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The Human Element — The Key To Safe Civil Operations In Adverse Weather

The safe completion of assigned flight missions often has been denied because of the undue influence of environmental conditions.

by

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Even though weather has always been the foe of safe aircraft operations, flight in adverse environmental conditions has become commonplace. Gusting wind conditions frustrated the first would-be aviators, and the first accident sustained by the Wright Brothers occurred in 1904 when Orville Wright encountered a sharp gust that resulted in a crash and almost killed him.

The battle against the environment was thus joined. Ever since Wright's crash, it has been a major objective of the aircraft designer to provide a machine that can sustain the assaults of Mother Nature while the objective of the operator has been to avoid, as much as is safely possible, the constraints otherwise imposed by weather.

The safety records of air carrier, corporate and private civil aviation continues to improve in terms of individual risk exposure. Schedule reliability of air carriers is taken for granted, despite current congestion delays and frustrations of many passengers. The present-day traveller expects to reach his or her destination without undue problems regardless of weather, because of the air carrier's good record of completing flights. There is good reason for this confidence. A solid base of technology, coupled with a curiosity about why things go wrong, and a determination to correct erroneous designs, procedures and operations, have built air transportation into a safe, highly-efficient and productive mode of travel.

Accident occurrences continue their downward trend. More is known about weather phenomena than ever before. Yet, the major weather phenomena: precipitation, turbulence, ice, fog and lightning, in all their manifestations, continue to figure in the determinations of accident probable causes and contributing factors.

Air carrier operational safety continues to improve, despite some rather spectacular accidents that have occurred within the past several years. Worldwide, scheduled civil air transport has achieved a safety record of one fatal accident per one million flights. The U.S. carriers' record is about 0.3 fatal accidents per one million flights. The Australasian carriers are operating at a rate of about 0.1 fatal accidents per one million flights (1), (2). Business aircraft operated by professional full-time crews logged seven fatal accidents in worldwide operations last year. General aviation's accident record has improved, and civil helicopter operations, with the exception of emergency medical service flights, have not degraded in safety.

These generally downward trends are indeed what we like to see and give us confidence that we are doing many things right. However, looking at the individual accidents that do occur tells us something about how we go about our business of civil flights. And it is not a picture to be particularly proud of. Statistics show that for the past 30 years, approximately 60 percent of all air carrier accidents occurred in the descent, approach and landing phases, while 30 percent occurred in the takeoff and climb phases. But this 90 percent share of accidents occurred within only about 40 percent of the total flight time. The same general proportions apply to business and general aviation operations. There is a remarkable congruence among many accident studies that indicates that the flight crews have the opportunity to prevent 60-70 percent of all accidents (3).

Some 70 percent of business and general aviation causal factors are attributable to the flight crew, and about 6 percent are attributable to weather. Buried in that flight crew figure, however, are many weather situations that taxed the flight crew's capabilities and judgment.

The Decision To Fly

The decision to fly is a human act. It should be based on a number of important factors. I emphasize "should be," because sometimes important factors are omitted or overlooked. The factors include:

- Aircraft type consistent with the mission;
- Condition of the aircraft;
- Equipment aboard;
- Pilot's experience with aircraft and missions;
- Pilot's physical and mental fitness for duty;
- Environmental conditions along the route;
- Conditions of airports and nav/comm aids available; and,
- Any unusual conditions expected.

The decision to fly is made by the pilot upon accepting the aircraft as airworthy. The handover from ground personnel to flight crew is a critical point in the process, for the duty of care that everyone in aviation has, demands that the airplane be presented to the flight crew in condition adequate for safe completion of the flight. The primary responsibility for the safety of the flight shifts from ground to flight crew at that moment, and the pilot, having accepted an airplane he or she believes to be airworthy, must now assess the remaining factors. Is the equipment aboard sufficient and functioning for the expected flight mission? Is the aircraft's performance and structure adequate for the expected flight? Is the pilot in good physical and mental state for the flight? Is the pilot's experience adequate for safe completion of the flight? Are the takeoff weather conditions satisfactory for launching? What is the forecast weather en route and at destination? Are navigation and communication aids along the flight path working? Are there adequate alternate landing sites?

