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The Role of Risk in Aviation Under Adverse Weather Conditions

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This paper will discuss the current air line weather information systems and why they are inadequate, what scientists and airlines want to achieve with the next generation of weather information systems, the dynamics of weather and what the scientists are up against, and how the next generation of weather information systems will provide pilots with a means to conduct effective risk assements with regard to weather; which will ultimately reduce the overall aviation accident rate.

Currently, most pilots get a sheet of weather data printed out right before takeoff. This sheet usually lists surface temperature, wind speed, cloud height, and thunderstorm warnings. Pilots also get updates from the particular airline operation center. These updates are sent to the aircraft via a 2400 baud modem, and include severe weather advisories from the National Weather Service and data from ground radar installations (Perry, 2000, p. 40). Pilots may also hear reports from other pilots flying in the area. However, such reports can prove to be inaccurate and out of date.

Because of the deficiency of some current weather information systems, pilots have often resorted to asking first-class passengers who are logged on to the Internet with their laptops to search for accurate weather forecasts on the Internet. That information is more likely to be more accurate and up-to-date than the weather data sheets and other information available in the cockpit.

Current Airline Weather Information Systems

In addition to in-flight weather information, airports also provide pilots with weather information from the ground. Airports have an automated ground weather information system called ASOS (Automated Surface Observing System) and also employ personnel to forecast and visually verify weather on a daily basis (Brogan, 1998, p. 1).

The ASOS system is under a certain amount of scrutiny, however, because it is unable to detect thunderstorms, tornadoes, hail, snow amount, cloud layers at about 12,000 feet, and other weather data officials say is crucial for pilots to know. So, most major airports employ weather forecasting personnel to generate timely and accurate weather forecasts for arriving and departing planes. These reports are, for the most part, timely and do help pilots with decision making.

Inadequacies of Current Weather Information Systems

Improving the weather information systems is challenging. First, weather itself is very unpredictable. Thus, once a weather report is issued, it may be virtually useless because of weather changes. The challenge is to provide continuous streams of current information to the pilot.

Thunderstorms and turbulence are two major weather phenomena that affect aviation. They illustrate the fact that weather can change drastically, without notice. Thunderstorms can grow and shrink depending on several variables; they can also change direction and produce lightning depending on even more variables. Turbulence can be created by air masses moving in opposite directions, heat, and even terrain such as mountains. Because of these variables and nature itself, we will probably never be able to predict weather with pinpoint accuracy.

The best we can do is to provide timely and accurate information on what the weather currently is. Since a plane's flight path can take it across and through many weather phenomena, it is vitally important

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that the pilot has current and comprehensive weather information.

Unfortunately, this is not the case with the current weather information systems. The weather data sheets printed out before take-off can be outdated almost immediately. The data that is sent to the aircraft via antiquated 2400 baud modems is not comprehensive enough to give the pilot a clear indication of what lies ahead, and while the weather reports for the airport area may be accurate, they are only useful in take-off and landing situations. Taken as a whole, the current weather information systems make it difficult for pilots to make decisions that incur the least risk.

The biggest culprit in the inadequacies of the current weather information systems is technology. While the rest of the world uses tremendous bandwidth and communication technology everyday, the airline industry is still decades behind digital communication. Modern weather graphics provide meaningful data, but are extremely dense with data, and displaying those types of graphics via a 2400 baud modem is not practical.

Environmental Dynamics of Weather

Some of the dynamics of weather include turbulence, thunderstorms, and conditions that cause icing of aircraft. While there may be more weather dynamics, these three items appear to have the most affect on aviation.

Turbulence

Turbulence, which is similar to the movement of waves in the ocean, can be caused by many factors. These factors include thunderstorms, jet streams, two air masses moving in opposite directions, terrain, and even the wake-vortex of another aircraft. The type of turbulence caused by mountains can exist for hundreds of miles. Federal officials say that turbulence causes more nonfatal injuries to airline passengers and crew than any other event involved in flying (Phillips, 1997, p. A01).

