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Cognitive Task Analysis of Business Jet Pilots' Weather Flying Behaviors: Preliminary Results

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July 2001

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Abstract

This report presents preliminary findings from a cognitive task analysis (CTA) of business aviation piloting. Results describe challenging weather-related aviation decisions and the information and cues used to support these decisions. Further, these results demonstrate the role of expertise in business aviation decision-making in weather flying, and how weather information is acquired and assessed for reliability. The challenging weather scenarios and novice errors identified in the results provide the basis for experimental scenarios and dependent measures to be used in future flight simulation evaluations of candidate aviation weather information systems. Finally, we analyzed these preliminary results to recommend design and training interventions to improve business aviation decision-making with weather information. The primary objective of this report is to present these preliminary findings and to document the extended CTA methodology used to elicit and represent expert business aviator decision-making with weather information. These preliminary findings will be augmented with results from additional subjects using this methodology. A summary of the complete results, absent the detailed treatment of methodology provided in this report, will be documented in a separate publication.

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1.0 Introduction

On February 12 of 1997, President Clinton called for a five-fold reduction in the rate of fatal aviation accidents within a decade, and directed NASA to support this national safety goal. Recognizing that weather contributes to approximately thirty percent of aviation accidents, Aeronautics Safety Investment Strategy Team (ASIST) workshops suggested that a NASA program should focus on improving the quality of National Airspace System (NAS) users' weather information (NASA 1997). NASA created the Aviation Safety program to accomplish this presidential aviation safety initiative. This program includes the Weather Accident Prevention project, which addresses a variety of the weather-related safety initiatives suggested by ASIST workshops. The objective of the constituent Aviation Weather Information (AWIN) element is, specifically, to improve pilots' weather situation awareness and the quality of weather-related flight decisions. This research project supports AWIN's objective by investigating decision-making of business aviators in weather flying.

1.1 Weather Flying

It is not surprising that weather is a major contributor to aviation accidents. Weather represents perhaps the most dynamic and least predictable aspect of the NAS environment. The dynamics of weather phenomena are multi-dimensional. Its characteristics vary in three-dimensional space, over time, and in intensity. Pilots' views on weather phenomena are limited by the weather information products that are available on the ground, and dramatically limited by the far fewer available once airborne. A pilot's weather situation awareness is further constrained by the limited usability of available information (*e.g.*, coded METAR text). The reliability of forecasted weather information is diminished by the unpredictability of the phenomena. Both forecasted and immediate weather information are only as reliable as the sensors that obtain and, in some cases, algorithms that interpret raw atmospheric data. Thus, even perfect information, perfectly perceived does not guarantee safe flight in difficult weather conditions. Finally, as aviation accidents and incidents result from a confluence of events, even perfect weather information that is understood perfectly must be considered in light of its implications for a particular flight. Weather information is only one aspect of the multifaceted decisions pilots must make. Pilots must integrate their understanding of weather conditions with understanding of the terrain, aircraft performance characteristics, airport facilities, their own skills and capabilities, airspace constraints, *etc.* to arrive at safe decisions *in situ*. Underlying these concerns is the normal multitasking nature of aviating, and the commensurate undulation of pilot workload. Pilots' susceptibility to both overload and complacency therefore further exacerbates problems of weather information interpretation, and aviation decision-making with weather information. This investigation focuses on the weather flying knowledge, skills and decisions of business jet pilots to better understand how to improve, and improve the use of, aviation weather information.

1.2 Business Aviation Operations

Business aviation has an excellent safety record. Since the mid-1980's, accident rates among corporate/executive operators have been lower than those of other operators in FAR part 135 operations and of any segment in general aviation, and comparable to FAR part 121 operators (NBAA 2000a). Despite this exemplary safety record, AWIN, as well as other NASA Langley efforts (Schutte & Willshire 1996), have recognized that business aviation offers several advantages for developing and implementing advanced flight deck concepts. The variety of business jet operational contexts serves as a broad basis from which to extend technologies to both general aviation and transport aviation. This breadth of operational contexts presents many of the most challenging conditions for flying.

There are also implementation advantages. Business aviation owners and operators are more likely to, and quicker to, adopt new technologies than those of other general aviation or commercial transport aircraft (Kauffmann & Pothanun 2000). The design cycle of business aviation jet aircraft is much shorter than that of commercial transport jets (Perry 1999). Business jets are redesigned more often than are other general aviation airplanes because their users demand new technology. These design cycle considerations allow more frequent opportunities for, and less resistance to, introducing new technologies. Finally, the market for business aircraft is increasing dramatically. In a poll of U.S. turbine-powered aircraft operators, use of business aircraft increased 44% in the past 12 months, and 32% of firms using business aircraft expected employees to make increasing use of these aircraft (NBAA 2000b). Business aircraft manufacturers anticipate this trend to continue (Phillips 2000). This study focuses on business aviation for reasons of operational variety, and market penetration. The following sections summarize characteristics of business aviation operations according to features originally described in Rogers *et al.* (1998).

Mission Characteristics

Typically, business jet pilots do not fly for compensation directly, but as an employee in the service of, or as contracted by, a professional organization. Because the goal of business jet operations is to serve business needs, trips are scheduled with relatively short notice. Most trips are scheduled with about two weeks notice, but more urgent trips also occasionally occur. Trip destinations are also dictated by the needs of business. As a consequence, and as allowed by aircraft characteristics, business jet pilots fly into a wider variety of airports and airfields than do either smaller general aviation or commercial transport pilots. Frequently, business aviation missions use smaller airfields to minimize costs and distance to business destinations. These smaller airfields are less likely to provide complete weather information available at larger airports. Perhaps as a result of mission differences, business aviators tend to discount preflight weather information relative to weather information and observations available in flight (Lapis 1998). Business jet pilots not only fly to a variety of destinations, as dictated by their passengers, they also may need to make in-flight deviations to serve the needs and desires of their passengers.

Aircraft Characteristics

The National Business Aviation Association (NBAA) compiles a description of the aircraft fleet used by business aviation pilots. Table 2 presents the percent of the NBAA fleet for each type of aircraft (NBAA 2000c).

Table 1. Aircraft types in the NBAA fleet.

Aircraft Type	Percent of NBAA Fleet
Light Jets (< 29,999lbs)	35%
Piston-powered (reciprocating)	20%
Heavy Jets (> 30,000lbs)	16%
Light Turbo-props (<12,500lbs)	11%
Heavy Turbo-props(>12,499lbs)	10%
Helicopters (most) (< 12,500lbs)	7%

In addition to the basic weather information services available to all aviators, business jet aircraft usually have on-board weather radar systems, and may have ACARS-like capability to uplink textual weather information and ground services to provide additional weather information (Lapis 1998). Business aviation aircraft are equipped to serve the business needs of passengers, and typically include: computer docking stations, fax machines, air phones, and other office technology.

Organizational Characteristics

The organizations that business aviators serve vary widely, and include commercial/industrial, government, academic, and not-for-profit agencies. Essentially, the worth of business aviation is established by the opportunity cost of not being able to make a trip when and where it is advantageous for that organization, and the opportunity cost of personnel work time absorbed by less efficient travel. Business airplanes that serve these needs can also vary in the infrastructure supporting operations (Rogers *et al.* 1998). Small companies, or those that share aircraft, typically fly smaller aircraft and use Fixed-Base Operators (FBOs) to conduct maintenance. Larger corporations, celebrity pilots, and fractional ownership businesses tend to use larger aircraft, and typically have full maintenance, flight operations, and ground support infrastructure. Large, global companies with multiple aircraft type fleets, international flights, and heavy aircraft most resemble commercial carrier airlines, and have similar standards for dedicated training, maintenance, and operational control departments.

Pilot Characteristics and Roles

Business pilot experience generally increases with the size of the business' aviation operations and duration of missions (Rogers *et al.* 1998). A small survey of business aviation owner/operators, found that approximately half have college degrees, and most are type rated in more than one aircraft (Rogers *et al.* 1998). Training is usually governed by internal operating procedures, unless operating under FAR Part 135. Business aviators typically are very familiar with the particular airplane they fly. This contrasts with commercial transport pilots, or rental general aviation pilots who may fly different instances of the same airplane, or even different airplanes. However turnover rate is high among business jet pilots, as they graduate to larger aviation operations. While most business aircraft are certified for single pilot operations, they are typically flown with pilot and co-pilot. Due to high turnover and use of "rental co-pilots," it is not unusual for crewmembers to be unfamiliar with each other’s skills, predilections, or experiences; as well as unfamiliar with the business' operating and crew resource management procedures.

Business aviation pilots must do more than simply pilot the aircraft to the destination. Business aviation pilots are particularly conscious of comfort of their passengers, their ability to conduct business during a trip, and their ability to make meeting times. Business flights must be timely, cost-efficient, comfortable, and enjoyable. Depending on the size of operations, and extent of auxiliary service departments, a business aviator’s job can include many other tasks, such as: planning point-to-point transportation and accommodations, overseeing cabin cleaning and catering, maintenance, ensuring appropriate facilities at destinations for servicing and de-icing, fuel determinations, cost/benefit analysis of fleet augmentation, assessing and developing training materials and procedures, and performing passenger briefings and in-flight "sight-seeing" tours (Rogers *et al. 19*98).

Weather Flying and Business Aviation

In summary, business aviation operations are a useful platform to consider the effect of weather information on piloting for many reasons.

- Missions can arise on fairly short notice, minimizing the opportunity to carefully watch weather trends.
- Mission destinations vary significantly, reducing the familiarity of pilots with local weather phenomena.
- Mission destinations can be to small airfields that provide little weather advisory information.
- Mission destinations and flight plans can change dynamically due to passengers' requirements.

- Passenger comfort and timeliness are extremely important to business aviation.
- Smaller business aviation aircraft have performance limitations in adverse weather conditions.

1.3 Cognitive Task Analysis

To affect aviation safety by improving the use of weather information, one must: 1) provide the appropriate information to support aviation weather decision-making; 2) present this information in an intuitive manner; and 3) aid pilots, especially inexperienced pilots, in gathering information, interpreting conditions and selecting appropriate responses. Prior efforts have typically approached this problem by asking NAS users to comment on existing, and desired weather information products and services. While user suggestions are extremely valuable, and user acceptance is of paramount import, user preferences are typically anchored by current conditions and may be inconsistent with performance improvements (*e.g.*, Antin 1988). Thus, it is imperative that, in addition to valuable user preferences, we more objectively ascertain how weather information is used for safe and effective operations in the NAS. In addition to ongoing traditional task analyses to objectively identify information requirements, this research used a cognitive task analysis (CTA) to better understand the most challenging decisions associated with, and the indicators of expertise in, weather flying for business jet pilots.

