refs. 3, 4, 5)

AIR TRANSPORT PILOT - Pilot who has obtained an air transport certificate by meeting specified experience requirements. Does not imply the pilot is a professional pilot.

AIRCRAFT ACCIDENT - An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto, or the aircraft receives substantial damage.

BUSINESS FLYING - The use of aircraft by pilots in connection with their occupation or in the furtherance of private business.

CAUSE/FACTOR - Categorizes the cause and related factors associated with an accident. There can be more than one cause of an accident.

CEILING - The height above the Earth's surface of the lowest layer of clouds covering more than half the sky.

COMMERCIAL PILOT - Pilot who has obtained a commercial pilot certificate. Does not imply the pilot is a professional pilot.

CONDITION OF LIGHT - The type of light available based on the time of day.

CONTROLLED COLLISION WITH GROUND/WATER - Includes accidents wherein the aircraft was capable of being controlled and was under control of the pilot when the collision occurred.

CORPORATE/EXECUTIVE OPERATIONS - The aircrafts are operated by a corporation or business firm for the transportation of personnel or cargo in furtherance of the corporation's or firm's business, and which are flown by professional pilots receiving a direct salary or compensation for piloting.

DECISION HEIGHT (DH) - The lowest altitude to which descent is authorized on final approach in execution of a standard instrument approach procedure where electronic glideslope is provided.

APPENDIX A

Glossary (cont'd)

ENGINE FAILURE OR MALFUNCTION - Includes accidents where the engine stopped or power was interrupted for any reason, including fuel exhaustion.

ENROUTE PHASE - The segment of flight from after the initial climbout until reaching the initial approach fix.

FATAL INJURY - Any injury which results in death within 7 days of the accident.

FINAL APPROACH PHASE - Segment of the landing phase between the final approach fix and the runway, airport or missed approach point.

FUEL EXHAUSTION - Aircraft ran out of fuel.

GEAR COLLAPSED - Collapse of gear due to mechanical failure other than malfunction of retracting mechanism.

GEAR RETRACTED - Retraction of gear due to inadvertant or premature retraction by crew or due to malfunction of retracting mechanism.

HARD LANDING - Stalling onto or flying into runway or other intended landing area with sufficient force to cause aircraft damage.

INITIAL APPROACH PHASE - Segment of the landing phase between the initial approach fix and the final approach fix.

INJURY INDEX - Refers to the highest degree of personal injury sustained as a result of the accident.

INSTRUMENT APPROACH PROCEDURE - A series of predetermined maneuvers for the orderly transfer of an aircraft under instrument flight conditions from the beginning of the initial approach to a landing, or to a point from which a landing may be made visually provided there is adequate visibility and ceiling.

INSTRUMENT METEOROLOGICAL CONDITIONS - Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling less than the minima specified for visual meteorological conditions.

LANDING MINIMUMS - The minimum visibility prescribed for landing an aircraft while using an instrument approach procedure. Prior to November 18, 1967, minimums included a ceiling. After this data, the ceiling was added to the airport elevation to determine the minimum descent altitude.

LANDING PHASE - The segment of flight from the initial approach fix until the aircraft reaches the missed approach fix at the prescribed altitude or taxis off the runway.

LEVELOFF/TOUCHDOWN PHASE - The segment of the landing phase from when the pilot raises the nose of the aircraft to stop the vertical descent rate to when the aircraft is firmly in contact with the ground.

MINIMUM DESCENT ALTITUDE (MDA) - The lowest altitude to which descent is authorized on final approach or during circle-to-land maneuvering in execution of a standard instrument approach procedure where no electronic glideslope is provided.

MISMANAGEMENT OF FUEL - Improper switching of fuel tanks, miscalculation of fuel consumption and duration, or failure to lean air/fuel mixture into engine.

MISSED APPROACH - The segment of the landing phase between the missed approach point, or point of arrival at decision height, and the missed approach fix at the prescribed altitude.

NONPRECISION APPROACH PROCEDURE - A standard instrument approach procedure in which no electronic glideslope is provided.

OVERSHOOT - Landing too fast or too far down the runway or other intended landing area resulting in (a) running off the end of the landing area, (b) ground looping, nosing down or overturning off runway, and (c) landing beyond the intended landing area. Used only when ground contact is made.

PHASE OF FLIGHT - The segment of flight during which the circumstances of the accident occurred. Includes static, taxi, takeoff, inflight, and landing.

PHASE OF LANDING - The particular segment of landing during which the circumstances of the accident occurred. Includes initial approach, final approach, leveloff/touchdown and rollout.

PILOT ERROR - The pilot in command failed to carry out his responsibility for the operation and safety of an aircraft during flight time.

PLEASURE FLYING - Flying by individuals in their own or rented aircraft for pleasure or personal transportation not in furtherance of their occupation or company business.

PRECISION APPROACH PROCEDURE - A standard instrument approach procedure in which an electronic glideslope is provided. ILS and PAR are the only types of precision approaches.

PROCEDURE TURN - The maneuver prescribed when it is necessary to reverse direction to establish an aircraft on the intermediate approach segment or final approach course.

PROFESSIONAL PILOT - Pilot whose primary occupation is piloting aircraft.

ROLLOUT - The segment of the landing phase from the point of touchdown to the point where the aircraft can be brought to a stop or exit the runway.

SERIOUS INJURY - Means any injury which (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received, (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose), (3) involves lacerations which cause severe hemorrhages, nerve, muscle, or tendon damage, (4) involves injury to any internal organ, and (5) involves second or third degree burns or any burns affecting more than 5 percent of the body surface.

