RISK PERCEPTION: A CRITICAL ELEMENT OF AVIATION SAFETY

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"At the end, risk taking is the cause of almost all accidents. But it is not always easy to find those who TOOK the risks; too often they are confused with those who RAN the risks." **(Wagenaar and Keren, 1986)**

Abstract: Designers of new automated systems typically conduct human-reliability analyses to account for potential human errors that may contribute to system risk. In aviation, the National Transportation Safety Board (1994) found that the second most common type of error in accidents was tactical decision errors. Efforts to improve flight safety frequently involve training crews in effective decision-making. One fact that has become apparent in developing such training is that decision-making depends critically on the crew's perceptions of the risks entailed by various threats in the environment. This paper addresses two issues critical to improving the quality of aviation decision-making. (1) How do crews perceive risks associated with aviation decisions? (2) How does risk perception influence flight crews' decision-making processes? Research findings that address these questions will be presented, along with implications for improving flight crew decision-making. *Copyright ã2002 IFAC.*

Keywords: Decision making, Human error, Risk, Socio-technical systems, Safety analysis, Systems design, Human reliability, Uncertainty, Group work, Aircraft operations

1. INTRODUCTION

When new automated systems are designed, engineers are always concerned with assessing potential risks to determine the likelihood that component parts will fail over time. Based on these assessments, they seek ways to mitigate those potential risks. A far more difficult task is to factor in the role of the human operator, even when risk assessments are designed to anticipate the likelihood of human error. Typically, human reliability analyses yield a probability that is entered into the broader equation, but these risk estimates often are based on expert judgment rather than on actual experience. Moreover, these efforts provide little guidance for understanding how and why human error occurs, nor

how to prevent it in the future. Recent advances in our understanding of how cognitive and contextual factors combine to influence human error (Reason, 1997) have led to new approaches to safety. Reason's work emphasizes the role of organizational decision making on the performance of individuals at the "sharp end," that is, on those who appear to *run* the risks. In fact, company policies and decisions typically influence the design of systems, procedures, and training, and reflect goals and values that influence individual performance. It is the company that often *takes* the risks.

Significantly, the aviation industry has long recognized the role of flight crews in aviation safety. However, only recently have they begun to pay

attention to the fact that people are human and will make mistakes, that the automated systems supposedly assisting crews often leave them confused and mystified, and that the crew's primary role is to *manage risk*. Doing so effectively depends on the kind of training provided by the companies. The current direction in flight crew resource management training for some airlines is threat and error management (Gunther, 2001; Helmreich et al., 2001). However, in order to manage threats and to prevent them from leading to unsafe situations, pilots must first assess the risks associated with them. Action decisions follow from one's understanding of the risks associated with various options.

This paper will address three issues relating to the role of pilot risk perception and the role of company policies in overall aviation safety.

- How do pilots think about flight risk? What risks are of greatest concern to them? What role does company policy play in their risk perception?
- How do pilots currently manage risk?
- How can flight crews be assisted in making safer decisions and in managing risk?

2. BACKGROUND

Analyses of flight crew behavior in commercial aviation accidents have shown that tactical decision errors were the second most prevalent factor in these accidents, contributing to approximately two-thirds of the accidents (NTSB, 1994). About three-quarters of these were "plan continuation errors" (PCE), or decisions to continue with an original course of action in the face of cues that signaled changed conditions (Orasanu, Martin, & Davison, 2001). This class of errors occurred predominantly during the approach and landing phases of flight and occasionally during preflight. This pattern suggests a strong predisposition to "go" even in marginal situations and to continue with the flight to destination, the well-known "get-home-itis."

The pervasiveness of this pattern is evident in recent data from MIT, which shows that pilots are more likely to penetrate rather than to deviate around thunderstorms with increased proximity to the airport (Rhoda & Pawlak, 1999). An analysis of Parts 91 and 135 accidents in bad weather also indicated that 62% of them involved plan continuation errors (McCoy & Mickunas, 2000). Thirty-five percent of Aviation Safety Reporting System (ASRS) incident reports from Parts 91 and 135 pilots concerning weather-related decisions reflected PCEs; in about two-thirds of those reports the pilots themselves said they "should have done something differently" (Orasanu, Burian, & Hitt, 2001). Because plan continuation errors are so common and are closely linked with

accidents, a better understanding of their causes and ways of reducing them should have a significant impact on flight safety.