Cognitive task analysis differs from traditional task analysis by focusing on operators' cognitive processing and knowledge base, or experience. CTAs are typically used when tasks are complex, or ill structured; and when these tasks occur in dynamic, uncertain, multi-tasking, real-time operational domains (Gordon and Gill 1997). To conduct a CTA, one uses knowledge acquisition tools to elicit and represent general and specific knowledge. Typically researchers use these methods with highly knowledgeable and experienced operators that are considered subject matter experts (SMEs). The knowledge elicitation phase of CTA uses a set of interview techniques to explore these experts' decision-making processes. The knowledge representation phase of CTA guides documentation and codification of data into formats that support systems design and training recommendations. Many of the CTA methods used in this study were adapted from Klein Associates' ACTA (Applied Cognitive Task Analysis) toolkit. In addition, this study employed the Critical Decision methodology. These tools and techniques are described below as they are generically used. The methods section of this report elaborates on how these tools and techniques were adapted for this study.

Applied Cognitive Task Analysis (ACTA) Methods

ACTA (Militello & Hutton 1998; Militello, Hutton, Pliske, Knight & Klein 1997) is a streamlined CTA method that was developed to be less resource intensive than traditional methods. Traditional CTA methods are extremely time-intensive, are therefore typically used with only a few participants, and are best used by experienced interviewers. Although ACTA was developed for less-experienced practitioners, experienced researchers also use ACTA to obtain a broad understanding of a domain. ACTA consists of three interview methods to conduct information elicitation about the cognitive demands and skills required for a task. The generic ACTA procedures are briefly described below. Details of the ACTA tools are provided in Appendix A.

The three ACTA interview tools are: the Task Diagram, the Knowledge Audit, and the Simulation Interview. The Task Diagram elicits a model of how a SME parses the way they perform a job. The Task Diagram results in a set of component tasks for a job, indicates where cognitive skills (interpretation, judgements, assessments, problem-solving) predominate, and identifies particularly difficult decision points. The Task Diagram structures the remainder of the CTA. The Knowledge Audit focuses on the role of expertise in the challenging decisions identified by the Task Diagram. For each of these tasks or decisions, the interviewer asks SMEs to identify how they recognize that they need to make this difficult decision, the strategies they employ, and to explain why this is a difficult situation. The Simulation Interview provides a view of SME problem solving in the context of actual operation. Context certainly guides behavior (Suchman 1987), and as such it is important to provide this context when eliciting SME problem-solving processes. Simulation scenarios should be challenging situations that require SMEs to exercise their expertise. These scenarios can be provided as text-based descriptions, video depictions, or as a scenario in a full-mission operational simulator facility. ACTA developers suggest that high-fidelity simulations are not required to obtain useful information. During the Simulation Interview SMEs are asked to interpret a situation, explain the cues and strategies they would employ as well as actions they would take. Finally SMEs are asked to consider what errors a less experienced and skilled operator might make in the simulated situation.

CTA also requires a format for representing elicited information in order to facilitate using this information in design and training. ACTA provides the Cognitive Demand Table as an initial representation framework. The Cognitive Demand Table describes why each of the cognitive demands is difficult, as well as the cues and strategies used, and errors that may occur in performing it. Other representation formats can be developed to support thematic analyses, for example to focus on the role of expertise.

Critical Decision Method

Klein Associates developed the Critical Decision method based on Flanagan's (1954) critical incident technique (Hoffman, Crandall & Shadbolt 1998). The Critical Decision Method uses a specific open-ended question to elicit an incident account from a SME. The nature and content of the opening query is determined by the research goals of the particular study, but is always asked in terms of an event that the SME has personally experienced. For example, in a study of Neonatal Intensive Care Unit nurses' clinical judgments, each nurse was asked to select an incident in which her patient assessment skills had made a difference to the patient's outcome (Crandall & Getchell-Reiter 1993). In several studies of fire ground command decision-making, participants were asked to recall an incident in which their expertise as a fire ground commander was particularly challenged (Klein, Calderwood, & Clinton-Cirocco 1988; Calderwood, Crandall, & Klein 1987).

Once a SME identifies a relevant incident, he recounts the episode in its entirety, without interruption. The SME's account, solicited in this non-interfering way, focuses and structures the following interview. Requesting personal accounts of a specific type of event maximizes response validity, and minimizes potential interviewer biases. Once the incident report has been completed, the interviewer revisits the incident with the SME several times, using probes designed to focus attention on particular aspects of the incident and solicit information about them. Probes elicit details about the recalled event and deepen the discussion to provide particular emphasis on perceptual cues (*e.g.*, what was actually seen, heard, considered, remembered) and strategies employed, rather than general value assessments, explanations or rationalizations about performance. Solicited information depends on the purpose of the study, but might include presence or absence of salient cues and the nature of those cues, assessment of the situation and the basis of that assessment, expectations about how the situation might evolve, goals considered, and options evaluated and those chosen.

2.0 Methods

This section characterizes participants in this investigation, provides the CTA protocol adapted from the ACTA and Critical Decision methods and explains the approaches used to analyze the resulting interview data.

2.1 Participants

Business jet pilots were recruited by advertisement in business aviation magazines and by direct contact to local businesses. Applicants were screened using the preliminary questionnaire (Appendix B) to find participants who had approximately five years of experience as corporate business jet pilots, and who had a minimum of 500 hours flying business jet aircraft. After this initial selection, preference was given to pilots who fly a wide range of missions, fly at least four or more times each month, and fly to some destinations that require three or more hours of flight time.

Eight male, business jet pilots were selected as participants (Table 2). Pilots' ages range from 33-61 years. All pilots are highly experienced and have flown business jets for more than a decade, accumulating well over six thousand flying hours in various light, medium, and heavy aircraft. Participants flew aircraft which included a variety of Cessna Citation and Gulfstream (II, III, IV, V) jets, DeHavilland DHC-8, Rockwell Sabreliner 65; Raytheon Be-200; Learjet 35; Fairchild F27; Dassault Falcon, and others. The most predominant type of aircraft flown were light jets (cf. Table 1).

Table 2. Participant Information

Participant #	Age	Years Business Jet Flying	Total Hours	Hours as PIC*
1	33	10	6800	2500
2	61	20	14000	10000
3	37	15	6200	4500
4	55	29	11500	6800
5	51	25	14500	8600
6	50	7100*	9700	3100
7	51	22	14500	10000
8	40	14	11000	10500
Median	50.5	20	11250	7700
Mean	47.25	19.28	11025	7000

* This figure was given in hours and is not included in the summary statistic calculations.

The participants typically fly throughout the United States and North America, and only occasionally fly overseas to Europe, Asia, and the Middle East. Participants reported they always have a co-pilot and on infrequent, long international flights may carry an extra pilot, flight attendants, and a mechanic. Typical flight missions are one-day flights to and from a domestic meeting site. These flights may carry customers to corporate offices or may transport corporate executives to customer sites. In addition to passengers, business aviation flights occasionally carry small sales demonstration materials, and aircraft parts and equipment.

Each pilot was interviewed for approximately 3-4 hours and asked to fill out additional questionnaires following the interviews[1]. Participants were assured that the content of the interviews would be referenced anonymously. All pilots signed a voluntary consent form and were paid $200 plus *per diem* for their participation.

[1] The data from the post-interview questionnaires supports a different study.

2.2 Protocol

In Phase 1 interviews, CTA procedures, materials, and questionnaires were administered to the first three participants. The remaining five subjects participated in Phase 2 interviews, using the materials and procedures refined based on Phase 1 interview experience and feedback. Interviews were conducted in a conference room at the NASA Langley Research Center. Two researchers participated as interviewers for each SME interviewed. One researcher led the interview. The other researcher primarily recorded participant responses and monitored the first researchers' adherence to the experimental protocol. Interviews were audio taped for subsequent transcription and verification of notes.

Phase 1 Interviews

An initial set of semi-structured interviews was conducted with participants 1, 2, and 3, as SMEs. These interviews obtained additional background and mission information from pilots and used the Task Diagram, Knowledge Audit, and Critical Decision methods. Appendix C provides the initial interview guide. Typically, the Task Diagram method begins with asking participants to note the major tasks in the job of interest. For this investigation, these steps were assumed to be the generally accepted phases of flight. Participants were provided with a Task Diagram of flight phases (Figure 1), and asked to identify the most cognitively challenging tasks that weather information affects. Knowledge Audit probes further explored participants' expertise in handling these challenging tasks with challenging weather conditions. Participants were then asked to list and characterize the weather information sources they currently use by completing the Weather Products Survey (Appendix D). Finally participants were asked, according to the Critical Decision method, to recollect a specific weather-related situation in which weather had a role that demonstrated their expertise. They were provided the following specific probe:

> *"You can probably remember some flights in which you had to make difficult decisions due to the current weather conditions. We would like you to describe an incident in which your experience made a difference in how you handled the situation—a situation in which a less-experienced pilot might have made a different decision than you did."*

This incident was then further examined to identify their performance goals, decision points, cues and the weather information sources they used.

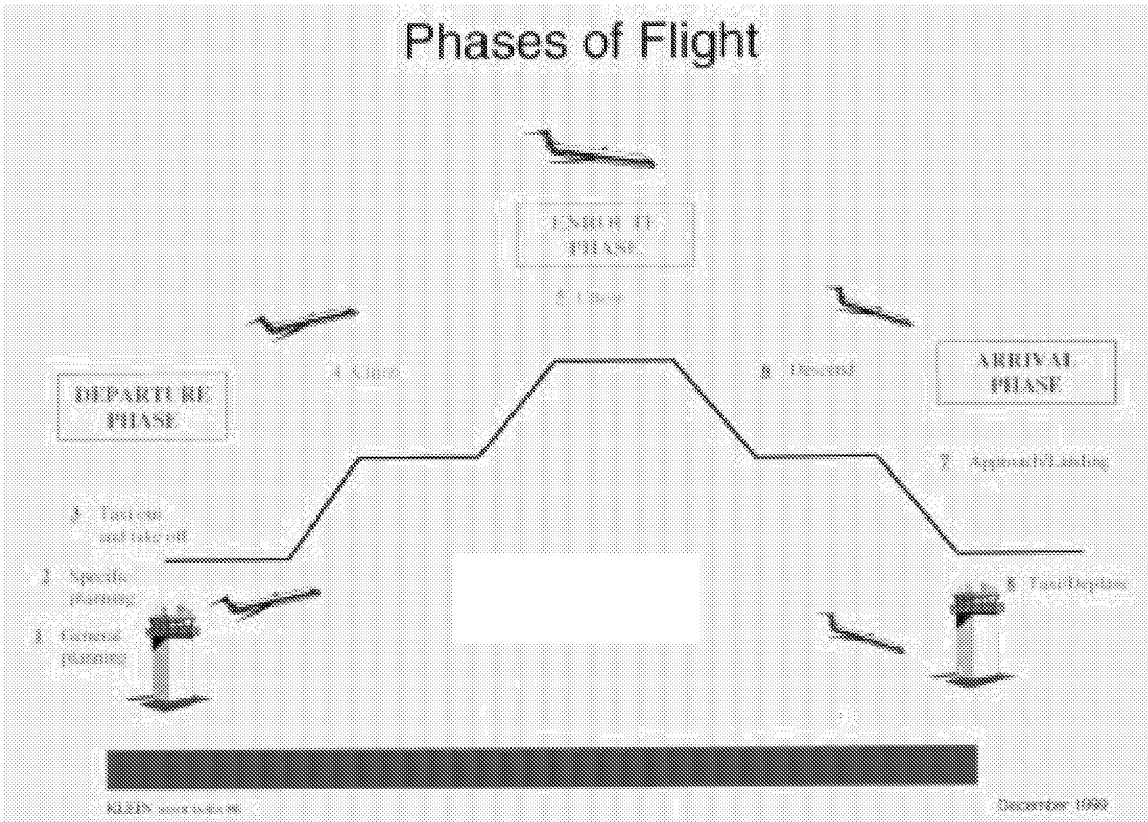


Figure 1. Task Diagram: Phases of Flight.