About half of all turbulence is "convective" and occurs near thunderstorms, while the other half is called "clear-air" turbulence because it occurs in clear sky with no warning. Turbulence can vary in size from approximately 300 meters to over 1,000 meters wide.

While most weather detection systems can easily identify thunderstorms, few can easily identify turbulence. Most often, pilots rely on each other's reports to determine whether or not turbulence is ahead. This lack of information can lead pilots to make incorrect decisions, which may be risky.

Thunderstorms

Most often, pilots will opt to fly around thunderstorms rather than fly through them because these storms can produce damaging lightning, severe turbulence, and low visibility conditions. Due to the unpredictability of thunderstorms, getting accurate, up-to-date information on them is almost impossible with the technology currently aboard airplanes.

Icing

Possibly the one area where current weather information systems work well is with regard to icing. A product called the "Weather Support to Deicing Decision Making System" provides accurate and timely forecasts of weather conditions that affect ice accumulation on aircraft and runways. WSDDM uses Doppler radar, surface weather data and snow gauges to provide meaningful information on icing conditions.

Knowing how fast, in freezing weather, airplane wings can become covered in ice is important because pilots and crews need to make decisions on how often to de-ice the plane before take-off. As little as 0.8mm of ice on a wing can dramatically decrease lift, or increase drag on an aircraft. Not having this kind of information available to pilots and crew has been the cause of many airline accidents.

Next Generation of Weather Information Systems

Since President Clinton's announcement in 1997 of a national goal to reduce the airline fatal accident rate by 80 percent by 2007, much research has been started. In the 2000 fiscal year alone, the Federal Aviation Administration (FAA) spent $19 million on research into aviation weather information.

LIDAR

A new technology aimed at detecting turbulence is LIDAR. LIDAR is a Doppler laser radar that uses a near infrared wavelength to bounce off dust and other aerosol particles as small as a micrometer in diameter. These particles exist at all altitudes, but are less dense around 35,000 feet. Therefore, detecting turbulence at higher, cruising altitudes will require more sensitive LIDAR equipment, which will be much more expensive. Once successfully developed, LIDAR systems will be on board aircraft and provide pilots with a graphical display of radar/LIDAR images detecting turbulence in front of the aircraft (Perry, 2000, p. 40).

Data Transfer/Digital Communication

As stated previously, bandwidth to and from aircraft is currently inadequate. Some reasons for this are aviation's unique requirements. In aviation, communications links must be robust, timely and secure. It is not as simple as transmitting a high bandwidth signal to and from the aircraft. However, much research is happening in this area and improvements are near.

Some current research efforts include ground-based microwave communications and satellite-based communications. Tradeoffs in these areas include quality of displayed images, ability to reach aircraft anywhere in the sky, and cost.

Ground-based communication systems usually use limited bandwidth, have problems reaching aircraft at higher altitudes, and can be disrupted by interference from other available aeronautical frequencies.

Satellite-based systems have better coverage, offer higher bandwidth, and can reach aircraft anywhere in the sky. Either alternative will be expensive, so researchers are already working on ways to offset some of the cost. Ideas include using the bandwidth for passenger entertainment. Passengers would also be able to surf the Internet at high speeds.

Current Efforts

Many researchers, government organizations, and manufacturers are working to improve the current weather information systems. They are attempting to improve the weather data and, moreover, improve the aircraft/airline technology infrastructure to better communicate weather data. Honeywell is building a new data center in Phoenix, Arizona, that will transfer large file uploads including business files, or color weather imagery to aircraft in flight anywhere in the world. This effort is not currently geared toward commercial airlines; rather it services business flights that can subscribe to the data for a cost. This effort is also a part of Honeywell's overall plan to have an integrated air traffic management system to improve decision-making (Proctor, 1998, p. 17).