Just as the maintenance organization provides support to the pilot, so does the duty of care extend to ATC and weather personnel. They must make certain that support is given to the operating crew in terms of supplying accurate up-to-date weather information and assessment of expected changes.

The pilot's decision to go includes two major weather considerations:

1. Is the expected weather within the pilot's capability?

The answer to this question lies in the training and experience of the pilot in weather flying and familiarity with the equipment, how much actual weather flying is expected, whether the flight is to be conducted with a solo pilot or multiple crew, the quality of the weather information available to the pilot for the flight, and any special detection equipment aboard the airplane, e.g., radar, navigation equipment, cockpit configuration and display, ice probes, etc., and the pilot's proficiency in operating the equipment.

2. Is the expected weather within the aircraft's capability?

The answer to this question depends on the aircraft's design (performance, structural strength, aerodynamics, powerplant, de- and anti-icing systems, maneuverability and handling qualities, etc.) and the aircraft's condition (airworthiness, minimum equipment list, operable systems, adequate fuel reserves for the flight, system redundancies, etc.).

Given this general structure, I will address some specifics that are illustrated by a random sampling from more than 800 civil aviation accidents involving weather as a factor that happened over the past decade. The specifics include:

- Deviation from planned flight;
- Inaccurate weather forecasts;
- Faulty judgment;
- Mismanagement of cockpit resources;
- Deficiencies in basic knowledge/understanding of the airplane, pilot capabilities and the environment;
- Lack of critical information for the crew;
- Failure to communicate critical information to the pilot in a timely fashion; and,
- Lack of adequate operational nav/comm ground facilities.

Facing The Moment Of Truth — Some Accident Cases

The following brief synopses have been culled from worldwide accident data:

Canada: DHC-6. Loss of directional control on the runway. Freezing drizzle covered the sanded area of the runway surface, but runway condition was still reported as sanded with poor to fair braking action — 0 fatalities to 12 exposed.

Kenya: Cessna 310. Aircraft struck terrain while maneuvering in the pattern. Visibility poor in holding pattern with rain and thunderstorms — 2 fatalities to 4 exposed, 2 seriously injured.

Japan: YS-11. Aircraft descended into terrain while maneuvering below low cloud base — 0 fatalities to 53 exposed, 18 serious injuries.

Venezuela: DC-9. Landed hard after ILS approach in dense fog, with damage to gear and subsequent fire — 23 fatalities to 50 exposed.

Germany: Cessna 414. Landed in heavy rain. Poor braking experienced and aircraft hydroplaned off end of runway — 0 fatalities to 5 exposed.

United States: Boeing 707. Aircraft encountered unforecast turbulence 25 minutes before landing. Cabin attendant thrown to ceiling, then fell to floor. Serious back injury — 0 fatalities with 191 exposed.

Orkney Islands: Twin Otter. Landed on 1.6 percent downslope with 28-knot crosswind gusting to 38 knots. Aircraft's left wing rose, aircraft swerved and catapulted as right wing struck ground — 0 fatalities to 12 exposed.

Spain: Boeing 727. On takeoff run, aircraft collided with DC-9 taxiing onto runway in heavy fog. DC-9 crew could not obtain adequate visual reference for taxiing — 57 fatalities to 93 exposed.

Malaysia: A300. During ILS approach in poor visibility, thunderstorms and heavy rain, aircraft undershot and came to rest 1,000 meters before runway threshold. The aircraft was leased and had different cockpit configuration than the main fleet aircraft. Heavy cockpit crew workload as a result distracted crew in low visibility approach — 0 fatalities to 247 exposed.

Australia: Rockwell Commander 685. Aircraft crashed soon after pilot reported descending to cruise at 500 feet agl. The weather was overcast with low clouds covering hills. Wreckage was found on northern slope of east-west ridge — 1 fatality to 1 exposed.