Phase 2 Interviews

The second set of interviews was conducted with participants 4, 5, 6, 7, and 8. Phase 1 interview data were used to revise the interview guide for the second set of interviews. Appendix E contains the Phase 2 Interview Guide. Rather than asking participants about their background and mission characteristics in the interview, the preliminary questionnaire was augmented to include these queries. The Task Diagram and Knowledge Audit methods were employed as previously described. In addition, pilots were provided with a low-fidelity "simulation" to support the Simulation Interview knowledge elicitation technique. This simulation was based on actual weather conditions along the Eastern U.S. coast on January 23, 2000. Table 3 lists the information provided to participants for this simulation. The constructed materials and captured weather products describing weather conditions are provided in Appendix F. A confederate researcher, in another conference room, acted as both Flight Service Station (FSS) and Flight Watch (FW) personnel. He was provided with scripted responses for anticipated questions as well as scenario weather information to answer unanticipated questions. Participants were told to use whatever information they had, and to ask for any additional information that they would consult during this mission. Not one participant requested information from FSS or FW. While this may have been an artifact of the environment, other research shows pilots frequently under-utilize these services in full mission simulation experiments as well (Yucknovicz *et al.* 2000).

Table 3. Simulation Interview Materials

Preflight	Enroute	Approach	Charts
Scenario Mission	PIREPS - ride reports	ATIS recordings	Approach Charts
Aircraft Description	Visual descriptions	PIREPS - terminal area	Airport Diagrams
Standard Briefing (DUATs encoded text)	FW scripts	METARS	IFR enroute low alt.
Weather Graphics:			IFR high altitude
Current Surface			Sectional charts
24 Hour Surface			
48 Hour Surface			
Current Flight Rules			
Doppler Radar			
Lifted Index			
Satellite Image			
Weather Hazards			

Essentially, the simulated mission required the pilot to fly passengers to a meeting during questionable weather conditions that included icing, limited visibility, and possible high wind conditions. After participants read the mission scenario and reviewed the other materials, they were queried for decision points. Experimenters further probed these decision points by asking participants to assess the situation at the decision point, explain critical cues they would seek, strategies they would use and actions they would take. Additionally, participants were asked to describe the difficulty of the decision point, and if difficult, how a novice pilot's behavior may differ from that of an expert.

In addition to the inclusion of a weather simulation, several other changes were made to the interview procedure based on the results of the first set of interviews. An additional Knowledge Audit question was developed to augment results from the Critical Decision method. This question asked participants to conjure a “Scenario from Hell;” that is, a situation that would be extremely challenging, and would benefit greatly from expertise and experience. To compensate for the addition of the Simulation Interview and "Scenario from Hell" queries, the Weather Products Summary questions were included in the Post-Interview Questionnaire (Appendix G).

2.3 Methods of Analysis and Representation

Data analyses were based on notes of all interview sessions. While the procedures for Phase 1 and Phase 2 interviews differed, the authors determined that the effects of these differences were far outweighed by the relevance of the resulting data. Information from the interviews was extracted as follows. The scribe researcher prepared a detailed summary of the interview content. The interviewing researcher reviewed the summary and noted revisions as needed. Audiotapes were consulted and transcribed when researchers were unclear about interview notes, or when researchers did not recall the interview content consistently. Interview notes and transcripts were then systematically reviewed to develop knowledge representations to support analyses.

Several different data representations were developed. The Cognitive Demands table, as defined by the ACTA toolkit, served as the primary knowledge representation, and an adaptation of this table was used to represent Simulation Interview results separately. In addition, we developed a model of weather information sources and reliability assessment, annotated incidents, and also conducted additional thematic analyses from the raw interview data. The methods for developing these representations are described below.

Cognitive Demand Tables

Recall that Cognitive Demand tables (CDTs) tabulate the most demanding cognitive aspects of a task, and for each of these "demands," identify why it is difficult, the cues and factors that are assessed, strategies and actions that would be taken, and what errors novices might make in these situations. We generated a CDT for each participant. The CDTs were based on all data obtained across the various knowledge elicitation methods. That is, they integrate data from standardized methods (*e.g.*, the Simulation Interview) with recollections of personal experiences (the Critical Decision method). Individual CDTs represent the cognitive demands identified by each SME according to phase of flight. Sometimes a similar cognitive demand was reported in different phases of flight, but different cues or weather information were used to make the assessment of the situation, or the same cues may have had a different meaning in the different phases of flight. In these cases, the same cognitive demand is listed under all relevant flight phases. Appendix H contains these individual CDTs.

Combining similar cognitive demands across individual CDTs generates two summary CDTs (Appendix I). The first table identifies indicated information requirements identified by SMEs for these decisions, and summarizes the sources used to obtain weather information and the primary performance goals for each decision. The second summary table also lists cognitive demands by phases of flight, but focuses on strategies the SMEs employ and errors they suggest novices may make. Together, these tables summarize information requirements for flight planning and in-flight decisions and highlight where current information sources are inadequate in helping pilots make these decisions. Additionally, they suggest challenging weather scenario elements and behavioral markers for erroneous/novice performance in these circumstances.

Simulation Interview Tables

Simulation Interview data was explicitly represented in a separate table, as well as being incorporated in the individual and summary CDTs. Rather than generalized cognitive demands, the Simulation Interview tables (Appendix J) presents Phase 2 SME responses to key decision points in a scripted, simulated weather-flying scenario.

Information Sources & Reliability Assessment

A diagrammatic model of information sources perceived as available to the business jet pilot, and a framework for how these pilots assessed information reliability was developed by reviewing individual CDTs and responses to the "Your Use of Weather Products" survey. This representation depicts the information sources as expressed by the subjects and is not a comprehensive model of all weather information that pilots may access.

Critical Incidents

Most participants described one or more specific "critical" situations in which their skills as an experienced pilot were challenged by weather-related factors. These incidents were intentionally elicited using the "Scenario from Hell" inquiry and the Critical Decision method probe. Each incident was analyzed to identify the critical decisions contained in the incident and the relevant cues and factors. An example of an annotated incident is shown in Table 4. The complete set of annotated Critical Decision probed incidents is included in Appendix K. Appendix L describes the "Scenarios from Hell" responses from Phase 2 interviews. These analyzed incidents provide actual scenarios that may be recreated in full-mission simulation evaluations of aviation information weather systems.

Table 4. An Example of an Annotated Incident

Narrative of Incident	Analysis
SME 4 had to miss an approach into a small, unsupported airfield near Traverse City, MI. He could not see the airfield even though the ASOS (Automated Surface Observation System) was telling him that the airfield was above minimums. SME 4 knew that the temperature and dew-point spread was close, and that the wind was in the "wrong direction." But the automated weather observation equipment was telling him that the airfield was within the limits. He said he "smelled a rat." He made the approach, but the visibility was only 2 ½ miles and the ceiling was under 700 feet. He could not see the runway, so he made a missed approach. He did not really know how the automated observation equipment worked, but he sensed that it might be wrong based on his assessment of the conditions, and his intuition proved him correct. He ended up flying to a close alternate airfield.	Cognitive demand: Can I accept low ceiling and limited visibility at destination? Information sources: ASOS at destination; pilot's observation of conditions at destination; pilots' experience with similar weather situations Cues: temperature/dewpoint spread; wind direction Actions: attempt approach; observe ceiling and visibility Cue: couldn't see runway Action: abort approach; fly to alternate destination

3.0 Results

These results are presented as general observations of expert business jet pilot responses to weather flying, and more specifically the cognitive demands and indicators of expertise of these pilots in difficult weather flying scenarios. Results were compiled to provide a representation of how these subjects perceive the weather information sources available to them, as well as how they assess weather information reliability. The results of this study are further interpreted for pragmatic purposes. They identify scenario characteristics and behavioral markers to support full mission simulation studies to evaluate AWIN systems. They also indicate both design and training interventions to improve business jet pilot decision-making for weather flying.

3.1 General Observations

Based on the entire corpus of data, we observed these general findings:

- Twenty-two weather-related critical decisions were identified for the business jet pilot community. Weather conditions impact decisions at all phases of flight and levels of decision-making, from general planning to tactical runway selection in changing winds.

- Three high-level pilot goals were identified: Flight Safety, Flight Efficiency, and Passenger Satisfaction. The pilots we interviewed emphasized that flight safety is *never* compromised to improve efficiency or passenger satisfaction. However, these pilots note that these goals are all influenced by weather and can potentially conflict, potentially requiring in-flight re-planning and communication with passengers.

- Individual differences were observed across the different pilots we interviewed. They varied in the amount of effort and time they expended to understand the weather picture in the Simulation Interview, and in their weather information acquisition and en route decision-making. There were also differences in the degree to which they relied on reported weather information (such as METARs, TAFs, PIREPs, ATC, ATIS, *etc.*) *versus* their own senses.

- Business jet pilots seek out and rely on the most timely weather information. The older the data, information, or forecast, or the further away from the pilot's position, the less reliable it is perceived to be. Business jet pilots tend to rely on the reports of experienced humans over automated or processed data and information. They have the most confidence in what they can observe directly.

- Weather-related decisions made by business jet pilots differ from those made by general aviation and transport pilots due to differences in mission and aircraft characteristics. Business jet pilots have more flexibility in achieving their mission than do transport pilots. They can accommodate weather situations by leaving earlier/later, flying into a different airfield, detouring around a wider area, *etc*. However, they have impoverished weather information to the extent that fewer have dedicated weather ground services, and they may have to fly into unsupported airfields. Business jet pilots tend to rely more on their piloting skills, and on the higher performance capabilities of their aircraft and possibly auxiliary equipment (*e.g.*, onboard weather radar) to tactically maneuver around weather they encounter. The pilots we interviewed suggested that they would be less likely to do this, and be more reliant on preflight and strategic weather information, when flying smaller general aviation aircraft.

- In the Simulation Interview, most SMEs exhibited frustration with the standard FAA/ICAO encoded DUATS text preflight information. Many admitted they did not typically use this type of preflight information. Many of our participants were accustomed to having tailored weather briefs from private weather providers, and were not facile with standard DUATS text reports. Reports tailored to the departure point, route of flight, and destination supported by graphical representations were preferred.