Another Honeywell effort involves developing a low-cost storm cell tracking system for onboard weather radars. The system would add dashed white lines to radar displays to illustrate projected storm cell movements over the next three to five minutes, again allowing pilots to make better decisions (Proctor, 2000, p. 13). The National Center for Atmospheric Research (NCAR), the National Weather Service (NWS), and the Massachusetts Institute of Technology's Lincoln Laboratory are developing a tool to provide near real-time forecasts (Asker, 2000, p. 67). The system, called the National Convective Weather Forecast, presents a sophisticated storm map and graphical forecast on the Internet with updates every five minutes. Forecasts in the zero- to six-hour range are very useful in aviation and this tool attempts to provide that kind of timely information.

This tool has been met with much acceptance. Pilots praise the system as an excellent decision-making tool. The system provides storm growth and decay algorithms that give pilots a good idea of what kind of weather is in front of them. The National Oceanic and Atmospheric Administration (NOAA) developed a new weather information system called the Aviation Grid Forecast System. This system generates high-resolution weather images on a screen much like television news programs where color indicates storm intensity. This system is not for use in aircraft, but is being utilized by airports (The Associated Press, 1995, p. A10).

Mitre is testing a prototype broadcast data link to exchange position information between aircraft and the ground, and for up-linking traffic and weather information to the aircraft. The company's goal is to produce this device for under $2,000, which would give aviators cheap, timely, and accurate weather information (Nordwall, 1997, p. 79).

Although it is not weather, wake vortices are a form of turbulence caused by jet engines and can be another unseen menace to aircraft. Honeywell is working on developing a system that will detect wake vortices and warn pilots. The information displayed to the pilot would contain wake vortex profiles and local wind information, which would give pilots enough information to avoid a potentially threatening wake vortex. One of the primary benefits of this system other than safety would be improved airport capacity. Currently, aircraft are spaced apart at a distance to avoid any chance of wake vortex turbulence while in a landing stream. With this new system, aircraft could be more closely spaced, with the assurance that the system would warn the pilots of a wake vortex ahead, which would allow more planes to land more quickly.

One challenge of all these new technologies and the information they provide is how to display or represent much more information to pilots and crews without creating a kind of "information-overload." Pilots and crews must be presented with complete and detailed weather information quickly and in a manner that is intuitive. Too much information can be just as damaging as too little.

Pilot Knowledge and Decision Making

A key to minimizing risk and better aviation decision making is pilot knowledge. The more information a pilot has about a situation, the more apt he/she is to make the best decision. NASA is working to improve pilot decision making by conducting extensive training (Dornheim, 2000, pp. 60-61).

Michael A. Dornheim published an article in *Aviation Week & Space Technology* called "NASA Boosts Decision-making Skills" that discusses the NASA's Ames Research Center's efforts to better pilot decision making. The Ames Research Center hopes to find out why pilots make poor decisions, why some pilots are more effective than others, and what the are precursors to bad decision making.

The Ames Research study set up the following test scenario:

- At the destination airport, should the pilots go around due to weather and crosswinds?
- After a go-around and failure of a hydraulic system, should pilots proceed to the alternate airport?
- At the alternate airport, what is the best plan for an approach with manual landing gear extension and alternate flap deployment induced by the hydraulic failure?

According to the research group, a significant pattern of differences emerged with regard to pilot and crew decision making. The better crews had better situational awareness, which included weather dynamics. They were better prepared for the first missed approach scenario, by going around the storm earlier. When the hydraulic system failed, they would hold a pattern to create time to check the implications of the system failure and gather more weather information. Then, once at the alternate airport, they planned the slow gear and flap extensions earlier and had time to rehearse them.

The good pilots and crews seemed to prepare for the worst—and hope for the best. They consistently tried to make the least risky decisions, which would buy them more time to further evaluate the situation. The captains in these crews made decisions on managing risk, while the first officer focused on planning the specifics and flying the plane.