United States: DC-10. Following an ILS approach in a tailwind, the aircraft landed 4,700 feet beyond threshold, 36 knots above programmed touchdown speed. The aircraft ran off the runway into a tidal inlet — 0 fatalities to 177 exposed.

Bolivia: F-27. Aircraft crashed after encountering adverse weather on arrival at San Borja. ATS/Com/Met/VHF, HF, and VOR/NDB radio aids were inoperative. Aircraft overflew airport at 1,500 feet. Ten minutes later, equipment operation was restored, and call was received from aircraft just before it hit a hillside — 23 fatalities to 23 exposed.

Pago Pago: DHC-6. Aircraft sustained a hard landing. Light to moderate turbulence led crew to fly slightly faster-than-normal approach. During flare, windshear was encountered, causing decrease in airspeed and excessive rate of descent. Despite adding power, the aircraft landed hard — 0 fatalities to 20 exposed.

France: Piper Cheyenne II. During second IFR approach in thick fog, aircraft diverted 30 degrees from centerline and collided with light post, struck ground and caught fire — 7 fatalities to 7 exposed.

Scotland: SA330 Puma. Helicopter was in cruise when No. 1 engine failed. Some ice had built up on the windscreen wiper blades and substantial rime ice had built up on the icing probe. Second engine failed in descent. Autorotation commenced and both engines were restarted in time for recovery at 200 feet agl. Engine inlet icing suspected — 0 fatalities to 12 exposed.

Katmandu: DHC-6. Collision with terrain during climb-out. Aircraft deviated from intended track. Suspect bad weather and possible load-limited rate of climb — 15 fatalities to 23 exposed.

New Zealand: B-737. While descending through 11,000 feet in VMC conditions, aircraft encountered brief period of clear air turbulence. Passenger standing in rear foyer was thrown to floor, suffering compression fracture of lumbar vertebra — 0 fatalities to 112 exposed.

Ireland: Shorts 360. Aircraft crashed short of the runway. It was established on ILS at 900 feet agl when periodic and divergent rolling motion developed. Bank angles up to 56 degrees with roll rates up to 55 degrees per second were experienced, along with a maximum rate of descent of 3,000 fpm. The descent was arrested in time to make a gentle ground contact 3.5 km short of runway. Airframe ice degraded aircraft stability and control, with turbulence and downdraft contributing — 0 fatalities to 35 exposed, 2 serious injuries.

Denmark: DC-8-63. Aircraft engine damaged on landing. During visual meteorological conditions (VMC) approach using ILS guidance, the aircraft was subjected to severe turbulence. At 1,000 feet, windshear brought IAS from 150 to 180 knots. On short final, conditions improved and pilot elected to land. Aircraft outboard engine pod contacted ground on touchdown — 0 fatalities to 258 exposed.

Iceland: PA-23 Aztec. Aircraft collided with terrain on air taxi flight in IMC conditions with icing above 3,000 feet in clouds. Wind at cruising altitude of 8,000 feet was up to 80 knots. Reaching mountain range, pilot requested minimum altitude and was cleared to 5,000 feet. He was seen descending to 4,500 feet and then disappeared. A very strong mountain wave, with roll cloud, was present. Rate of descent of the air on leeward side was calculated to be up to 5,000 fpm. The aircraft altimeter very likely showed 600 feet too high because of wind and temperature deviations — 5 fatalities to 7 exposed, 2 serious injuries.

Sweden: DHC-2 Beaver. Aircraft collided with ground due to whiteout. Pilot had taken off from mountain lake on advice of chief pilot. Weather was bad and pilot lost all visual references after takeoff. Lack of instrument training made him decide to make precautionary landing — 0 fatalities to 1 exposed.

Japan: DC-10. Cruising at FL210, aircraft encountered severe turbulence that injured several passengers. Seat belt sign was not on. Digital flight data recorder (DFDR) showed G values varying from +0.29 to +1.97 of 16 seconds duration — 3 serious injuries to 137 exposed.

Japan: MD-80. Severe turbulence was encountered at FL290 in cruise, injuring several passengers. DFDR records showed G forces ranging from -1.1 to +1.76 of two seconds duration — 2 serious injuries to 104 exposed.