STATIC PHASE - The segment of flight when the aircraft is on the ground and not moving. Includes when the engines are operating and not operating and includes when the aircraft is at the ramp or the run-up area.

TAKEOFF PHASE - The segment of flight from the beginning of the takeoff roll through the initial climb out.

TAXI PHASE - The segment of flight when the aircraft is in transit on the ground. Excludes the take off and landing roll.

TRANSITION - Change from one phase of flight condition to another. Usually refers to change from flight by reference to aircraft instruments to flight by outside visual reference.

TYPE AIRCRAFT - As used with respect to the certification, ratings, privileges, and limitations of airmen, means a specific make and basic model of aircraft, including modifications thereto that do not change its handling or flight characteristics.

UNCONTROLLED COLLISION WITH THE GROUND/WATER - Includes accidents in which the aircraft is capable of being controlled but is not under control of the pilot. Does not apply if aircraft previously struck another object or collided with another aircraft.

UNDERSHOOT - Landing or making contact with ground or object short of the runway. On IFR approaches, an undershoot can occur only after the field is in sight.

VISIBILITY - The average forward horizontal distance at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night.

VISUAL DESCENT POINT - A defined point on the final approach procedure from which normal descent from the MDA to the runway touchdown point may be commenced, provided visual reference is established.

WEATHER BRIEFING - A service provided by Flight Service Stations and National Weather Service to pilots which includes weather information and Notices to Airmen.

WHEELS-UP - Landing gear not lowered and locked prior to contact with the ground. Excludes inadvertant retraction on ground and collapses due to failure or malfunction. Includes intentionally retracting or not extending landing gear.

APPENDIX B

Abbreviations

ADF - Automatic direction finder

ASR - Approach surveillance radar

DH - Decision height

FAA - Federal Aviation Administration

FAR - Federal Air Regulation

IFR - Instrument flight rules

ILS - Instrument landing system

LOC - Localizer

MDA - Minimum descent altitude

NDB - Nondirectional beacon

NTSB - National Transportation Safety Board

PAR - Precision approach radar

SPIFR - Single Pilot Instrument Flight Rules

VFR - Visual flight rules

VOR - Very high frequency omnidirectional range

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3. Annual Review of Aircraft Accident Data, U.S. General Aviation Calendar Year 1974, NTSB-ARG-76-1.

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5. Shaughnessy, John D.; and Pardue, Mark D.: Helicopter Sling Load Accident/Incident Survey: 1968-1974. NASA TMX-74007, 1977.