The reason we are focusing on plan continuation errors, in addition to their prevalence in accidents, is that one major hypothesis to explain this class of "error" is inappropriate assessment of risk, especially in situations with ambiguous cues (See Figure 1).

Risk refers to the possibility of a negative consequence (e.g., reduction of a safety margin) as a function of some type of threat. How a person perceives risk is inherently subjective, reflecting one's familiarity and experience with the threat, whether one is personally affected by potential negative consequences, how imminent the consequences are, and one's sense of control over the situation (Huber, 1997; Slovic, 1987; Yates & Stone, 1992).

Fig. 1. Threat-Risk-Action Loop

Consequently plan continuation errors may occur because pilots underestimate the risks inherent in a dynamically changing situation or because they overestimate their own capability to deal with it. This explanation for plan continuation errors may also reflect personal "biases" toward competence and control, that is, people tend to believe that they are more skilled and more in control than they actually are in many circumstances (Taylor & Brown, 1988; Wilson & Fallshore, 2001).

Inappropriate risk assessment may be compounded by incorrect interpretation of significant cues, resulting in failure to update one's situation model. As shown in Figure 1, perception of risks and the decisions that follow are influenced both by individual cognitive factors, as well as by organizational pressures relating to company productivity, economics, and its safety culture. Organizationally driven goal conflicts often pit safety

against production pressures or social factors, thereby creating dilemmas for their flight crews. The bottom line is that flight crews routinely deal with inherently ambiguous information about the current and future state of the environment and uncertain outcomes associated with various courses of action. This poses a challenge to both system designers and to organizational managers to devise aids and policies that support flight crews in making difficult decisions.

Despite its significance to aviation safety, there is surprisingly little empirical research on the role of risk perception in pilot decision making. Most of the existing work deals with general aviation pilots and examines the relation between pilots' attitudes towards risk and their decisions to continue or to divert in a computer-simulated cross-country flight (Jensen, 1995; O'Hare, 1990; O'Hare and Smitheram, 1995). Our current NASA Ames research projects were designed specifically to address risk perception in air transport pilot decision-making. Several issues have driven our research: First, what risks are of greatest concern and salience to pilots? Second, how do those risks influence pilots' decision making? And, third, how do pilots manage risk? This paper will present findings from several studies and consider their implications for designing safer systems.

3. PILOTS' PERCEPTIONS OF RISK

A casual conversation with pilots about the risks they perceive in flight yields a surprisingly diverse set of responses, going beyond the usual safety concerns such as losing an engine halfway across the North Atlantic, an onboard bomb or fire, etc. The research literature supports this diversity. Several researchers have pointed out that there are various types of risk: physical, professional, economic, social, ethical and psychological (Jacoby & Kaplan, 1972; Nygren, 1995; Yates & Stone, 1992). Moreover, these risks may occur in the same situation and may be pitted against one another. For example: A flight from Washington, DC (DCA) to Minneapolis (MSP) is running late and the DCA curfew is nearing. After pushback, it is found that there are 185 passengers aboard, but only 184 seats (ASRS, Report #115914). Risks in this situation include economic (getting passengers where they want to go; hotels/meals for passengers at departure location if curfew is missed), passenger safety (if crew decides to seat the extra passenger in flight attendant jumpseat), productivity (getting passengers onto a flight the next day), and professional (Federal Aviation Regulations violation if they decide to continue the flight with the extra passenger). Crew decision making involves balancing these risks and deciding which are most important at a particular time. As Nygren pointed

out, risk dimensions are additive, meaning that as the number of threats increases, the more serious and difficult the decision becomes.

A survey was conducted with pilots from a major US carrier to examine the types of risks pilots encounter in their profession. The survey sought to determine what risks were of greatest concern to pilots, which were most frequently encountered, and how they influenced decision-making strategies. With increasing flight experience, sensitivity to risk becomes part of pilots' perceptual filters. Accordingly, the goal of the first question in our survey was to learn which risks are most salient to pilots.