Argentina: Boeing 727. During landing roll, aircraft drifted outside runway which was wet and had quartering gusts from 90-110 degrees at 23 gusting to 35 knots. Loss of directional control was followed by nose gear collapse — 10 fatalities to 114 exposed.

England: Boeing 747. Aircraft was struck by lightning on departure. No thunderstorms were forecast nor did aircraft radar show any returns. After third strike, aircraft radar failed and autopilot disengaged. Pilot returned for overweight landing which was normal except for no reverse thrust on No. 2 and No. 3 engines, and no auto spoilers. More than 100 discrete burn marks were found on the fuselage; a four square-foot area of paint was discolored. The tip of the right tailplane was damaged and the aft section of the tip cap was missing. HF radios, two bonding straps at the hinge position on the right elevator and part of the passenger address system also failed. The flight data recorder was unserviceable — 0 fatalities to 243 exposed.

USSR: YAK-40. Aircraft crashed during rejected takeoff following attempted go-around. Approach was flown with tailwind in heavy rain shower. Weather presumed below crew minima. Following a high speed touchdown, a go-around was attempted. The takeoff was aborted and the aircraft overran the end of the runway, collided with obstacle, broke up and caught fire — 8 fatal to 29 exposed, 12 serious injuries.

USSR: TU-134. Aircraft collided with terrain. Flight was cleared for non-standard approach in IMC at night. The crew was not informed that navaids were turned off and weather had changed. Entering conditions of reduced visibility with no reliable visual contact with approach lights and with landing lights turned off, pilot and copilot continued approach through decision height. The aircraft, which was not in landing attitude, made a hard landing beside runway, broke up on impact and caught fire — 20 fatalities to 51 exposed, 30 seriously injured.

Discussion of the How and Why

To the above list can be added some better-known accidents that occurred in the United States: the wind shear landing accident in Dallas/Fort Worth, Texas, the icing takeoff accident at Washington National in Washington, D.C., the icing/gusting wind takeoff accident at Denver, Colo., and the no-flaps takeoff accident at Detroit, Mich., where crew concern over possible wind shear conditions contributed to a checklist distraction. I purposely chose the less well-known accidents from the accident reports to show clearly that adverse environmental factors do not respect geography, aircraft type or the particular human operator. Many of the pilots involved were highly-skilled and highly-experienced. Although mercifully, many aircraft occupants escaped injury or death, the numbers exposed to risk are high and should be kept in mind as we all perform our tasks with a duty of care.

Although the pilot or crew was often determined to be at fault, the presence of adverse environmental situations was the determining factor in many of these accidents; that is to say, lacking the added complication of low visibility, gusts, wind shear, icing, thunderstorms, etc., the accidents likely would not have happened. What does this mean? Well, for one thing, it means that we have been collectively unable to get a basic understanding of the hazards represented by adverse environmental factors instilled in flight crews. Also, we have been unable to raise management thinking to a high enough level to bring the proper questions to the decision-making process.

The judgments of the pilot or crew thus become the key factors. What influences this judgment? There are many influences and it is impossible to quantitatively rank their importance, for each situation calls for its own hierarchy of priorities. However, included in these influences must be: fundamental knowledge and understanding of weather processes and hazards by both operations and management people, situational awareness on the part of the pilot or crew, peer pressure, schedule pressure, ATC slot assignments, and cockpit resource management or how well the crew works together to provide adequate checks and balances in the man-machine-environment interface.

Commitment to Safety

Senior management's visible commitment to safe operations has probably the largest potential positive effect on judgment. Such commitment is manifested in tight crew selection procedures, training and organization of the operation so as to operate with the highest practical level of safety. However, self-discipline and professionalism are also important attributes for the pilot or crew.

A major contribution to crew performance improvement is the modern flight simulator, where weather situations can be experienced with such realism that the training is highly effective. Private pilots and small operators are often unable to avail themselves of such training, although technologies are continually emerging that promise to bring this excellent educational and training tool within the reach of the smaller operator.