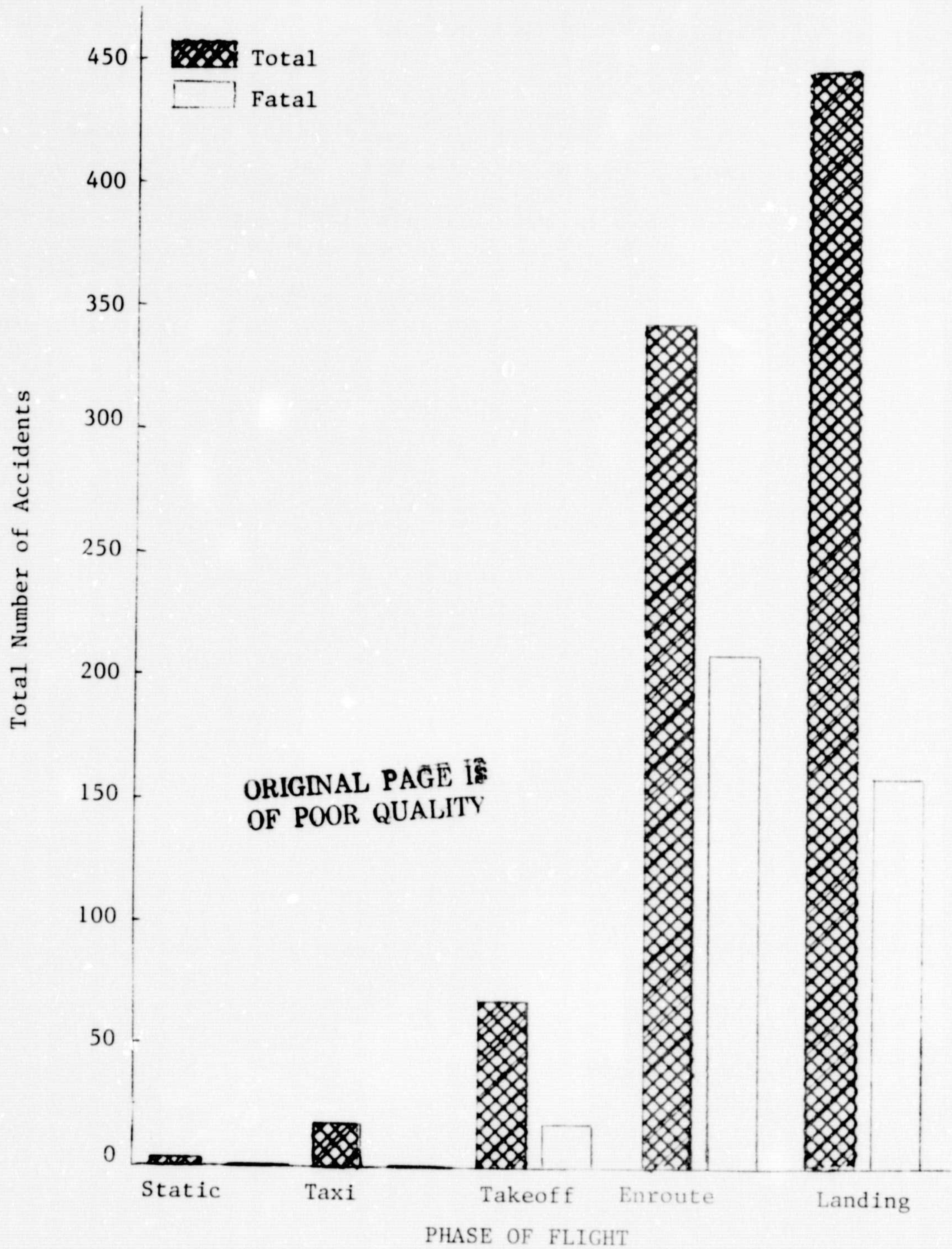

Figure 1.- Twelve year (1964-1975) totals of SPIFR pilot error accidents by phase of flight. Includes flight which were and were not on IFR flight plans.

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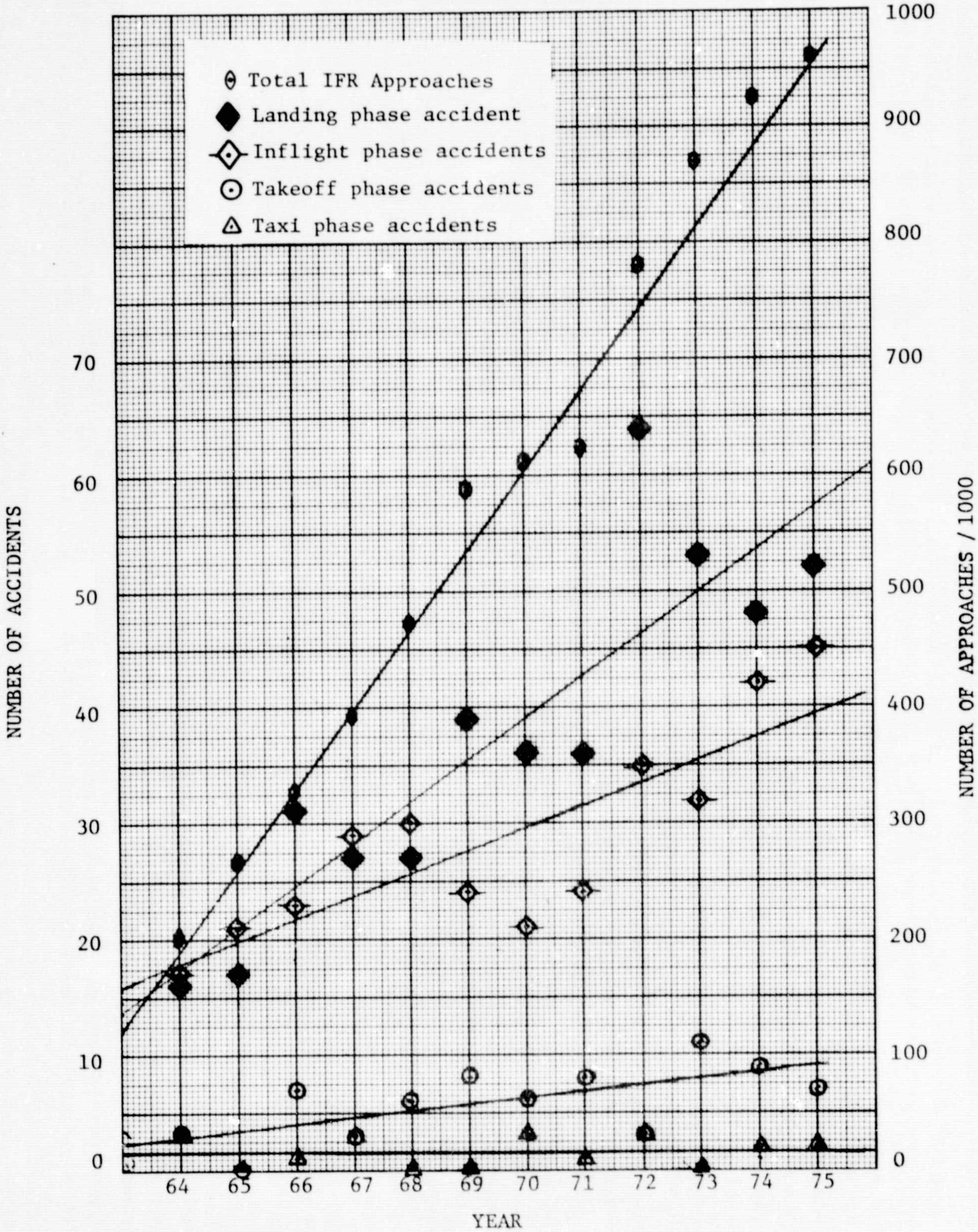

Figure 2.- Yearly totals of general aviation IFR approaches and SPIFR-pilot error accidents by phase of flight. Fitted with straight lines using linear regression.