Question 1: Risk Salience. *"When you think about risk in your professional life, what comes to mind?"*

Pilots' responses were evaluated by outcomes or consequences of a decision, all of which are losses of some type (e.g., safety, job, money, respect). Responses were sorted into the five categories described in the left column of Table 1, which also shows examples of each type of perceived risk.

Most of the responses reflected concerns with safety: 79% of all responses fell into the physical risk category. Concerns with job security ranked a distant second, 16% falling into professional risk. These two categories accounted for 95% of the responses, with the remainder distributed across the other three categories. Examples of responses coded into the five risk categories are shown in the right column of Table 1. As can be seen, these are very specific operational issues that have consequences for pilots.

Those responses identified as referring to physical risk were classified into nine sub-categories. The largest group of responses (32%) referred to the role of the individual pilot in contributing to risk, including comments such as "ability to manage risk," to make good decisions, fatigue, and skill loss. The next most frequent category of responses (23%) was environmental, including severe weather, turbulence, and slippery runways. Aircraft equipment problems, such as engine failure and fire, were also cited fairly often (13%). Risks arising from the crew or others, such as maintenance failures and air traffic controller (ATC) errors, were cited 9% of the time, as were problems with the National Airspace System, such as ATC overload and runway incursions. Accounting for 5% or less of the responses were passenger problems, such as unruly or violent behavior; hazardous operations, such as in-flight fires and land & hold short operations; organizational influences, such as training and two-pilot cockpit workload; and communication difficulties, including frequency saturation and language differences between pilots and controllers.

Table 1. Definition of types of risk and examples of each as reported by pilots.

RISK TYPE	EXAMPLES PROVIDED BY PILOTS
Economic *Actions that may have negative consequences for a flight, such as fuel usage or missed passenger connections.*	"Fuel consumption associated with diverting around thunderstorm"
Productivity *Actions that may have consequences for flight efficiency, such as delaying a flight departure or arrival, or rejecting a placarded aircraft.*	"Delays associated with weather or ATC," "Rejecting an unsuitable aircraft"
Professional *Actions that could have negative consequences for career goals or job security.*	"Will I correctly handle my next check ride?" "Being charged with a crime, losing medical certificate or job"
Physical *Actions or events that may have negative consequences for flight and passenger safety.*	"Fear of making a bad decision, not managing risk," "Overloaded, fatigued," "Aircraft system failures," "Weather, high-traffic density," "Deferred maintenance, substandard de-icing facilities, runway collision, jammed radio frequencies, terrorism, turbulence, terrain"
Social *Actions that may negatively impact how others (e.g., pilots, passengers, managers, controllers, flight attendants) judge your competence and skill.*	"Telling a captain to go around or divert," "Whether to continue flying with a captain who is a jackass," "Exercising authority," "Smooth landing"

Given the pattern of findings regarding the relative salience of risk factors, the second question was whether risk salience reflects how often pilots actually encounter the various types of risks.

Question 2: Frequency of Exposure to Various Types of Risks: *"How often do you feel each type of risk plays a role in decisions you are routinely called upon to make as a pilot?" (Rate from 1 to 5)*

As shown in Figure 2, the salience of various risk types clearly was not related to the frequency with which they were encountered. Productivity, economic and professional risks were most often encountered in flight decision making, even though these were not of great concern to pilots. In contrast, physical risks, which dominated pilots' concerns, actually were encountered significantly less frequently in daily flight. Social risks, also of low salience, were encountered least often, about as frequently as physical risks. Hence, the relative salience of various types of risks clearly does not reflect how often pilots encounter those risks in actual decision making situations.