The changes taking place today in aviation are dramatic. The accident reports reviewed leave no doubt that the modern airplane is very forgiving of human error. Likewise, it is protective of its occupants in all but the most severe accidents. Nevertheless, new demands are being placed on the operation, and new equipment and procedures are being introduced that have subtle requirements for the support system. Extended Range Operations (EROPS), for example, is a technologically sound concept for the newer twin-engined transport aircraft, but it demands a much more precise forecasting of en route and destination weather, so that contingencies for the safe conclusion of flight may be maintained. Likewise, the hub-and-spoke route structure in the United States, brought about by deregulation, has introduced requirements for more precise scheduling to efficiently make the hub transfers of passengers.

There is thus a subtle pressure to make a schedule, or else throw the entire system out of synchronization. In Europe, the congested air traffic and airport systems have caused an enormous amount of anxiety about obtaining and maintaining a slot in the traffic flow, and a recent item appeared in the U.K.'s CHIRP reports wherein a pilot was reported as having suffered a mild heart attack in the cockpit while awaiting takeoff clearance, but elected to continue with the takeoff rather than lose the assigned slot!

The nature of delivery of weather services to the operator has also changed, with datalinking via computer and satellite. The measurement, collection and analysis of meteorological data has made great strides, but in some cases it has become more remote from the traditional flight operation. Software design is accomplished in many cases by people who have more software orientation than operational awareness. Acquaintance with operational needs by weather personnel may not be as focused as in earlier years, but improvements in measurement and forecasting precision likely compensate to some extent. We must, however, maintain our own engineering and scientific situational awareness to ensure that our end product is functionally safe.

As key to this situational awareness we must realize that at the operational end, the rapid expansion in aviation operations has strained the ready supply of pilots and mechanics just as it has the delivery of weather services. Air carrier and corporate operators no longer have the luxury of the military services' screening and training of pilot hires. An increased number of ab initio training schools has been established by airlines and manufacturers. Civil operators are recruiting inexperienced candidates and variations in selection standards are wider than for military flight candidates. Maintenance training has to compete with many other career fields that are attractive and financially rewarding to young people today.

Experience Levels Degrade

This has led to an overall lowering of experience levels in the maintenance and operational ranks. The larger airlines now recruit personnel from commuters, air taxi and business aviation operators. These sources have largely replaced the military as a major supplier of pilots for the major airlines. Not only are the smaller operators lacking a uniform standard of strict selection and training practices compared with the military, but the constant turnover in pilot and mechanic staffing condemns these smaller operators to a never-ending low-experience level.

The situation holds strong implications for the need to technically compensate with research on environmental hazards that will yield more certain information and forecasts so that the criticality of pilot judgment is less dependent on training and seasoning. Likewise, the importance of initial and recurrent training of pilots in adverse weather phenomena cannot be underestimated.

What Must Be Done

Adverse weather is a given. It is up to the human to deal with it. We must measure it, analyze it, continue to design our machines to withstand its assaults, define safe operating boundaries, and train ourselves to operate within these boundaries. We must provide pilots with a stronger education in weather and its potential for risk.

Our support system of air traffic control and weather observation, analysis, forecast and warning must be improved to provide the pilot with the information needed to make quick and prudent decisions. Our air transportation system, whether public carrier or private, must recognize the limits imposed by adverse environmental conditions, and thereby avoid subtle transgressions of the pilot decision-making process that might encourage undue risk-taking. We must continue our refinement of the forecasting art and science.

A breakdown of the process by which the pilot recognizes a deteriorating situation calling for safer alternative action occurs frequently. Initial and recurrent training in weather must be strengthened. Likewise, the failure to provide accurate and up-to-date weather information to the pilot in a timely fashion is demonstrated time and time again in the accident reports.

Continued research activities are absolutely essential to ensure that these deficiencies are overcome. They should be carried out fully mindful of our duty of care and with the realization that the understanding and knowledge gained will not be useful unless the operational system can exploit it in the interests of safe completion of the flight.♦

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