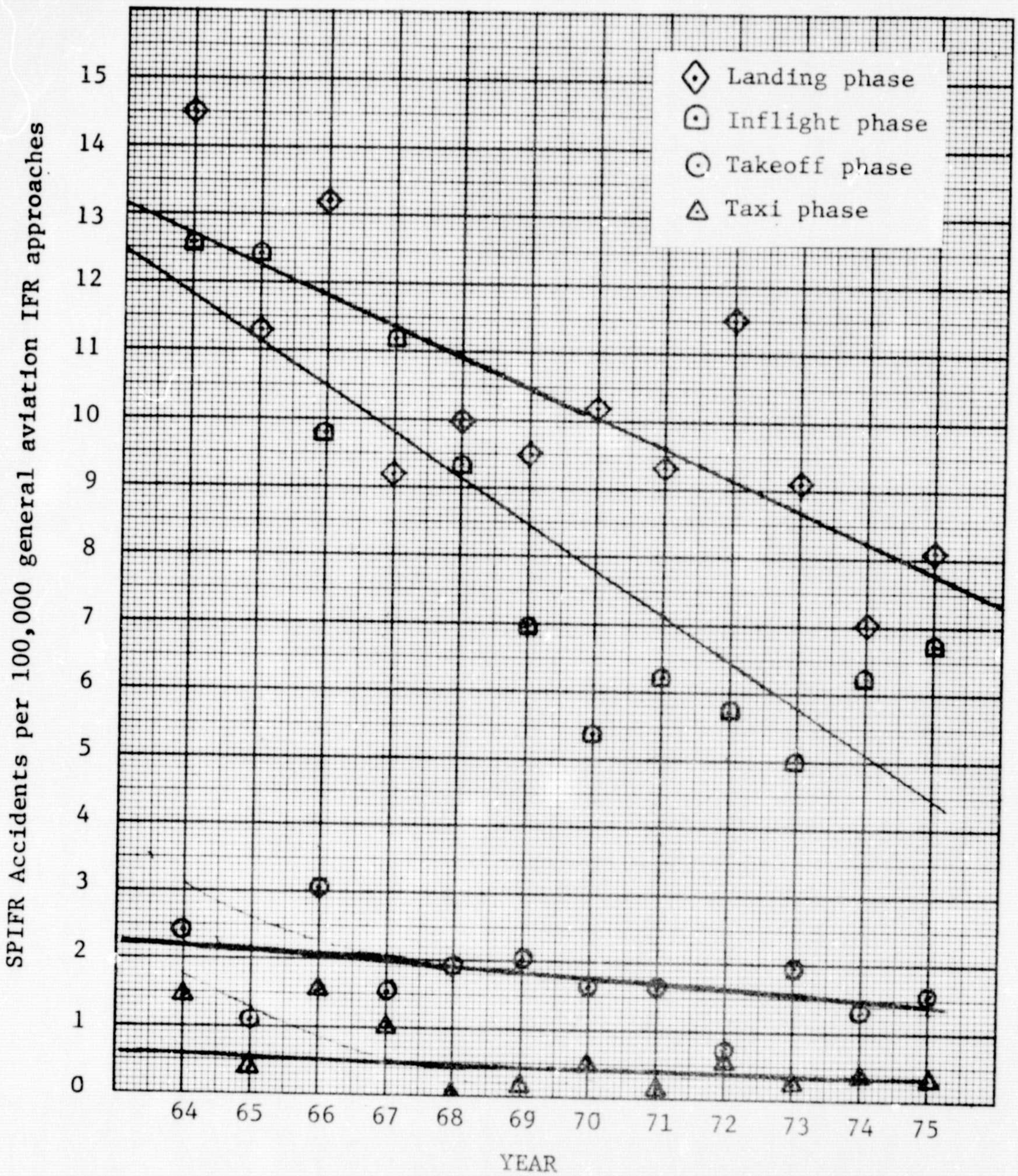

Figure 3.- Yearly rates of SPIFR pilot error accidents by phase of flight. Fitted with straight lines using linear regression.