Question 3: Specific Types of Risk Experience: *Please describe an example of the following types of RISK related to flight (Physical, Professional, Social,*

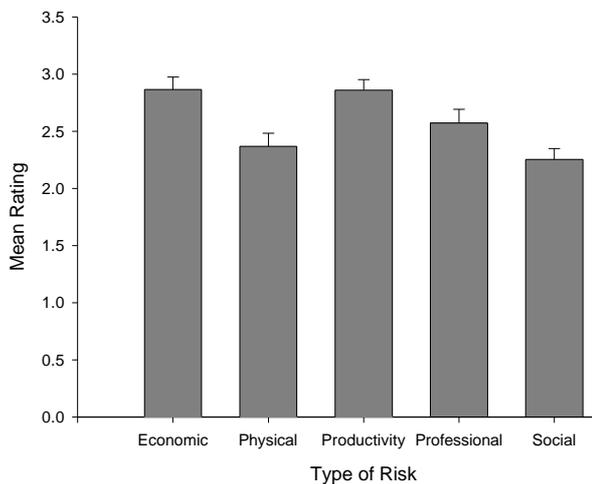*Productivity, and Economic), based on your own personal experiences and opinions in the field of aviation.*

Fig. 2. Mean ratings of frequency of encounter of various types of risk.

This element of the survey was designed to collect specific examples of each type of risk actually experienced by the pilots, regardless of frequency of encounter or salience. Given that we have already presented detail on pilots' perceived safety (physical)

risks (Q1), this section will focus on the four other types of risk.

Professional risks mentioned by both captains and first officers included legal and professional culpability. Legal culpability refers to legal violations, which have consequences for one's career. Professional culpability refers to being challenged for professional actions or decisions such as decisions to divert, failure to report an inoperative system, or landing with an unstable approach. They are not illegal, but may cause professional difficulties with the company. Captains, but not first officers, also mentioned union issues as a professional risk, including going on strike.

Threats to *productivity* resulting primarily from delays typically were related to flight safety, such as rejecting an aircraft due to a placarded system or its inappropriateness for the planned route, deicing, or off-loading hazardous materials. Delays for aircraft maintenance also entailed productivity risks.

Economic risks typically resulted from fuel load or fuel usage (either due to rate of burn or to routing). A second major source of economic risk was missed passenger connections resulting from flight cancellations or diversions.

While *social* risks generally concerned conflicts with other crew or non-crew individuals, power struggles and exercise of authority, the reported incidents varied widely by crew role. Captains worried about their competence being judged on the basis of aircraft handling skills, decisions, and professional performance. First officers expressed concern with upsetting passengers due to delays or cancellations or handling of unruly passengers. They also were concerned with maintaining a positive self-image.

The final question in the risk survey was designed to identify pilots' perceptions of what makes decisions difficult and to see how those factors compare with those that were evident in our second study described below under Risk Management.

Question 4. What makes decisions difficult? *"Please describe a very difficult decision you have had to make as a professional pilot and what made it difficult"*

This question sought to determine whether pilots' perceptions of what makes decisions difficult corresponded with factors that had been previously identified as contributing to decision difficulty (Orasanu & Fischer, 1997). Pilots' responses were categorized according to their consequences. Three major categories emerged: Metacognitive, Personal/Professional and Safety shown in Figure 3. [Note: Not all pilots responded to this question.]
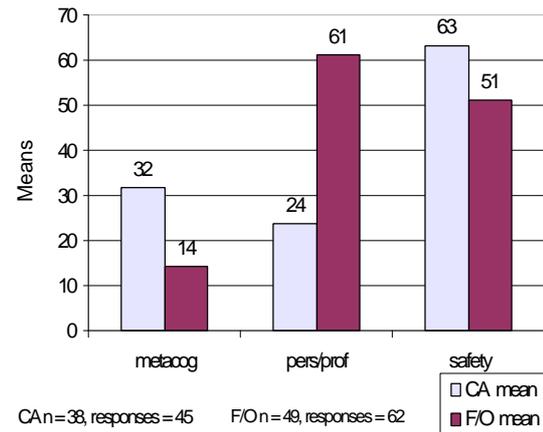

Fig. 3. Frequency of Factors Mentioned by Pilots as Contributing to Decision Difficulty.

The most commonly mentioned category dealt with safety, in particular, with goal conflicts that pitted safety against achieving passenger satisfaction (e.g., getting them to their destination on time) or other goals. Another frequently mentioned problem was having no good options (e.g., your destination airport just closed due to a disabled aircraft on the runway and your alternate is fogged in).