- Experienced business jet pilots are able to accurately judge the severity and dynamic nature of the weather most of the time. They have a good understanding of the performance characteristics of their aircraft and are typically able to "fly around" significant weather situations. They have well-developed self-monitoring skills that enable them to make effective judgments about their ability to fly in difficult weather conditions.

3.2 Cognitive Demands

The identified cognitive demands and decisions faced by business jet pilots in making weather-related decisions and judgments are described below according to these flight phases: preflight planning, taxi & take-off, climb, cruise, descent & approach, land & taxi.

Preflight Planning

- What's the general weather picture? Will it be affecting my flying in the next few days?
  This judgment is a very broad, early, assessment of expected weather problems for operations in the subsequent day or days, and the kinds of weather phenomena that the pilot will need to pay attention to for detailed planning. This judgment relies heavily on knowledge of atmospheric dynamics and regional trends.

- What are the weather problems for this flight?
  - *Departure: Is it a Go/No Go ? VFR/IFR? Will the weather affect my departure time?*
    Pilots consider whether the weather is severe enough to cancel the mission. Concerns about weather hazards for a mission lead pilots to consider alternate flight plans. For business aviation operations, this requires a conference with passengers to determine viable options for alternative departure times and/or destinations. In special circumstances, this requires planning for different departure points. For example, one study participant flew under Visual Flight Rules (VFR) conditions from the location of his business jet's hanger to a small private airfield in order to pick up the passengers. If he anticipated weather conditions would not support the VFR portion of his mission, he would have to arrange to meet his passengers at the public airfield. Weather also affects the flight rules that a mission is operated under. Considering the weather in context of departure concerns leads pilots to consider general problems that can occur in taxiing, takeoff, and climb. These considerations include, for example, the effect of possible icing on climb performance.

  - *En route: Which route will I take? Will I need to detour around weather?*
    This includes decisions relating to the planned route of flight, potential detours and added time required to reach the destination, any specific safety concerns, *etc*.

  - *Destination: Is it still viable? Do I need to consider alternative destinations? If so, where?*

This includes planning decisions related to the destination itself. These include: Is it even feasible to land at the preferred airfield? Should I consider an alternative now and/or plan to deviate en route? If so, which will be the most feasible and convenient for my passengers?

- How does the weather affect the fuel I carry?
  Pilots assess whether extra fuel will be needed for possible deviations from route, delays, holds, or diversions to an alternate airport due to weather. The desire to carry additional fuel for mission flexibility must be considered in light of the costs of doing so. These costs include: expense of extra fuel, and reduced aircraft climb-rate and payload capability.

- How much confidence do I have in the co-pilot's weather flying abilities?
  This assessment affects how comfortable a pilot might be in making a mission, the workload distribution he expects during the mission, and how often he might engage in monitoring and cross-checking his co-pilot. This assessment is based on familiarity with the co-pilot, knowledge of their general flying experience as well as region-specific and weather-exposure experience.

Taxi & Take-off

- Can I taxi/take off in this weather?
  The weather concerns relate directly to the ability of the pilot to safely taxi and takeoff, but also affect passenger comfort and schedule. Pilots consider weather factors such as ceiling, visibility, crosswind, windshear, runway conditions, and icing probability, in these assessments.

- Will I need to consider a rejected takeoff?
  Pilots consider the likelihood of having to abort a takeoff and the contingency actions if a takeoff is aborted. Cross wind speed and direction, thunderstorms, runway conditions, and other weather phenomena can influence these plans.

- Do I need to delay my takeoff?
  Sometimes weather conditions can change significantly between preflight planning and actual departure. Pilots must reconsider the safety of departing at the planned time, and may consider delaying departure. As previously mentioned, such a decision requires a conference with passengers to preserve, if possible, success of the ultimate business mission. Delays can also be required to ensure that the aircraft is properly configured for weather conditions. Deicing, and ground use of the onboard weather radar are specific examples of such delays.

- Do I need to plan post-takeoff actions?
  Pilots think beyond takeoff to plan for actions based on weather factors that may impact the aircraft immediately during the takeoff. For example, they may plan a specific maneuver to avoid a weather cell in the vicinity. They may consider wind conditions when planning for engine failure contingencies.

Climb

- Do I anticipate icing problems?
  Pilots anticipate the likelihood of icing on the climb-out and judge the impact of icing on flight safety and aircraft performance. The pilot must continually be aware of the aircraft's performance in potential icing conditions.

- Do I anticipate wind-related problems (turbulence, windshear, crosswinds)?

Pilots are also aware of wind conditions that impact aircraft performance and ability to maintain lift. Pilots also consider wind conditions' effects on passenger comfort.

- Do I anticipate any weather obstacles on climb out?
  Hazardous weather phenomena, such as convective cells, rain shafts, wind shear activity, and reported lightning create obstacles that the pilot tries to avoid, for safety and passenger comfort reasons. Deviations around these obstacles should be considered in advance and with respect to other constraints such as terrain and airspace restrictions.

Cruise

- Is my destination still viable?
  These decisions relate directly to judgments and assessments made during the cruise phase of flight. If the weather at the destination is uncertain or less than anticipated, pilots will more frequently sample weather data for the destination during cruise. This information is used to continuously assess the viability of the destination, and alternate destinations. Viable alternates must be appropriate not only in terms of weather conditions, but also for the aircraft's fuel available, and performance capabilities. Further, alternates should be acceptable for the business mission (*i.e.*, passengers will still be able to accomplish the business purpose of the mission).

- Is the flight proceeding according to expectations?
  This is a general assessment of actual progress against planned progress; of unexpected occurrences or weather, of planned ground speed *versus* actual ground speed (unexpected headwinds aloft), of estimated-time-of-arrival (ETA) versus the passengers' schedules. The pilots we interviewed mentioned using PIREPs as well as checking with FSS and ATIS just after the hour, when new information may be available. Deviations from expected occurrences and performance spur pilots to acquire additional information about environmental conditions and engage in replanning. Pilots may also decide they need to alert their passengers if the flight is not proceeding as planned (*e.g.*, ETA changes).

- If I see an unexpected weather hazard, how can I avoid it?
  Perfect weather information would enable perfect strategic flight planning to avoid weather hazards. However, because weather dynamics cannot be perfectly modeled and therefore forecasted, and because weather information may not be immediate or precise enough, some pilots "wait and see" what the weather looks like before attempting to avoid it. Tactical avoidance strategies include flying around or over the weather, and most conservatively, simply turning around. Tactical avoidance of weather hazards requires pilots to consider weather dynamics and intensity, aircraft performance characteristics, and other airspace constraints (*e.g.*, terrain, airspace). In addition to simply tactically avoiding weather they could see, several interviews suggested that pilots query ATC to better understand how pilots closer to the anticipated hazard are choosing to avoid it.

- How can I provide passengers with the most comfortable ride?
  En route decisions also must consider the impact on passengers: Are they comfortable? Can they work or sleep comfortably? Turbulence from weather cells, and the jet stream is the primary concern with regard to passenger comfort. If turbulence is unavoidable, pilots attempt to notify passengers prior to onset. Advance notice of such turbulence is therefore valuable information.

Descent & Approach

- Do I anticipate significant weather on descent?
  When in the vicinity of the destination airfield, pilots obtain local weather information (*e.g.*, ceiling, visibility) and reconsider the safety of landing at this airfield and on the designated runway. Pilots consider suboptimal conditions (*e.g.*, icing, windshear, turbulence, crosswinds, runway conditions) that require additional contingency planning for missed-approach planning.

- How do I deal with weather hazards on descent?
  This judgment is difficult because the options narrow for the pilot as the airfield gets closer. Different obstacles require different avoidance strategies. Also, the closer to the ground the aircraft is, the more severe the consequences of loss of lift. Expert pilots develop these strategies in advance and consider airspace and terrain, as well as aircraft performance characteristics.

- Do I want to hold or divert to an alternate destination?
  This decision may be instigated by weather conditions, but must also be evaluated in light of weather conditions. While one might decide to hold to see if an airfield's visibility improves, it is unwise to hold in what may be icing conditions. The decision to hold or divert also affects passengers' schedule and ground transportation logistics; and requires additional fuel and therefore expense. If the pilot chooses to not carry extra fuel, for improved payload capacity or climb performance, s/he may eliminate the option of holding at the destination. Provided safety is not compromised, decisions regarding changes to the final destination are often shared with passengers.

- Do I anticipate a missed approach and go-around?
  Pilots consider the likelihood of a missed approach or go-around due to weather conditions, and the effect of weather conditions on the ability to perform these maneuvers.

- What kind of approach do I need to make (Visual, ILS)? Which runway? Is it suitable?
  This more specific judgment addresses selection of approach and runway. Even if local weather information defines the airfield conditions to be safe, pilots still must consider the appropriateness of the approach and runway for the weather conditions. For example, ice-contaminated runways and runway length must be considered in light of aircraft landing requirements.

Landing & Taxiing

- What kind of landing do I need to make?
  This decision is made based primarily on safety factors, although it influences passenger comfort. If the runway is very wet, it may be necessary to bring the aircraft down hard to avoid skidding on the wet surface. To inform such decisions, the pilot needs to have an accurate appraisal of the runway surface conditions and surface winds.

- Do I need to prepare the aircraft for a quick turn-around for my next leg/trip?
  This cognitive requirement is faced when the aircraft has to be turned around quickly for the next leg of a trip. Pilots must think about how the weather will change while they are on the ground and how they may have to accommodate that into their plans.

3.3 Indicators of Expertise

Consideration of expert/novice performance differences is useful to design supportive aiding technologies and training programs. In addition, these differences and the errors that novices may make define behavioral markers for assessing performance. In this study, we only interviewed experienced business jet pilots, so our conclusions about these differences are derived from these individuals' perceptions of their own skill development and contrasts of their behavior with less experienced colleagues. Study participants were specifically asked to consider the types of errors less-experienced pilots might commit. The benefits of piloting expertise and deficiencies of novices are as follows:

- Expert business jet pilots accurately judge the severity and dynamic nature of the weather most of the time. Novice business jet pilots are more likely to misinterpret weather severity or fail to anticipate changing weather patterns. Novices, therefore, may not be able to adjust properly to changing conditions, either disrupting safety, efficiency, and/or passenger comfort.

- Expert business jet pilots build a dynamic, "big picture" of a situation by understanding how a situation developed, assessing relevant current and forecasted data, and projecting the situation. Novice business jet pilots build incorrect or incomplete pictures by either not thinking far enough into the future (*e.g.*, not contingency-planning), failing to continuously monitor changing weather conditions, and failing to use all relevant resources to check the reliability among them.

- Expert business jet pilots have a good understanding of the performance of their aircraft and onboard equipment, the limitations imposed by weather conditions, and strategies for recognizing and compensating for these limitations. Novice business jet pilots may not consider how changing weather affects aircraft performance and therefore are forced into a reactive mode of control. Novices may not have a refined knowledge of how to use instruments to their fullest potential to best acquire weather information and recognize effects of weather on aircraft performance.