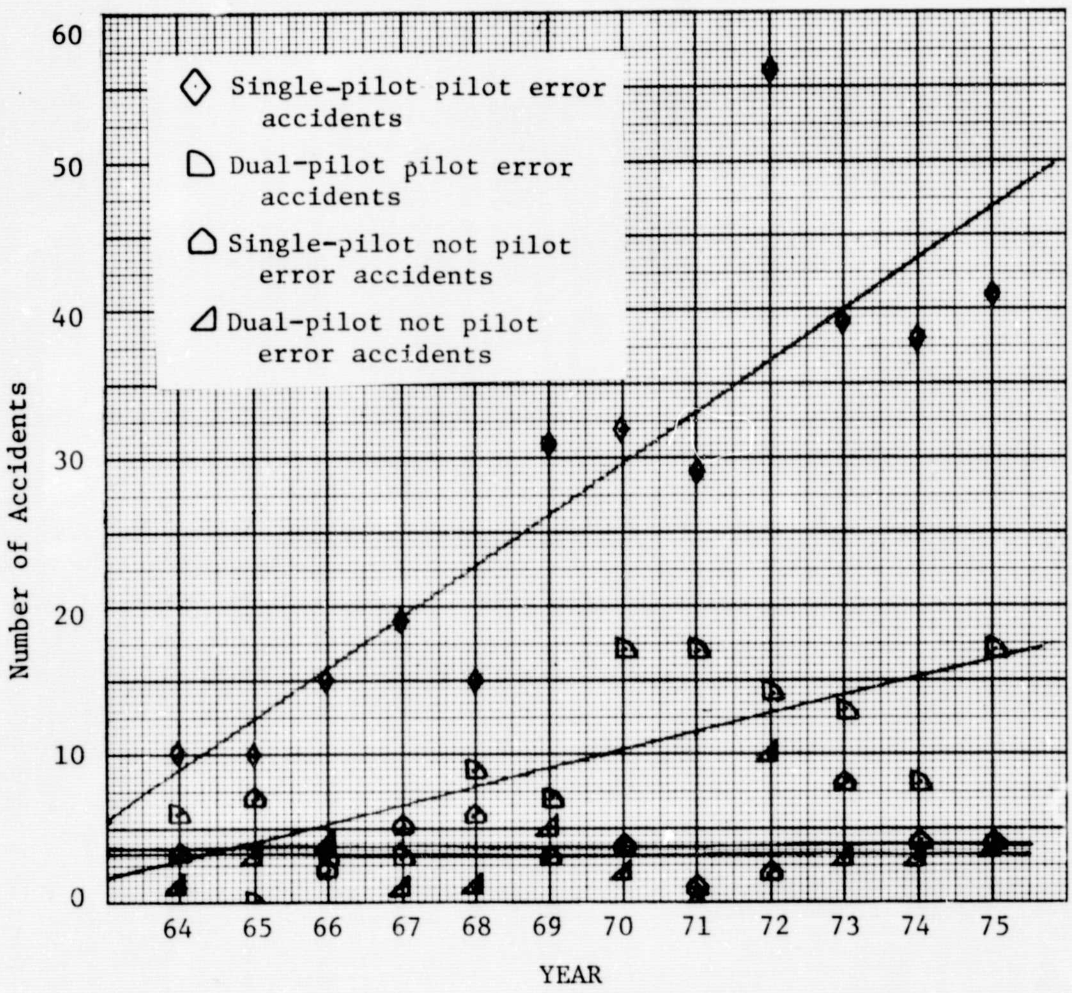

Figure4.- Yearly totals of IFR flight plan landing phase accidents by number of pilots in cockpit and pilot error as cause/factor.

TABLE I.- FREQUENTLY CITED PILOT ERRORS AND RELATED CAUSE/FACTORS IN SPIFR LANDING ACCIDENTS

Related Cause/Factors \ Pilot Errors	NUMBER OF ACCIDENTS	IMPROPER IFR OPERATION PROCEDURE	FAILED TO OBTAIN/MAINT. FLYING SPEED	IMPROPER IN-FLIGHT DECISION OR PLANNING	INADEQUATE PREFLIGHT PREP. AND/OR PLANNING	ATTEMPTED OPERATION WITH KNOWN DEFICIENCIES IN EQUIPMENT	FAILED TO FOLLOW APPROVED PROC., ETC.	IMPROPER LEVELOFF	DIVERTED ATTENTION FROM OPERATION OF AIRC.	SPATIAL DISORIENTATION	MISMANAGEMENT OF FUEL	EXERCISED POOR JUDGMENT	FAILED TO MAINTAIN DIRECTIONAL CONTROL	OTHER
NUMBER OF ACCIDENTS	335	170	34	28	27	27	24	24	22	21	18	14	13	10
Low Ceiling	163	68	21	18	10	16	12	3	4	13	4	8		42
Fog	138	104	14	15	5	11	12	1	7	13	3	6		36
Rain	57	36	9	6	1	4	2	2	1	6	2	1		21
Icing Conditions - Includes sleet, etc.	56	13	14	9	7	17	4	10			2	3		19
Ice - Airframe	47	10	14	7	3	12	3	9			1	2		12
High Obstructions	30	24		2	3	1	5		2		3	2		11
Overload Failure	28	4		1	2	2		9		1	1	2	1	15
Misread or Failed to Read Instrument	25	22		1	2		2		7	1	1	1		4
Snow	20	11	4	2	5	2	4			1	2	4	1	6
Pilot Fatigue	15	10	1		1	2				2		1		8
Fuel Exhaustion	14	4	3	6	9			1	1		14			4
Not Aligned with Runway	14	4	3	1	2	2	1						2	10
No Other Cause/Factor Given		11	1	2	1	1	1	1	6				1	26
Others[a]		79	15	19	23	25	25	7	16	15	3	6	21	131

[a]The numbers in this row can exceed the total for each column since there can be multiple cause/factors per accident.

TABLE II.- PAIRS OF MISSION VARIABLES AVAILABLE FOR EXAMINATION USING NTSB ACCIDENT REPORTS AND PAIRS OF VARIABLES ACTUALLY EXAMINED AND ANALYZED.

x - pairs examined and discussed
o - pairs examined but not discussed
Blank - not examined