The second category refers to metacognitive processes. It includes difficulty arising from uncertainty, ambiguity, workload or time pressure inherent in many decision situations. Captains, who are ultimately responsible for making decisions, were far more sensitive to these factors than were first officers. In contrast, first officers most frequently expressed concerns relating to professional and social factors (49% of their responses), such as career choices, personal health and well being.

4. PILOTS' RISK MANAGEMENT IN DYNAMIC FLIGHT SITUATIONS

In the risk perception survey, pilots indicated that their greatest concern was with safety-related risks (physical threats). In addition, they reported that (a) decisions are difficult in situations that involve conflicts between safety and other goals, e.g., productivity or customer satisfaction, and (b) ambiguity, uncertainty and time pressure also contribute to decision difficulty

The factors mentioned above may influence pilots' decision making in several ways. Interpreting ambiguous cues and resolving goal conflicts are cognitively taxing, especially when decisions must be made in the face of dynamically changing time-pressured conditions. These conditions may thus set

the stage for errors and poor risk management. In order to accommodate competing goals, e.g., economic as well as safety goals, pilots may underestimate the seriousness of safety threats. Perceived economic pressures in conjunction with pilots' professional self-image of competence may induce pilots to think that they ought to – and thus, that they *can* – handle all safety threats posed by the environment.

Thus, a second study examined how pilots' decision-making processes reflected their perceptions of risks associated with ambiguous problems, uncertain outcomes, and competing goals. Specifically, the following issues were addressed.
- Which goals primarily influenced pilots' risk management?
- How do they deal with situations that pit safety risks against economic, productivity, and social considerations? Do they avoid negative consequences associated with one goal while neglecting other goals? Or do they find a compromise that enables them to maximize gains and minimize losses across different goals?
- Do pilots who choose different risk management strategies differ in their risk assessment?
- How consistent are pilots in their risk management strategies, i.e., are they consistently risk-avoiding or risk-taking with respect to safety risks?

Two hypothetical decision scenarios were created to address these issues. Both scenarios involved decision dilemmas aggravated by ambiguous conditions and uncertain outcomes. In both scenarios, continuing with the original plan posed a threat to flight safety. . However, if the plan were successful, it would also bring economic gains. On the other hand, changes to the original plan would increase the margin of safety, but would also incur economic or other losses.

One scenario presented study participants with a decision dilemma at take-off: to continue with take-off although there was a possibility of windshear, or to go back to the end of the take-off line and delay departure even more (the flight had already been delayed for four hours due to weather at the destination). The second scenario evolved during approach: it is Christmas Eve, bad weather is delaying the approach, and an airport curfew is looming. Pilots had to decide on a course of action: to continue with the approach or to divert. Risks in this situation include productivity (getting passengers where they want to go at an important time), safety (possibly running out of fuel), and economic (hotels/meals for passengers at the divert location and then transporting them to their original destination).

Both scenarios presented participants with an unfolding sequence of events reflecting progress over time. At each point in time, pilots could ask for more information than was presented in the event description, such as the current radar image, or company input. Participants were asked to think aloud about their concerns and reasoning while they decided on how to proceed at each point in the evolving event.

4.1 How Risky Were Pilots' Decisions?

In the "Take Off Scenario" most of the pilots (64%) indicated that they would take off although there was a chance of windshear, thus choosing the riskier option in terms of safety. In contrast, most pilots in the "Approach Scenario" (66%) favored the safer course of action and chose to divert to their alternate. However across both scenarios, 90 % of those who selected the riskier course of action (i.e., continuing with the original plan) did so with specific contingencies. They did not blindly continue with their current plan; but instead invented solutions that allowed them to minimize the safety risk while achieving their productivity goals. In the "Take-Off Scenario" pilots indicated that they would take certain precautionary steps against the windshear such as full power take-off and delayed rotation. In the "Approach Scenario" they asked for priority handling or changed their alternate to an airport that was closer than their designated alternate to avoid becoming fuel critical.