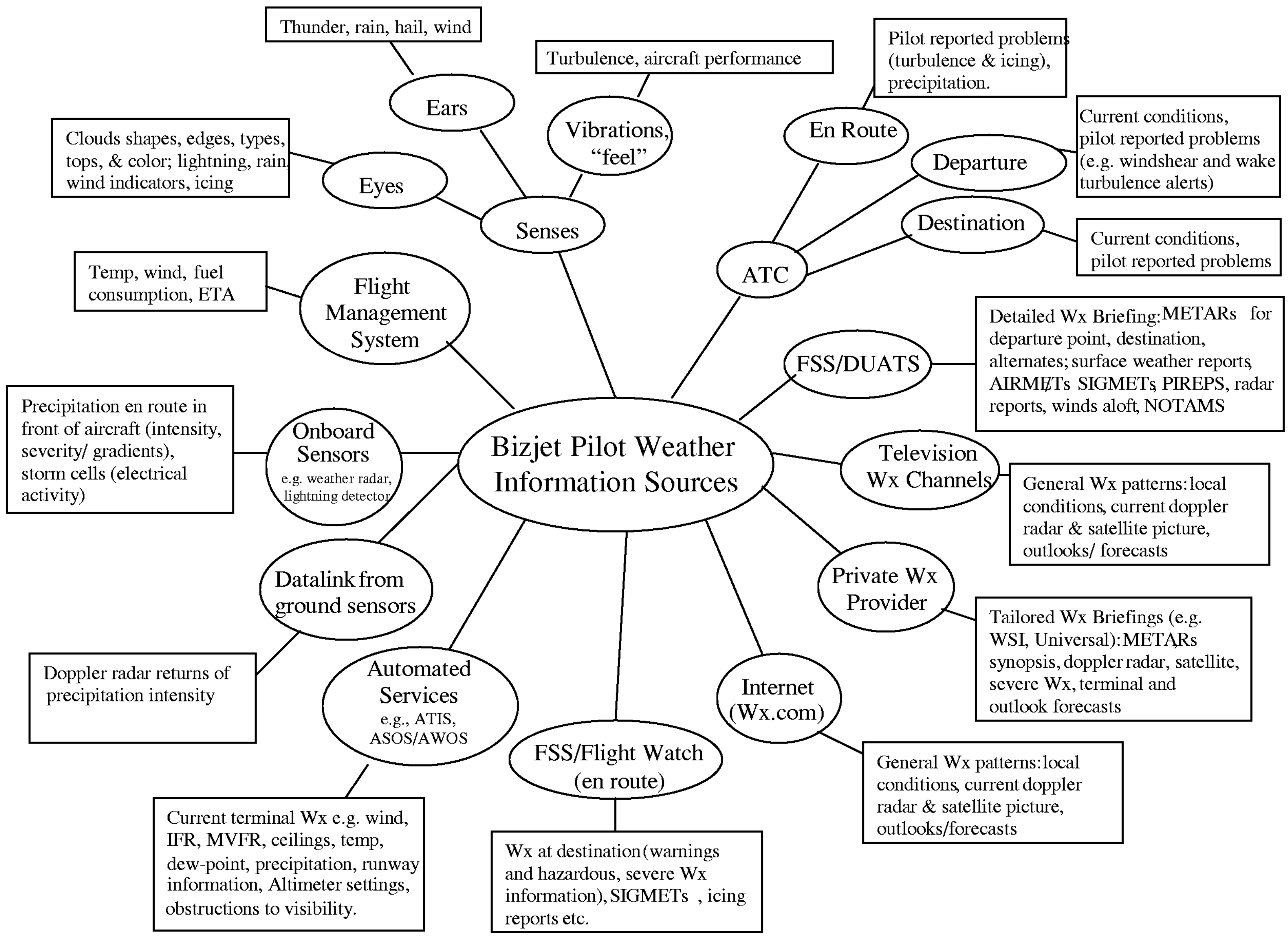
- Expert business jet pilots have strong self-monitoring skills that enable them to judge when they should avoid weather rather than manage through it. They more accurately judge their own abilities to fly in certain conditions, and more readily catch their own judgment errors before they are enacted. Novice pilots who have not experienced difficult weather flying, have not developed diagnostic skills for identifying hazards or decision-making skills for selecting appropriate responses, can have a cavalier attitude and venture into hazardous situations. This deficiency in skills, in conjunction with the delayed realization that one is in a novel and hazardous situation, can quickly overwhelm and confuse a novice pilot.

- Expert business jet pilots are more aware and attentive to all details of flight, from passenger schedules to atmospheric pressure changes to providing passengers services such as catering. Novices tend to be more focused on piloting and making the next point in the flight plan.

3.4 Weather Information Sources Diagram

The Weather Information Sources diagram (Figure 2) represents all the sources of weather information and types of weather information that the SMEs referred to in interviews. The diagram does not represent all possible sources of weather information that are available to the pilot community. The sources depicted are those that are *most commonly reported by the business jet pilots we interviewed* to help them understand the weather picture and its implications for flying. These sources, the ovals, are described in terms of the weather information, the rectangles, for which they are referenced.

Figure 2. Sources of Business Aviation Weather Information.



3.5 Assessing Weather Information Reliability

The Weather Information Sources diagram illustrates that pilots use a variety of weather information sources to arrive at their "weather picture." SME responses also were analyzed to determine the characteristics that these pilots use to assess the reliability of weather information, and thereby prioritize weather source usage. These interrelated factors include: directness of perception; timeliness and useful-life of data; spatial dislocation of the pilot/sensor from the weather, sensor and transmission equipment quality, and spatial resolution, and meta-cognitive interpretive skills.

Pilots in this study indicated that they are more likely to trust their own *direct perceptions* than those of others, or of automatically-sensed information, and more likely to trust the perceptions of other humans in the NAS than that of automated weather information services or sensor-driven displays. Of course not all weather information of significance is available to direct visual perception. To the degree that presented data is isomorphic with the atmospheric conditions, it is more "direct." For example, a satellite picture of cloud cover is considered more direct than a mosaic radar return of the same area.

The *timeliness and useful-life* of the data are interrelated. Subjects assessed the credibility and reliability of current weather reports based on how long ago the reading was taken, and on the dynamism of the observed weather phenomenon. For example, a report of a low-lying fog over an airfield may be valid for several hours after the report was made. Conversely, a turbulence report at flight level 310, may rapidly become obsolete or may be valid for several hours, depending on the weather phenomenon's dynamics. Generally speaking, pilots trust weather reports that are more recent than those that are less recent, and use their knowledge of weather dynamics to assess when reports are likely to be obsolete. Weather forecasts are similarly assessed. Pilots are unlikely to rely on forecasts to the degree that the weather they predict is dynamic. Some subjects in this study mentioned that they assess the validity of forecast information by comparing past forecasts and current conditions.

SMEs in this study also mentioned *spatial dislocation* of the sensor (either human or automated) from the phenomenon as a significant factor affecting their assessment of weather information validity. In essence, this factor can be described as either due to the effects of the prior factor, "timeliness and shelf-life" *vis a vis* atmospheric dynamics, or to inaccuracies that increase in sensor and transmission capabilities with increased distance. This factor is described next.

SMEs are aware that the weather information available to them is only as good as the equipment used to detect, transmit, and present this information. Directly perceived weather information is subject to, for example, the limitations of visual perception. Similarly, for automated sensing systems, the *sensor quality* (sensitivity, false alarm rate) and the *transmission quality* (timeliness and completeness of uplinks) must be considered when assessing the validity of the resulting weather information. Both human vision and automated sensors are likely to be degraded with distance. Many of the pilots interviewed reported that their onboard radar provided varying degrees of reliable and accurate data. These data are dependent on the range of the phenomenon from the aircraft, the power of the radar, the radar range setting, the presence of atmospheric or ground clutter, and the intensity of the weather phenomenon itself (which may block the extent of the radar's effective range).

The *spatial resolution* of the weather information is relevant to SMEs reliance on this information. These pilots rely on weather information to the degree that it is spatially precise and appropriate for their flightplan. For example, the general outlook for a 24-hour forecast may predict "half-mile visibility in the vicinity of Greenville Airport" but a pilot may still fly out because the hazard is localized to the South side of the airport. This forecast does not provide the relevant level of detail to fully trust this information to make such a decision.

Finally, *meta-cognitive skills* are important in determining how pilots use weather information sources. The subjects in this study demonstrated a range of comfort in understanding atmospheric phenomena, weather hazards and dynamics, and technical details of weather information sensors and services. These pilots determined appropriate reliance on abstracted and sensed weather information sources to the degree that they are confident in their weather assessment skills. Their self-confidence in interpreting weather data, detecting false indications in weather products and predicting weather behavior allowed them to more intelligently assess the reliability of individual reports and forecasts. These assessments were often derived from regional experience and history of exposure to the interaction of atmospheric conditions and terrain. Some of our participants made their own assessments of raw information, and generated their own forecasts. They were able to generate a reasonable explanation of the weather in certain areas for certain periods. If the existing weather data, information, and forecasts matched their own predictions, they could place more faith in it. They “owned” their weather data, rather than relying on someone telling them what was happening and what was going to happen. Less meteorologically skilled participants were more likely to either blindly trust preflight weather information or tended to completely dismiss this information and be more reliant on, and reactive to, in situ direct and PIREP observations.

3.6 Scenarios and Measures for AWIN Simulation Experiments

AWIN researchers will be evaluating aviation weather information systems in flight experiments and full-mission simulation evaluations. One critical facet of such experiments will be defining, and in the case of simulation evaluations designing, scenarios that stress pilots' weather-flying skills and decision-making. It is equally important to evaluate pilot performance using sensitive, operationally significant measures. Data obtained from the Critical Decision and "Scenario from Hell" probes provide a foundation for defining scenario elements that stress weather-flying skills and decision-making and indications of good performance in these conditions. Cognitive Demand tables provide behavioral markers of novice pilot errors.

Appendix M parses Critical Decision and "Scenario from Hell" incidents into scenario elements. These elements are further classified by phase of flight, type of element (weather condition, system malfunction, environment, and infrastructure), the sources of information to cue the pilot, and behavioral markers for good performance. Some weather situations that may be used as scenario elements include:

- an uncontrolled airport as a destination with weather near minimums and non-precision approaches,
- unreliable or uncertified AWOS,
- highly dynamic weather conditions at the destination,
- difficult crosswinds on the assigned runway,
- weather cell in vicinity of airport and further constraints from terrain,
- ground sensors or personnel provide optimistic weather intensity and closure rate assessments,
- runway ice contamination in conjunction with anti-skid failure,
- engine failure at take-off with crosswinds,
- bleed air failure and icing conditions,
- icing during a night flight with pitot-static occlusion,
- onboard radar clutter and attenuation,
- dense fog occurs just after reaching rotate speed.