The poorer crews didn't seem to prepare for the worst. They almost immediately went to the alternate airport without checking the weather there. They also did little preparation for dealing with the manual landing gear and flaps, which left them scrambling on approach.

Most of the bad decisions made by these crews occurred during the approach and landing phases, and were because the crew ignored increasing evidence that the original plan was no longer appropriate. According to Judith Orasanu of the Ames Research Center, this is not surprising because the urge to continue to the destination grows stronger the closer one gets to the destination.

Some causes of the bad decisions were faulty assessment of the situation, faulty action selections, lack of knowledge, and failure to foresee consequences. Factors that promote faulty decision making are little or ambiguous information, changing risk, and even stress. Clearly, better weather information would improve crew's decision making in many of these situations.

Orasanu went on to list improvements that would help decision making. These include more information, such as timely and accurate weather information, and better pilot risk assessment. Orasanu said, "If a pilot realized the situation is deteriorating, he may not continue his original plan." The Ames Research Center is helping airlines develop a risk-management course aimed at helping pilots make better decisions.

Aircraft Performance Characteristics

Because turbulence seems to be the most significant problem stemming from weather conditions, aircraft manufacturers are experimenting with ways to offset the effects of turbulence.

Dealing with Turbulence

Most modern aircraft have flight control systems that smooth the ride, but such systems can't handle significant turbulence. Airline manufacturers are researching this area, but it is yet unclear whether the cost of developing such systems will be worth the improvements in ride. As stated earlier, turbulence can be caused by many weather conditions and having aircraft that could deal with significant turbulence would go a long way towards easing pilot stress and decision making. Vertical gusts are the most disruptive as they act on a large wing area. The gust changes the aircraft's "angle of attack" and causes it to pitch to regain its original "angle of attack." With very strong gusts an aircraft can drop into a zero-"g" flight, which causes the pilot to have to pitch the aircraft significantly to fight the turbulence. A better solution is to alter the wing's lift with spoilers and trailing edge controls that can respond much faster (Dornhiem, 1998, p. 76).

Some aircraft have these "direct lift" control systems, but these systems are intended to help reduce structural loads, not improve ride. The pilots of these aircraft have noticed, however, that these aircraft have a much smoother ride in turbulent conditions. Following are a few other aircraft performance enhancements currently under development. A "lateral gust suppression system" prevents aircraft from "weather-cocking" into side gusts. With this system, a plane's rudder will move in the opposite direction as the gust to prevent the aircraft from swinging with the gust. The system uses static pressure ports on opposite sides of the aircraft. When an airplane is affected by gusts, the pressure on one port will be different than on the opposite port. This difference in pressure is compared to the aircraft's yaw rate to determine the gust factor and adjust the rudder.

The "pilot's pitch control law" is a system that controls load factor and pitch rate. It tries to maintain a 1 "g" flight and reject pitch upsets, which smooths the ride for minor turbulence, but does not have much effect on major turbulence. A "landing attitude modifier" added to the Boeing 777 last year keeps pitch attitude somewhat constant on approach by varying the flap position with airspeed. The landing attitude modifier helps compensate for low frequency gusts.

Conclusion

The FAA, NASA, and the U.S. government have been developing better resources to reduce the risk that pilots face each time they fly. By taking advantage of the latest tools and methods of developing software, pilots will receive more accurate information—in a more timely fashion—that will help them when it comes time to make crucial decisions. n

References available on request from author.

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Decision Sciences Institute Budget Summary FY 2001-2002

July 1, 2001-June 30, 2002

Revenues summary		
Publications	$ 151,645	
Membership Revenues	164,489	
Electronic Publishing	0	
Convention	324,932	
Total revenues		$641,066
Expenses summary		
Publications	$189,796	
Member Services	191,336	
Electronic Publishing	17,544	
Convention	223,154	
Total expenses		$621,829
Net Revenue Over (Under) Expenses		19,236
Plus Depreciation Expense (Not a cash expense)		8,944
Net Revenue Over (Under) Cash Expenses		$28,181