4.2 How Consistent Were Pilots' Decisions?

Interestingly, pilots were not consistent in their choices (risk avoiding versus risk taking) across the two scenarios. Only 41 % of the pilots were consistent in choosing either risk-averse or risk-tolerant actions. This finding suggests that personality factors contributed little to pilots' decision-making strategies. Similarly, level of experience had no apparent effect on pilots' decision making, as captains and first officers did not differ in their decisions or strategies in either scenario.

4.3 Which Goals Influenced Pilots' Decisions?

To answer this question, pilots' think-aloud protocols were analyzed to determine what concerns and goals were most often expressed. These were analyzed to see whether pilots who chose risk-avoiding options expressed concern with different issues and goals than pilots who chose riskier options. For the "Approach Scenario" five topics were discerned, as shown in Figure 4: weather at destination, fuel status,
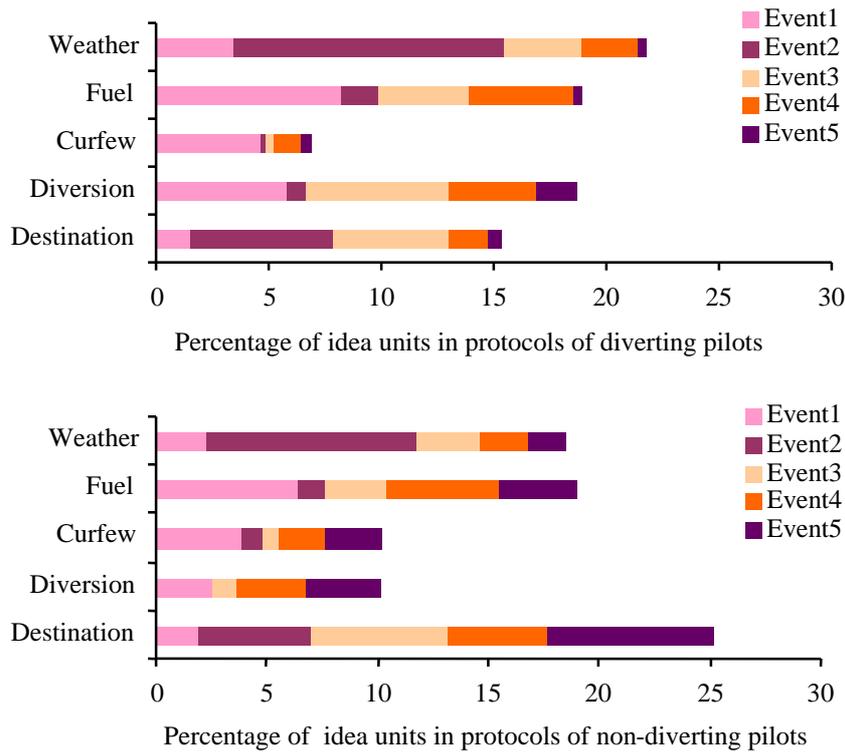
Fig. 4: Distribution of topics in pilots' think-aloud protocols: "Approach Scenario"

airport curfew, diversion to alternate airport, and landing at their original destination. Analyses of their think-aloud protocols indicated that pilots who ultimately decided to divert raised this issue early on. Sixty-eight percent of them considered the possibility of a diversion already at the first event in the scenario. In contrast, only 30 percent of the pilots who decided to continue with the approach considered or checked on the alternate at that time. Moreover, pilots who chose to divert talked significantly less about landing at their original destination and its airport curfew than did pilots who decided to continue the approach.

The "Take-Off Scenario" also involved several issues. In addition to safety concerns (storm cells, airspeed loss, windshear), there were also external pressures (four hours delay, 20 aircraft in line waiting for take-off). However, unlike the curfew in the "Approach Scenario," these external pressures played no visible role in pilots' decision making. Pilots hardly mentioned any of the external pressures; only 4.2 percent of their talk referred to them. The important considerations for all pilots, regardless of their final decision, were safety-related, i.e., the fact that bad weather was approaching and that windshear was possible. Pilots who decided to delay departure devoted 54 percent of their talk to these issues and pilots who decided to take off made reference to the weather in 60 percent of their talk.