	Type of Accident	Type Approach	Phase Landing	Injury	Damage	Visibility	Condition of Light	Obstruction Vision	Precipitation	Airport Proximity	Flight Purpose	Pilot Certificate	Wind Direction	Sky Condition	Type of Power	Type of Operator	Emergency Circumstances	Weather Briefing	Weather Forecast	A/C Equipment for IFR	Class of Airport	Runway Condition	Runway Lighting	Tower Unicom.	Terrain	Airspace Segment	Medical Certificate	Pilot Ratings	Pilot Rated	Pilot Occupation	General Weather	App. Aids Available	Land Wx. Minima (Cat.)	Results of Tox Exam	Alcohol Content	Attitude at Impact	Autopilot	Approach Coupler	Gross Weight	Center of Gravity	Stab. Aug. Syst.	Elec. Com. Com. Syst.	Inertial Nav.	HUD
Type Approach	O																																											
Phase Landing	X	X																																										
Injury	X	X	X																																									
Damage	O		O	X																																								
Visibility	X	X	X																																									
Condition of Light	X	X	X	X		X																																						
Obstruction Vision	X	X	X	X		X	X																																					
Precipitation	O	O	O			O	X	X																																				
Airport Proximity		O	O			O	O	O	O																																			
Flight Purpose		O	O	X		O	O	O	O	O																																		
Pilot Certificate	O	O	O	X		X	X	O	O	O	O																																	
Wind Direction			O																																									
Sky Condition																																												
Type of Power	O		O									O																																
Type of Operator			O																																									
Emergency Circumstances	O		O			O	O		O		O				O																													
Weather Briefing	O			X		X	O	O			X	O					O																											
Weather Forecast	O		O			O	O	O			O						O	O																										
A/C Equip. for IFR		O	O			O	O										O		O																									
Class of Airport		O	O			O	O											O		O																								
Runway Condition			X			O	O			O																																		
Runway Lighting			O			O	O			O										O																								
Tower Unicom.		O	O			O	O													O																								
Terrain	O	X	X			X	X	X		O				O					O	O																								
Airspace Seg.			O																																									
Medical Certificate												O																																
Pilot Ratings		O	O			O						O					O																											
Pilot Rated			O																																									
Pilot Occupation											O	X					O																											
General Weather	X	O	O			O	X	O	O		O		O	O		O	O	O							O			O																
App. Aids Available			O																	O											O													
Land Wx. Minima (Cat.)																															O													
Results of Tox. Exam.																																												
Alcohol Content																																		O										
Attitude at Impact			O																																									
Autopilot			O																																									
Approach Coupler		O	O																																		O							
Gross Weight		O	O																																									
Center of Gravity	O		O																																				O					
Stab. Aug. System	O		O																																									
Electric Com. Com. Sys.																																									O			
Inertial Nav.																																												
Heads Up Display																																											O	
Type Wx. Cond. in Area Accid.			X								X							X	O		O				O						O		O											

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TABLE III.- FLIGHT PURPOSE AND SELECTED MISSION VARIABLES IN SPIFR LANDING ACCIDENTS.

Mission Variables / Flight Purpose	Pleasure	Business	Corporate	Air Taxi Pass.	Air Taxi Cargo	Ferry	Other	TOTAL
TOTAL	121	82	49	37	30	11	4	335
INJURY INDEX								
None	36	29	22	11	12	1	3	114
Minor	19	8	4	2	5	3		42
Serious	22	5	5	6	2	4	1	45
Fatal	44	40	18	18	11	3		134
Below Minimums	17	15	9	11	5	5	0	62

TABLE IV.- TYPE OF WEATHER BRIEFING RECEIVED BY PILOT AND SELECTED MISSION VARIABLE IN SPIFR LANDING ACCIDENTS.

Mission Variables \ Weather Briefing	Phone	Radio	In person	Method unknown	Other	Unknown if any received	No briefing	TOTAL
TOTAL	164	60	53	12	9	35	2	335
INJURY INDEX								
None	44	12	26	3	2	22		114
Minor	22	11	6	1	1		1	42
Serious	23	10	5	2	3	2		45
Fatal	74	27	16	6	3	7	1	134
FLIGHT PURPOSE								
Pleasure	61	25	18	5	1	11		121
Business	45	13	9	2	1	11	1	82
Corp./Executive	23	7	8	1	3	7		49
Air Taxi-Pass.	12	11	9	1	1	3		37
Air Taxi-Cargo	14	3	6	2	1	2	1	30
BELOW MINIMUMS	27	19	8					62
VISIBILITY								
Zero	4	1	1					6
1/4 mile	17	10	1		2	1	0	31
1/2 mile	15	6	7	3	2		1	34
3/4 mile	13	5	3			2		23
1 mile	32	12	12	2	1	6		65
2 miles	46	9	14	4	2	10	1	86
3 miles	19	6	9	2	1	7		44
4 or more	16	9	6		1	8		39

TABLE V.- OBSTRUCTION TO VISION AT THE ACCIDENT SITE AND SELECTED MISSION VARIABLES IN SPIFR LANDING ACCIDENTS.

Mission Variables \ Obstruction to Vision	Fog	Haze	Blowing snow	Other	None	TOTAL
TOTAL	240	14	14	27	40	335
INJURY INDEX						
None	69	8	6	5	22	114
Minor	27	3	2	6	4	42
Serious	36	1	2	2	4	45
Fatal	108	2	4	10	10	134
VISIBILITY						
Zero	3		2		1	6
1/4 mile	28		3	1	2	31
1/2 mile	25		3	3	3	34
3/4 mile	19	1			3	23
1 mile	56	1	1	3	4	65
2 miles	64	4	5	8	5	86
3 miles	33	4		4	3	44
4 miles	11	4	3	3	18	12
PRECIPITATION						
Rain and drizzle	111	2		6	9	128
Snow	14	2	13	1	15	45
Freezing rain and drizzle	17	1	0	1	2	21
Other (including none)	98	9	1	19	14	141
TERRAIN						
Mountains	14			1	3	18
Hilly	28		2	1	2	33
Rolling	22	2	2	1	5	32
Level	34	3	1	6	4	48
Dense with trees	55			7	4	66

TABLE VI.- CONDITION OF LIGHT AT TIME OF ACCIDENT AND RELATED MISSION VARIABLES ON SPIFR LANDING ACCIDENTS

Mission Variables \ Condition of Light	Dawn	Day	Dusk	Dark		TOTAL
TOTAL	5	132	18	180		335
INJURY INDEX						
None	2	58	9	45		114
Minor		16	1	25		42
Serious		11	2	32		45
Fatal	3	47	6	78		134
VISIBILITY						
Zero		3		3		6
1/4 mile	2	12		17		31
1/2 mile	1	7	2	24		34
3/4 mile		11		12		23
1 mile	2	27	5	31		65
2 miles		40	3	43		86
3 miles		13	6	25		44
4 or more		17	1	21		39
OBSTRUCTION TO VISION						
Fog	5	90	13	132		240
None		18	3	19		40
PRECIPITATION						
Rain and drizzle	2	44	9	73		122
Snow		20	2	23		38
Freezing rain and drizzle		9	1	12		21
Other	3	59	6	72		140