Subjects mentioned other factors that are relevant to business jet operations that exacerbate bad weather condition situations. These include:

- obvious alternates that don't provide sufficient ground transportation for passengers,

- late and anxious passengers,
- uncooperative co-pilot,
- ground switches runways at last minute,

The expert subjects in this study were specifically asked to consider what errors novices would make in challenging weather flying situations. These data are presented in their entirety in the Critical Decision Tables. A summary of these novice aviator errors follows:

- inappropriate fuel loading: failure to consider need to reach alternates & performance implications
- over-reliance on forecasted weather in dynamic conditions
- failure to intermittently monitor changing weather conditions at appropriate sampling rate,
- failure to acquire information from multiple weather sources to cross check for validity,
- over-reliance on automatically sensed weather information,
- acquiescing to passenger pressure to make trip when concerned about weather,
- failure/inability to develop trend information; to predict if conditions are worsening or improving,
- failure/inability to consider, temporally project weather intensity and location,
- failure to appreciate limitations of, and/or appropriately manipulate onboard radar sensors,
- insufficient understanding of aircraft performance and implications for weather avoidance,
- failure to appreciate effects of weather, and weather equipment use, on aircraft performance,
- failure to accurately predict effects of weather on passenger safety and comfort,
- failure to continue to monitor fuel in weather avoidance,
- staying on a visual flight plan (VFR) in instrument meteorological conditions (IMC),
- over-confidence in abilities,
- failure to assess runway crosswinds until too close in.

3.7 Design & Training Interventions

The cognitive task analysis of business jet pilot weather-related decision-making generated several recommendations for this niche in the flying community. Some of the recommendations are very specific to the business jet community, whereas others are probably applicable across other groups within the flying community. We have identified two areas for our recommendations: business jet flight deck design and business jet pilot training.

Design Interventions

The following recommendations address system design issues for the business jet pilot community. They address only issues specific to decisions and judgments related to weather.

- **Integrated Source Displays.** Currently, pilots must integrate multiple types of information from multiple sources. These include up-linked radar pictures, up-linked satellite, textual ATIS reports, voice reports of turbulence over common broadcast radio frequencies, automated observations from specific locations, weather alerts issued by various agencies, *etc.* Flight deck displays should provide an integrated representation of weather information to support the cognitive demands of situation assessment and response planning.

- **Big Picture Radar Representations.** Due to the flexibility required of business jet missions, it is particularly important that these pilots understand the big picture of the weather situation.

Augmenting onboard aircraft radar capabilities with up-linked "big picture" radar information would aid challenging en route re-routing decisions.

- **Radar Image and Usage.** Pilots need weather hazard displays, rather than radar return displays. Subject matter experts should be used to develop rules for interpreting onboard weather radar data and rules for understanding when that data might be suspect. In addition, subject matter experts could serve as the basis for codified guidance on how to more expertly and sensitively manipulate the onboard weather radar system to gather the most appropriate weather information, as well as be able to assess the reliability of that information. Onboard weather radar systems, as well as on board aviation weather information systems more generally, would benefit pilots by relieving workload if they performed automated monitoring for weather hazards and changes, and provided indications of these events in a manner consistent with their import.

- **Significant Weather Alerts.** Participants frequently mentioned problems associated with unreliable weather information in terms of timeliness, and relevance in terms of proximity to their own position. Pilots do not always know when to seek information, or when the weather situation changes, for better or worse. Remembering to obtain weather information and actively doing so are significant workload impositions on a pilot. Onboard aviation weather information systems as well as ground-based weather information systems, would benefit pilots by relieving workload if they performed automated monitoring for relevant weather hazards and changes, and provided indications of these events in a manner consistent with their import. Currently, ATC broadcasts weather alerts to pilots on IFR flight plans or who are using VFR flight following. However, these alerts are weather-centered, i.e., they describe the location and severity of weather, not pilot-centered, i.e., considering a specific route, aircraft performance capabilities, etc. These weather-centered reports provide necessary information, but in a manner that has the following disadvantages: they may be irrelevant to a particular route and/or aircraft, they may be delayed, and they rely on radio frequency availability - which becomes saturated in difficult weather conditions.

- **Decision-Centered, Action-Oriented Alerts.** The goal of in-flight aiding systems should not necessarily be to tell pilots what to do, but to support their own situation assessment and decision-making process. One aspect of this support is to provide interpretations and implications of different weather situations on the pilot's intended course of action. For example, by considering the implications of weather alerts to the possible alternative runways in an approach and landing decision, one might receive a warning such as:

  > *"Crosswinds at destination X conflict with chosen runway Y. .*
  > *Wind speed and direction are above aircraft landing minimums…*
  > *Selected runway Y is now marginal or non-viable.*
  > *Suggest runway X, or suggest alternate airfield."*

  This warning provides the current wind conditions at the destination airfield in relation to the intended landing runway, indicates the current status of the runway for landing, and suggests alternate courses of action. Ultimately, pilots would be responsible for acting on this information, or they may choose to wait, and reassess the intended runway conditions when closer to the airport.

- **Winds Aloft Information System.** Pilots reported that winds aloft information is particularly unreliable. This information is critical to business jet pilots who are trying to maximize passenger satisfaction and flight efficiency. Pilots suggested that the winds aloft forecasts could be improved by using data from aircraft in the air that are sensing wind speed and direction in real-time. These data could be transmitted to a central location, aggregated and integrated into current wind readings. This would improve current observations of winds aloft that are currently collected by the 12-hour weather balloon recordings.

- **Weather-Integrated Route Planning Decision Support.** One of the challenges faced by the business jet community is to understand the impact of weather on their route of choice and to select alternate routes based on this information. Because the business jet community has flexible routing and scheduling, route planning is more challenging than it is in the transport aviation world. One solution would be to integrate route selection planning with current weather information to provide the most feasible routes given current weather hazards. Pilots reported that the flight planning systems they typically use calculate routes to their destination without taking into account the current weather situation. Only after the routes are planned are weather concerns superimposed on this route and the route evaluated for safety. An improved flight planning system would incorporate routing around such weather hazards and consider the dynamics of weather system movement and intensity, and consider these hazards in conjunction with terrain and airport capacity constraints.

- **Tailored Weather Planning Information.** Many private weather information providers provide the aviation community with weather information tailored to specific routes and aircraft capabilities. These tailored weather briefings are preferred over standard DUATS text preflight information. Pilots expressed preference for graphical weather information. Reference locations used in AIRMETS and SIGMETS are often difficult to interpret in terms of the pilot's route, a problem exacerbated when a pilot is unfamiliar with the region.

- **Anomaly Detection Support.** Pilots would benefit from decision support that would flag deviations from expected flight progress or weather status. Rather than a wide area broadcast, this information would be specific to a mission. It would relate to the current flight parameters (*e.g.*, route and ETA), and would reflect any changes above a "threshold" (to be empirically determined or user-set), to alert pilots that their situation awareness is based on old information, and therefore would more sensitively alert them to slowly developing problems that may otherwise go undetected. For example, an alert would draw the attention of the pilot to variations from the ETA based on projected route, speed, altitude, and wind conditions. If any of these parameters altered the ETA significantly the pilot could be alerted and the winds aloft projections could be recalculated in order to assess their fuel situation. Aiding could monitor and assess the impact of de-icing equipment on aircraft performance and alert the pilot to any significant impacts on fuel consumption.

Training Interventions

The following recommendations address training issues for the business jet pilot community. They address only issues specific to decision-making and judgment related to weather.

- **Radar Usage.** Onboard weather radar provides very helpful, real-time information, however, pilots are not adequately or routinely trained to manage this technology or interpret radar return images. Previously, we recommended aiding technologies to support these management and interpretation tasks. This recommendation does not obviate the necessity of training pilots to manually manage radar, interpret radar images, and, in particular, understand the limitations of this technology.

- **Training Scenarios.** During training, weather problems are often provided as a single obstacle that introduces sudden flight problems. Training scenarios should also address more complex, often seemingly benign, weather situations that may be encountered by pilots. These scenarios should include conflicting passenger comfort and flight efficiency goals based on the interpretation and assessment of uncertain weather conditions. Scenarios should also present situations that have combinations of weather-related problems, and combinations of weather and equipment failure scenario elements. Training scenarios should be designed to sharpen the pilot's ability to gather weather information, interpret the weather situation, identify the time course of weather dynamics and response requirements, and select and evaluate options.

- **Goal Deconfliction.** Training for the business jet pilot community needs to focus on the efficiency and comfort goals as well as the safety goals. The pilots we interviewed did not describe situations in which they had compromised the safety of their passengers. Many of the difficult judgments pilots reported were related to conflicts between organizational and passenger-related goals. For example a participant reported *"Ceiling and visibility restrictions may not allow me to get my clients to their preferred destination—should I go ahead and attempt the trip, even though I may have to turn around and bring them back to the departure point?"* Pilots could be explicitly trained to identify goal conflicts, and effectively use weather information to evaluate options. Scenarios designed to pit these goals against each other or introduce factors that may generate several conflicts within a goal would help the pilots make better use of their weather products, recognize situations where these conflicts are likely to arise, and develop strategies for identifying the best course of action.

4.0 Conclusions

This study conducted a cognitive task analysis with eight expert business jet aviators to better understand challenging weather-related decisions. Several CTA methods, developed by Klein Associates were used. In addition, we extended the Simulation Interview method by providing participants with a description, and weather information materials from an actual challenging weather day.

Several representations were developed to codify interview data and facilitate analyses. Results distilled to 22 different cognitive demand categories faced by experienced business jet pilots related to weather conditions. The expert participants suggested how novice pilots might have difficulty with these challenging conditions. We developed a representation for the information sources the participants in this study mentioned while describing challenging weather-flying situations, and developed a framework to describe the factors that these pilots consider when evaluating trust in weather information sources. Results were considered in light of supporting empirical simulation evaluations, through scenario and measurement development, and in light of identifying design and training interventions.

The objective of this report is to document the CTA methodology developed for this study and to present these preliminary findings. While many CTAs are conducted with as few as eight SMEs, the complexity of the flight mission and variety of themes addressed in this study necessitated a broader treatment in the interview. For this reason, additional CTAs should be conducted with the documented protocol to fortify, or perhaps extend, these preliminary findings.

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5.0 Acronyms & Abbreviations

ACARS - Aircraft Communications and Reporting System.
ACTA - Applied Cognitive Task Analysis toolkit (copyright, Klein Associates, Inc.).
AIM - Aeronautical Information Manual.
AIRMET- Airman's Meteorological Information.
ASIST - Aeronautics Safety Investment Strategy Team.
ASOS - Automated Surface Observing System.
ATC – Air Traffic Control.
ATIS – Automatic Terminal Information Service.
AWIN - Aviation Weather Information.
AWOS - Automated Weather Observing System.
CDT - Cognitive Demands Table.
CTA - Cognitive Task Analysis.
DUATS - Direct User Access Terminal System.
ETA - Estimated Time of Arrival.
FBO - Fixed Base Operator.
FMS – Flight Management System
FSS - Flight Service Station.
FW - Flight Watch.
GPWS – Ground Proximity Warning System
IFR - Instrument Flight Rules.
IMC – Instrument Meteorological Conditions.
METARs - roughly translates from French as Aviation Routine Weather Report.
NBAA - National Business Aviation Association.
PIREP- Pilot Report.
SIGMET – Significant Meteorological Information.
SME - Subject Matter Expert.
SPECI - roughly translates as Aviation Selected Special Weather Report.
TAF - Terminal Area Forecast.
NAS - National Aerospace System.
NASA - National Aeronautics and Space Administration.
TV – Television.
UNICOM – Universal Communications station.
VFR – Visual Flight Rules.
WSI – Weather Services International, Corp.
WX – Weather.