4.4. Risk Assessment And Risk Management Strategies

To address this issue, we analyzed how pilots talked about the relevant topics in a scenario. Pilots' think-aloud protocols were coded both in terms of what they talked about and also in terms of how they processed the information. Codes include whether they requested additional information about a particular topic (e.g., weather), reviewed or monitored its status, evaluated it positively or negatively, identified it as a goal or condition, made plans for it, or initiated an action or decision about it.

In both scenarios pilots who took the riskier option had more positive things to say about conditions than pilots who were risk-avoiding (12.5% versus 6% of total talk were positive evaluations). In the "Approach Scenario" pilots who decided to continue with the approach expressed more optimism about the conditions, likelihood of landing at their original destination and making the curfew than were pilots who decided to divert. In the "Take-off Scenario" those who decided to take-off evaluated the weather and airspeed loss more positively than those who delayed the departure. "Risk-takers" in this scenario emphasized the fact that the weather was behind them, still 8 miles away, and that their departure path was clear. In addition, they focused on the quantity

of airspeed loss, which they considered to be within limits, and interpreted the decrease in reported airspeed as an indication that weather conditions were improving. In contrast, pilots who delayed the take-off were primarily concerned about the airspeed loss per se and took the variability in reported loss to indicate unstable winds. In line with this interpretation, they stressed the fact that the weather was getting closer. Since they assumed that they could not outrun the storm and that the winds were getting unpredictable, they decided not to risk a take off but instead to wait for the weather to pass.

These findings indicate that concerns for flight safety featured prominently in pilots' decision making while organizational pressures were not explicitly addressed. All pilots were aware of the safety risks in both scenarios and all pilots chose a course of action that they thought would eliminate that risk or at least reduce it to an acceptable level. Across the two scenarios three risk management strategies were discerned: avoid the safety risk altogether (e.g., divert to alternate), mitigate the safety risk (e.g., request priority handling), or plan for the worst-case (e.g., implement windshear procedures). While the first strategy takes account only of the safety risk, the latter two strategies satisfy economic and productivity concerns as well. Which risk management strategy pilots ultimately chose reflected differences in their assessment of the safety risk rather than personality characteristics. If they considered the threat to flight safety to be serious, they took a cautious approach and changed their planned course of action. On the other hand, if they painted a less negative picture and felt they could mitigate or control the risk by taking certain precautions, they modified their plans accordingly. Clearly, their normative model is to "go" (or continue) unless something occurs that surpasses a subjective threshold of safety. This kind of thinking is most vividly illustrated in statements such as "Nothing has come up that would make me decide not to make the departure."

Differences between pilots in their choices of more or less risk tolerant decisions clearly reflects the ambiguity inherent in the problem cues and uncertainties concerning solution outcomes. The fact that no single choice dominated in either scenario indicates that in fact there was no single "correct" interpretation of the situation and no "best" option choice. Pilots in the "Approach Scenario" who continued with the approach talked more about the curfew than did pilots who diverted, suggesting a greater concern with uncertainty about landing before curfew. Diverting pilots, on the other hand, talked more than the others about conditions at the alternate airport. No such distinguishing pattern was observed in the "Take-Off Scenario." In this scenario, eternal pressures such as the schedule delay

or long line of planes behind them were hardly mentioned by the pilots, no matter what their final decision. Instead, pilots based their different decisions on different interpretations of the same cues (weather/windshear diminishing or increasing). In sum, protocol data indicate distinct differences in pilots' concerns, but offer no clues as to their sources.

5. DISCUSSION

Safety clearly dominated pilots' thinking. As indicated in their think-aloud protocols, pilots were primarily concerned with reducing threats to flight safety; economic or productivity considerations were of secondary importance. A similar picture emerged in the survey study. Pilots mentioned safety-related issues most frequently, while acknowledging that they had to deal more frequently with other types of risk in their professional lives.

The most commonly encountered types of risk were productivity, economic and professional. Productivity risk deals with flight delays, an everyday issue for pilots. Companies, along with the flying public, put pressure on airline employees, not just pilots, but also gate agents, mechanics, and dispatchers, to take off and arrive on time. Likewise, economic issues play a role in each flight, stemming from questions of how much fuel to load and rates of fuel burn. Deviating around storms or increasing speed to make up for ATC delays involves economic consequences. Similarly, professional risks are present everyday, when actions are considered that may skirt legal requirements or when pilots' interpretation of a regulation may be second-guessed after the fact.