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TABLE VI.- Continued

Mission Variables \ Condition of Light	Dawn	Day	Dusk	Dark		TOTAL
GENERAL WEATHER						
Variable Ceiling		3		8		
Freezing Temps.		12	1	10		
TERRAIN						
Mountains		10	3	5		18
Hilly		11		22		33
Rolling		10	1	21		32
Level	2	14	3	29		48
Dense with trees	2	14	1	49		66

TABLE VII.- PHASE OF LANDING AND SELECTED MISSION VARIABLES IN SPIFR LANDING ACCIDENTS

Mission Variables / Phase of Flight	Final IFR	Initial IFR	Missed Approach	Traffic Pattern Circling	Leveloff/ Touch-Down	Roll	Final VFR	Go Around VFR	Other	TOTAL
Total	139	59	20	7	59	27	16	1	7	335
INJURY INDEX										
None	17	7	7	1	50	25	7			114
Minor	19	5	1	3	7	2	3	1	1	42
Serious	29	9	1		2		4			45
Fatal	74	38	11	3			2		6	134
VISIBILITY										
Zero	2	4								6
1/4 mile	20	5	5		1					31
1/2 mile	20	6	2	1	3		1		1	34
3/4 mile	11	7	1		3	1				23
1 mile	29	8	7		12	3	3	1	2	65
2 miles	33	10	2	1	25	10	3		2	86
3 miles	15	8	1	2	6	5	5		2	44
4 or more	6	10	2	3	8	6	4			39
CONDITION OF LIGHT										
Night	103	30	5	3	14	13	7	1	4	180
Day	31	25	12	4	39	2	7		2	132
Dusk and Dawn	5	4	1		6	12	2		1	23
OBSTRUCTION TO VISION										
Fog	115	38	18	5	36	11	9	1	7	240
None	9	7	1	1	11	8	3			40
TERRAIN										
Mountains	5	10	2							18
Hilly	19	9	3			1	1			32
Rolling	19	7			1	1	2		2	33
Level	28	8	5	2		1	3	1		48
Dense with trees	42	17	3	1			2		1	66
BELOW MINIMUMS	45	9	20	7	59	27	16	1	7	62

TABLE VIII.- TYPE OF APPROACH EXECUTED AND SELECTED MISSION VARIABLES IN SPIFR LANDING ACCIDENTS.

Type of Accident / Mission Variables	PRECISION					NONPRECISION										
	Straight-in			Circling		Straight-in					Circling					
	PAR	ILS w/ASR	ILS w/o ASR	ILS w/ASR	ILS w/o ASR	VOR	NDB	LOC ONLY	LOC BC	ASR ONLY	VOR	NDB	VISUAL	OTHER	BLANK	TOTAL
TOTAL	2	37	51	3	5	57	18	23	7	10	33	3	4	24	58	335
INJURY INDEX																
None		7	18	1	2	16	5	2	4	2	9		1	7	40	114
Minor		5	4			4	1	8	1	1	4	1	3	3	6	42
Serious		5	6	1	1	13	3	3	1	1	4			2	5	45
Fatal	2	21	20	2	1	24	9	11	1	6	16	2		19	7	134
VISIBILITY																
Zero			c 1			1	1	1			1			1		6
1/4 mile		b 2	6	1	1	5	5	1		2	2		1	4	1	31
1/2 mile		7	7			6	1	4		1	3	1		4		34
3/4 mile		3	6		1	4	1	1		3	1			2	1	23
1 mile		11	13			10	1	4	4	2	6		1	2	11	65
2 miles	1	9	10	1	3	15	3	7	2	1	10		1	7	16	86
3 miles		2	6			7	5		1	1	8	1	1	2	10	44
4 or more	1	4	2	1		8		2			2	1		1	17	39
CONDITION OF LIGHT																
Night		25	31	2	2	32	12	15	3	6	14	1	3	12	22	180
Day	2	11	6		2	22	6	8	4	4	17	2	1	10	29	132
Dusk and Dawn		1	14	1	1	3					2			2	7	23
OBSTRUCTION TO VISION																
Fog	2	25	41	3	3	46	14	18	3	8	24	1	4	12	31	240
None		7	6		1	6	1		1	1	1	1		2	9	40
TERRAIN																
Mountains		1	2			2	2	2		1	3	2		2	1	18
Hilly and Rolling		3	6			12	3	3		1	7			6	9	65
Level	1	7	12	1	1	6	1	2		1	5			2	8	48
Others	1	29	39 c	2	4	49	16	19	7	8	25	1	4	21	49	204
PHASE OF LANDING																
Initial IFR		7	12			11	6	3	2	1	6	2		2	7	59
Final IFR	1	20	24	2	2	27	8	16	2	5	16			12	7	139
Leveloff		5	5		3	11	2	3	3	2	2		3	1	19	59
Traffic Pattern						1					2		1	1	2	7
Missed Approach	1	2	4			2	1			2	2	1		1	4	20
Roll		2	4	1										4	16	27
Other		1	2			5	1	1			5			1	3	24