7.0 Appendices

7.1 Appendix A: ACTA Toolkit Methods (Copyright Klein Associates, Inc. Reprinted with permission.)

ACTA - TASK DIAGRAM

Purpose: The **Task Diagram** is intended to serve as a road map to the rest of the CTA. The **Task Diagram** acts as an advance organizer, providing an overview of the task and identifying the cognitively complex elements of the task.

How to get started: Before you begin, have clearly in mind what the task is you intend to investigate. In this interview, you want to find out about the interviewee's processes as they perform the task of interest.

CONDUCTING THE TASK DIAGRAM INTERVIEW

* Write the **Task of Interest** at top of whiteboard.

* Elicit the steps required to do the task. Record them across the board from left to right in chronological order. Use arrows to indicate the order in which the steps occur.
  - Ask your SME, "*Think about what you do when you (Task of Interest) . Can you break this task down into between three and six steps?*"

* Elicit information regarding which of the steps require cognitive skills. Circle the elements that require cognitive skills.
  - Ask your SME, "*Of the steps you have just identified which require difficult cognitive skills? By cognitive skills I mean judgments, assessments, problem solving—thinking skills.*"

At this point, you should have a very broad overview of the task, with an indication of where the complex cognitive skills lie. If the task seems too big or the steps you have identified are too broad for further investigation, you may choose to focus on one or two of the subtasks you have identified as requiring cognitive skills. In this case, you should complete a Task Diagram on the step(s) you have chosen to focus the rest of the cognitive task analysis.

TIPS FOR DOING THE TASK DIAGRAM INTERVIEW

* Your interviewee may immediately start talking at a very fine level of detail. Make it clear early on that you are looking for a very broad overview with this interview. You will be interested in hearing lots of stories and details later in the session (with the **Knowledge Audit** and the **Simulation Interview**).

* If your interviewee begins listing things to consider rather than the steps of the task, help reframe the topic for him/her. "*What do you do when you (Task of Interest) ?*"

* This may be a new way for the interviewee to think about the job. Give him/her time to think. You may need to repeat or rephrase the question.

* The Task Diagram serves as a road map to the rest of the cognitive task analysis. You are not trying to elicit detailed, specific cognitive information with this interview. You are trying to get a sense of which parts of the task require complex cognitive skills.

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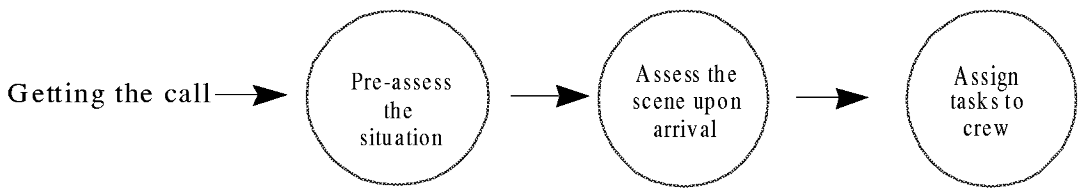
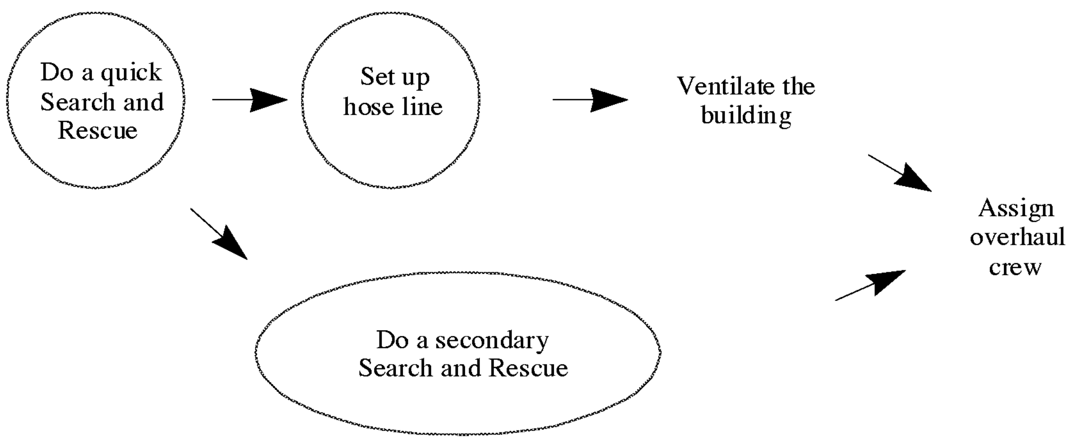
EXAMPLE: Task Diagram of Fireground Commander's Job in Commanding Crew



The interviewer decides this is too broad — really wants to focus on the assignment of tasks during an incident.

EXAMPLE: Task Diagram of Assign Tasks



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ACTA - KNOWLEDGE AUDIT

Purpose: The **Knowledge Audit** provides details and examples of cognitive elements of expertise; it contrasts what experts know and novices don't.

How to get started: You used the **Task Diagram** to identify parts of the job that require skilled judgment, decision-making and evaluation. In the **Knowledge Audit** you will elicit the expertise necessary to do each of those tasks. Use the Task Diagram to help you decide which tasks and subtasks you want to explore with the Knowledge Audit. Go into the Knowledge Audit interview knowing what you want to analyze.

Task of Interest		
Example	**Cues & Strategies**	**Why Difficult?**
Past & Future Example...		
Big Picture Example...		
Noticing Example...		

CONDUCTING THE KNOWLEDGE AUDIT

* Write the **Task of Interest** at top, center of whiteboard.

*Divide the space below into three columns; label as shown.

* Elicit an example of one element of expertise, using the definitions and probes provided. Start with the first probe, (*e.g.*, "Is there a time when you walked into the middle of a situation and knew exactly how things got there and where they were headed?)

* Elicit information for the remaining two columns before proceeding to another element:
- Ask your SME, "*In this situation, how would you know this? What cues and strategies are you relying on?*" Record answers in middle column under **"Cues and Strategies."**
- Ask your SME, *"In what way would this be difficult for a less-experienced person?" What makes it hard to do?"* Record answers in final column under **"Why Difficult**?"

* It is important that you cover the six basic Knowledge Audit probes; you may also want to use some or all of the optional probes.

TIPS FOR DOING THE KNOWLEDGE AUDIT

* Examples allow you to get at specifics and help you understand the task better. Ask for an example for each element of expertise.

* Don't try to write everything; but write enough so you will know later what was said and meant. With practice you will develop a sense of the level of detail you need.

* Some of the questions may take a few minutes for the SME to answer thoughtfully; don't rush; give the SME time to think over what you are asking about.

* Confusion about what to write and in which columns may be a signal that the SME has misunderstood your question; the information you are getting is not what you expect. You may want to take a timeout, restate the question, and check that your SME understands what you are trying to get at.

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ELICITING INFORMATION WITH THE KNOWLEDGE AUDIT

Provide an explanation of the type of information you want; then ask the probe questions. You can read the definitions below or paraphrase them.

BASIC PROBES:

* **Past & Future** Experts can figure out how a situation developed, and they can think into the future to see where the situation is going. Among other things, this can allow experts to head off problems before they develop.
  Is there a time when you walked into the middle of a situation and knew exactly how things got there and where they were headed?
* **Big Picture** Novices may only see bits and pieces. Experts are able to quickly build an understanding of the whole situation—the Big Picture view. This allows the expert to think about how different elements fit together and affect each other.
  Can you give me an example of what is important about the Big Picture for this task? What are the major elements you have to know and keep track of?
* **Noticing** Experts are able to detect cues and see meaningful patterns that less-experienced personnel may miss altogether.
  Have you had experiences where part of a situation just "popped' out at you; where you noticed things going on that others didn't catch? What is an example?
* **Job Smarts** Experts learn how to combine procedures and work in the most efficient way possible. They don't cut corners, but they don't waste time and resources either.
  When you do this task, are there ways of working smart or accomplishing more with less—that you have found especially useful?
* **Opportunities** Experts are comfortable improvising—seeing what will work in this particular situation; they are able to shift directions to take advantage of opportunities.
  Can you think of an example when you have improvised in this task or noticed an opportunity to do something better?
* **Self** Experts are aware of their performance; they check how they are doing and make **Monitoring** adjustments. Experts notice when their performance is not what it should be (this could be due to stress, fatigue, high workload, *etc.*) and are able to adjust so that the job gets done.
  Can you think of a time when you realized that you would need to change the way you were performing in order to get the job done?

OPTIONAL PROBES:

* **Anomalies** Novices don't know what is typical, so they have a hard time identifying what is atypical. Experts can quickly spot unusual events and detect deviations. And, they are able to notice when something that ought to happen, doesn't.
  Can you describe an instance when you spotted a deviation from the norm, or knew something was amiss?
* **Equipment Difficulties** Equipment can sometimes mislead. Novices usually believe whatever the equipment tells them; they don't know when to be skeptical.
  Have there been times when the equipment pointed in one direction, but your own judgment told you to do something else? Or when you had to rely on experience to avoid being led astray by the equipment?

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ACTA - SIMULATION INTERVIEW

Purpose: The **Simulation Interview** provides a view of the expert's problem-solving processes in context. The interview provides specific detailed information on expert cognitive processes.

How to get started: You will need to obtain a simulation of the task. The simulation you choose should address difficult, challenging elements of the job. It does not have to be high fidelity; it can be a paper and pencil simulation, a video depicting a scenario, or whatever is available. It is important that the simulation you choose presents a challenging scenario.

CONDUCTING THE SIMULATION INTERVIEW

- Divide a whiteboard into five columns, labeled as shown on the next page.
- Have the SME experience (*i.e.* read, watch, interact with) the simulation.
  - Tell the SME, "*As you experience this simulation, imagine you are the* <u>(Job you are investigating)</u> *in the incident. Afterwards, I am going to ask you a series of questions about how you would approach this situation.*"
- Elicit a list of the major events in the simulated incident and record in the first column.
  - Ask your SME, "*Think back over the scenario. Please list the major events that occurred during the incident. These events could include judgments or decision points. As you name them, I am going to list them in the left column of the board.*"
- Begin with the first major event and elicit information for the remaining four columns before proceeding to the next major event.
  - Ask your SME, "*As the* <u>(Job you are investigating)</u> *in this scenario, what actions, if any, would you take at this point in time?*" Record answers in the second column under **Actions**.
  - Ask your SME, "*What do you think is going on here? What is your assessment of the situation at this point in time?*" Record answers in the third column under **Situation Assessment**.
  - Ask your SME, "*What pieces of information led you to this situation assessment and these actions?*" Record answers in the fourth column under **Critical Cues**.
  - Ask your SME, "*What errors would an inexperienced person be likely to make in this situation?*" Record answers in the fifth column under **Potential Errors**.