Situations that involve a conflict between different types of risk, especially those that pit safety against economic considerations, are difficult for pilots to resolve. How they resolve these kinds of decision dilemmas was found to depend on their perception of the safety risk. If they judged the safety threat to be "close to or beyond their comfort zone," they adopted a plan that would assure safety but might incur economic or productivity losses. On the other hand, if they judged the safety risk to be less serious, they modified their current plan to mitigate threats to flight safety while satisfying their company's economic and productivity goals. These findings attest to the inherent subjectivity of risk assessment, especially in situations that are characterized by ambiguous and dynamically changing conditions.

Pilots, especially captains, appear to be quite sensitive to limitations on their own decision making and risk management skills. An unexpected finding of our survey was that captains appreciated their own vulnerability to stressors and their potential

contribution to safety risks. In describing examples of physical risk, they commonly expressed concern about their own ability to manage risks and to make good decisions. First officers were not so sensitive to this factor, but were more concerned with fatigue or medical factors that might affect safety.

6. CURRENT AND FUTURE SOLUTIONS TO SUPPORT RISK ASSESSMENT AND MANAGEMENT

Solutions to managing flight risks that have been proposed to date focus primarily on system aiding and on training. System aids support risk assessment by providing "objective" information about threats, such as color coding of information on weather radar displays and potential traffic conflicts (Traffic Collision Avoidance System, or TCAS). More recently, the ITWIS (Intelligent Terminal Weather Information System) system has been developed to provide controllers (and eventually pilots) with current and forecast weather in the terminal area, to support decisions about final approaches (Rhoda and Pawlak, 1999). The Federal Aviation Administration's (FAA) Capstone project provides color-coded terrain information that is linked to the aircraft's location using GPS and ADS-B technologies (FAA, 2001). These kinds of aids, especially those that provide trend information, should be helpful to pilots, while reducing their cognitive load during high workload situations.

The second approach is training. Air carriers have invested considerable resources in developing training activities directed at very specific threats, such as windshear. Windshear escape training has been credited with reducing windshear accidents, which occurred frequently in the 1980s. More recently, carriers have developed courses to assist their pilots in coping with the kinds of uncertain situations associated with plan continuation errors. Continental Airlines has a course on Threat and Error Management (Gunther, 2001) and United Airlines has a course on Risk Assessment (Barcheski, 2001). These training programs typically are based on the trainers' expertise and good intuitions, rather than on empirical findings, due to the absence of good theory and relevant data. While the emerging programs are grounded in documentation of actual threat encounters (Helmreich, et al., 2001; Tesmer, 2000), they do not consider factors that influence how pilots perceive and manage these threats.

The third factor that must be considered is the organization: how its norms, values, goals and reward system influence pilots' decision-making. All airlines are under enormous financial pressures in our current economic climate, which translates into efforts to save fuel and to satisfy customers so they will develop loyalty. Pilots are aware of those pressures; they are responsible members of their community and want to support their employers. Companies do not tell their pilots to cut safety corners, but pilots may share the goals of the company and on occasion try to reduce fuel costs or to take off on time even if they are not completely satisfied with the condition of their aircraft. Moreover, pilots have their own professional images: they are confident in their skills and abilities to handle difficult decisions, as we would hope they would be. Despite their concern over making a poor decision that may lead them into harm's way, they have a "can do" attitude that serves them well – until a difficult decision arises that involves ambiguous cues, unfamiliar situations, goal conflicts, and uncertain outcomes. These conditions challenge even the most skilled pilot, and companies must train their pilots both to understand their own vulnerabilities in these situations and to recognize factors that may lead them into error. Companies also realize that pilots may face difficult goal conflicts and that their implicit messages can significantly influence pilots' behavior in critical situations. Which pilot behaviors does the company reward and which are sanctioned? That is one of the clearest messages to pilots

Our continued research will address the issues raised in this paper and will develop strategies concerning how best to support pilot performance in what we now know are challenging and threatening high-risk situations.

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