[b]Includes 2 localizer only approaches

[c]Includes 1 localizer only approach

TABLE IX.- TYPE OF ACCIDENT AND SELECTED MISSION VARIABLES IN SPIFR LANDING ACCIDENTS

Relayed Variables \ Type of Accident	Collided with Stationary Object	Uncontrol Collision with Ground	Stalls	Engine Failure	Under-Shoot	Over-Shoot	Hard Landing Gear Up Gear Ret. Etc.	Roll	Other	TOTAL
TOTAL	152	22	28	33	12	11	49	18	10	335
INJURY INDEX										
None	21	1	4	12	2	8	47	15	4	114
Minor	19	1	5	8	1	1	2	3	2	42
Serious	28	2	2	4	6	2			1	45
Fatal	84	18	17	9	3				3	134
PHASE OF FLIGHT										
Initial	34	6	1	11	1				6	59
Final, IFR	98	15	2	8	7				9	139
Leveloff	2		1			11	40	2	3	59
Traffic Pattern	1	1	1	3					1	7
Missed Approach	10		1	7					2	20
Roll							9	16	2	27
Other										
VISIBILITY										
Zero	4			1	1					6
1/4 mile	25	2		3		1				31
1/2 mile	26	1	2	3			2			34
3/4 mile	11	2	2	2	1	1	2	1	1	23
1 mile	29	3	9	8	1	2	10	1	1	65
2 miles	27	6	8	6	5	5	15	9	3	86
3 miles	17	2	6	4	2	1	7	3	2	44
4 miles or more	9	6	1	6	2	1	8	4	2	27
CONDITION OF LIGHT										
Night	107	16	6	12	11	5	9	10	4	180
Day	35	6	20	18	1	6	33	7	6	132
Dusk and Dawn	10		2	3			7	1		23

TABLE IX.- continued

Relayed Variables \ Type of Accident	Collided with Stationary Object	Uncontrol Collision with Ground	Stalls	Engine Failure	Under-Shoot	Over-Shoot	Hard Landing Gear Up Gear Ret. Etc.	Roll	Other	TOTAL
OBSTRUCTION TO VISION										
Fog	128	15	22	19	9	9	26	7	5	240
None	11	2	2	5	1	1	11	5	2	40
GENERAL WEATHER										
Freezing Temps	4	3	5	2	1	1	5	1	1	23
Winds	4		3				6	2		15
Turbulence	1	3	2						1	7

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TABLE X.- TYPE OF PILOT CERTIFICATE AND SELECTED MISSION VARIABLES ON SPIFR LANDING ACCIDENTS

Mission Variables \ Pilot Certificate	Private	Commercial	Air Transport	Other		TOTAL
TOTAL	85	187	60	2		335
INJURY						
Fatal	35	73	25	1		134
Serious	11	24	9	1		45
Minor	13	24	5			42
None	27	66	21			114
VISIBILITY						
Zero	1	4	1			6
1/4 mile	8	17	6			31
1/2 mile	4	25	4	1		34
3/4 mile	5	16	2			23
1 mile	17	37	9	1		65
2 miles	23	45	18			86
3 miles	11	23	10			44
4 or more	16	16	7			39
CONDITION OF LIGHT						
Night	43	106	30	1		180
Day	36	69	25	1		132
Dusk and Dawn	6	12	5			23
OCCUPATION						
Profess. Pilot	1	103	50	1		155
Company Executive	20	13	1			34
Saleman	5	12	2			19
Physician	7	7				14
Engineer	7	4				11
Others	45	48	7	1		101

TABLE XI.- SPIFR LANDING ACCIDENTS AND ACCIDENT RATES IN TERMS OF PILOTS' TOTAL TIME

Total time, hrs	200-299	300-599	600-699	1000-2999	3000-4999	5000-7000	> 7000	TOTAL
No. of Accidents 1964-1975	6	31	36	109	62	40	51	335
Accidents not incl. ATR pilots	6	31	36	101	42	27	32	275
IFR rated private & commercial pilots in 1968 (Ref. 2)	923	10,971	13,842	39,680	12,714	7,792	15,687	102,532
Accidents per year per 100,000 pilots	54	23	22	21	28	29	17	--

TABLE XII.- SPIFR LANDING ACCIDENTS AND ACCIDENT RATES IN TERMS OF PILOTS' ACTUAL INSTRUMENT TIME

Actual Instrument time, hours	< 20	20-49	50-99	100-299	300-600	> 600	Unknown	TOTAL
No. of Accidents 1964-1975	34	25	24	82	33	38	99	335
Accidents not incl. ATR pilots	34	25	24	67	22	22	42	275
IFR rated private & commercial pilots in 1968 (Ref. 2)	20,916	17,943	16,405	22,249	8,510	7,587	9,018	102,532
Accidents per year per 100,000 pilots	13	12	12	25	22	24	--	--

TABLE XIII.- SPIFR LANDING ACCIDENTS AND ACCIDENT RATES IN TERMS OF PILOTS' TIME IN LAST 90 DAYS

Time in last 90 days, hours	0-24	25-49	50-99	100-149	150-199	200-299	> 300	Unknown	TOTAL
No. of accidents 1964-1975	30	41	57	41	20	32	12	100	335
Accidents not incl. ATR pilots	25	37	47	31	13	23	7	10	275
IFR rated private & commercial pilots in 1968 (Ref. 2)	25,530	18,046	24,710	14,662	7,792	8,613	1,948	1,248	102,532
Accidents per year per 100,000 pilots	8	17	16	18	14	22	30	--	--

TABLE XIV.- SPIFR LANDING ACCIDENTS IN TERMS OF PILOTS' TIME IN TYPE OF AIRCRAFT

Time in type, hrs.	0-19	20-49	50-99	100-299	300-600	> 600	Unknown	TOTAL
Number of accidents 1964-1975	21	32	27	68	73	78	36	335