TIPS FOR DOING THE SIMULATION INTERVIEW

- Eliciting major events is critical to this interview. The major events should be turning points or segments of the story. You do NOT want a recount of the entire scenario.
- People often want to critique the simulation. Assure your interviewee that you are interested in their critique, but that for the first part of the interview, you would like to work with the scenario as it has been presented. Be sure to follow up and ask for a critique at the end.
- Don't try to write everything; but write enough so you will know later what was said and meant. With practice you will develop a sense of the level of detail you need.
- Confusion about what to write and in which columns may be a signal that the SME has misunderstood your question; the information you are getting is not what you expect. You may want to take a timeout, restate the question, and check that your SME understands what you are getting at.

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EXAMPLE: EXCERPT FROM A FIREGROUND SIMULATION

Events	Actions	Situation Assessment	Critical Cues	Potential Errors
On-scene arrival	- Account for people (names) - Ask neighbors (but don't take their word for it, check it out yourself) - Must knock on doors or knock it in to make sure people aren't there	- It's a cold night, need to find place for people who have been evacuated	- Night (time) - Cold — 15 degrees - Dead space - Add on floor - Poor materials (wood) punk board metal girders — buckle and break under fire - Common attic in whole building	- Not keeping track of people (could be looking for people who are not there)
Initial attack	- Watch for signs of building collapse - If signs of building collapse, evacuate and throw water on it from the outside	- Faulty construction: building may collapse	- Signs of building collapse include: what walls are doing, cracks (building ready to collapse), floor groans (floor ready to cave in), metal girders (click— coming out of wall—popping), cable in old buildings holds wall together, fire collapses walls	- Ventilating the attic, this draws the fire up and spreads it through the pipes and electrical system

7.2 Appendix B: Preliminary Screening Questionnaire

1. General Information

Full Name: ____
First, Middle, Last

Address: ____
Street and Number, or P.O. Box

____
City, State, Zip Code, and Country (if not USA)

Home Phone: ( ) _________________ Work Phone: ( ) ____________________

Birth Date: _____________
Month/Day/Year

Do you wear corrective lenses when you fly?(circle one) Yes No

2. General Experience Information

Current/Most Recent Airline:____

Current/Most Recent Position: ____
Captain, First Officer, Engineer, *etc*.

Are you currently flying military?(circle one) Yes No

Years Flying Commercial (approximate): _____________

Years Flying Military (approximate): _____________

Total Hours Flying (approximate): ____________________

Total Hours Flying as Pilot-in-Command (approximate): _____________

Years of formal education: _____________(*e.g.*, high school graduate = 12)

3. Specific Aircraft Experience Information

Please list the types of aircraft on which you have experience, beginning with the most recently flown.

For each aircraft, please check the columns to indicate your approximate number of hours flying experience and approximate number of hours simulator experience.

If you were an Instructor (I) or a Check Airman (CA) on any of these aircraft, please indicate by checking the last column.

Aircraft Type	Hours in Type			Simulator Hours			I/CA ?
	< 300	300-1000	> 1000	0	< 50	> 50	

Please check the appropriate column to indicate the approximate number of years of experience you have for each of the following categories:

Specific Aeronautical Experience	Years Experience		
	< 1	1-5	> 5
Long-range, Over-water (Class II) Operations (2 engines)			
Long-range, Over-water (Class II) Operations (> 2 engines)			
Total Multi-Engine (Captain or F/O, Military or Civil)			
Glass Cockpit (*i.e.* EFIS/CRT or FMS)			

7.3 Appendix C: Phase 1 Interview Guide

1. Inform the pilot that what they tell us will be **confidential.** Ask for permission to tape record the interview. (Take good notes!)

2. State **purpose** of our research. Say something like:
   Becky, Rob, and Jason work for a small R & D company called Klein Associates. Klein Associates studies decision makers in many different domains in order to develop improved training programs and to design decision support systems. Kara works for NASA Langley's AWIN (Aviation Weather Information) program. We want to learn how pilots use weather information when they make decisions before and during their flights.

3. Obtain **background information** on pilot [review preliminary questionnaire from recruitment].
   - Where, geographically, do you usually fly?
   - How varied are the routes you fly?
   - Are there any typical weather systems along your typical routes?
   - What degree of pressure do you feel to make a trip?
   - Under what FAR Parts do you operate?
   - What types of "cargo" do you carry? Do you have any sensitivity associated with this cargo?

4. **Focus the interview**. We've read that weather is identified as the causal factor in 30% of all general aviation accidents. We have also read that most fatal weather-related accidents occur during the cruise phase of the flight.
   - Do you think these facts hold "true" for business jet operations?
   - Why? Why not?

5. Use basic questions from the **Task Diagram** figure along with the list of the 12 phases of flight to identify the most **cognitively challenging tasks for the pilot that weather conditions may impact**.

6. Use the **Knowledge Audit** to follow-up on the tasks identified with the Task Diagram. Try to elicit the pilot's expertise for **decision situations impacted by weather conditions**. Try these probes:
   - Big picture
   - Noticing
   - Past & future
   - Opportunities/Improving
   - Anomalies
   - Equipment difficulties

7. Obtain a list of all the weather products the pilot currently uses or has used in the recent past. You can use the **Weather Products Summary** sheet to help collect and/or record this information.

7.3 Appendix C: Phase 1 Interview Guide

8. **Collect an incident.** Try a probe something like this:

You can probably remember numerous flights in which you had to make difficult decisions due to the current weather conditions. We would like you to describe an incident in which your experience using weather products made a difference in how you handled the situation—a situation in which a less-experienced pilot might have made a different decision than you did. [Explore this incident for about 20-30 minutes, have some colored pencils & blank paper handy to get diagrams.]

a. Construct the incident timeline. Be sure to relate this timeline to the different stages of flight operations.
b. Review the timeline to verify the content and sequence of events.
c. Identify key decision points involving weather.
   - Did you consider other alternatives?
   - Might someone else in this situation have responded differently?
d. Situation Awareness probes:
   - What was it about this situation that let you know what was going to happen?
   - What led up to this decision?
e. Cue probes:
   - What were you noticing at this point?
   - What were you seeing (or hearing) at this point?
f. Knowledge probes:
   - What information did you use in making this decision?
   - How did you get that information?
g. Goal probes:
   - What were your specific goals at this time?
   - What were you hoping/intending to accomplish at this point?

7.4 Appendix D: Weather Products Survey

Pilot ______________________

Date ______________________

Wx **product**	What **information** does this product provide? How do you use this product?	**Where** do you get this product/ **When** is it used (pre-flight, on flightdeck)?	How **credible/ trustworthy** is the information provided?	How **current** do you need this information to be?	How **important** is this information? What impact does it have on your decisions?	Additional comments/ notes

7.5 Appendix E: Phase 2 Interview Guide

Introductions

- Background information on AWIN
- Consent forms
- Klein Associates Inc.
- Schedule for the day, facility layout, overview of interviews

Generating Cognitive Demands

- "We want you to tell us about what you do when you fly a mission. We are interested in the judgments and decisions you make throughout your typical mission that are affected by weather. We have identified eight different phases of flight. For each phase we will ask you to describe the judgments and decisions you make that are directly affected by the weather."

- Use the **phases of flight diagram** to go through each of the steps listed on the following pages (*e.g*., "For the General Planning phase, what decisions/judgments do you make that are impacted by weather?") Keep the participant focused on judgments and decisions that are related to weather. If they cannot generate their own cognitive demands, use prompts from the list.

{Additional probes for eliciting cognitive demands for the different Phases of Flight }

- **General Planning** (24-48 hrs prior)
  What time should I depart/should my passengers be ready to depart?
  What are the general Wx problems for the day going to be? Factors to be aware of in Specific Planning?
  Is the destination feasible? Go/No Go?
  Is departure point feasible?
  Is there any reason why I shouldn't fly at all? (Ex: menacing fog at departure or destination point)

- **Specific Planning** (30 mins – 2 hrs prior)
  [When is flight plan filed? How long does it take to put together a flight plan?]
  How long will the flight take?
  How much fuel will I need? (wind considerations)
  What's my best route? (wind or other Wx problems)
  Are there any Wx obstructions? (fronts, t-storms)
  Is it safe to takeoff? If not, when?
  Will it be safe to land?
  Do I need to plan for alternates? Which alternates?
  Will I be able to get back in sufficient time?

- **Taxi/Take-Off**
  IFR or VFR?
  Can pilot see runway? Runway contaminated? (ice, snow, foreign objects)
  Is there risk of icing?
  Are there dangerous wind conditions – downdrafts, windshear, etc? (aircraft configuration for taxi-ailerons)
  Request alternate runway to takeoff from?
  Are there aircraft configuration issues to think about for taxi due to wind?

- **Climb**
  Is there risk of icing?
  Is aircraft performance affected by any current Wx condition?

7.5 Appendix E: Phase 2 Interview Guide

- **Cruise**
  What's my destination like, will it still be safe to land? Is destination still viable?
  Will I need to divert to an alternate? Which alternate? (Holding and Wx problems)
  Is my route still appropriate (obstacles)? Change route?
  Is this altitude comfortable? (turbulence)
  Is my heading appropriate for navigation (wind)?
  Am I getting appropriate fuel consumption? (speed and altitude)
  Am I getting expected ground speed? Will I have enough fuel?
  Will I need to refuel on the way? If so, where?
  Is there risk of icing?
  Is there risk of lightening strike?
  Will I be there on time? Do I need to reschedule anything or communicate with work to reschedule meetings, *etc*.?
  Do I need to communicate with passengers and/or 3rd parties about passenger schedules?
  Do I need to reschedule ground transportation at primary destination; arrange ground transportation at alternate airport?

- **Descend**
  Holding? Is it safe to enter holding pattern? Do I need to reschedule/coordinate with ground transportation?
  Are there weather phenomena that will affect aircraft performance (icing, severe winds, t-storms)?
  Is there severe windshear? Turbulence, microburst/downdraft activity?
  Is my destination still viable? Do I need to divert to an alternate?
  Call FBO? Call tower?

- **Approach/Land**
  Am I going to land?
  Is my destination viable? [at this stage is the pilot already committed to land?]
  Do I need to go-around? Do I need to divert?
  Is the runway clear (visibility, ice, snow)? Request alternative runway due to Wx? (wind, runway obstructed)
  Is the ceiling OK? Is the visibility OK?
  Effects of crosswinds?
  Are there downdrafts/microbursts? Windshear?
  Do I need to request an alternate runway?

- **Taxi/Deplane**
  Obstructed runway? (ice, snow, other objects)
  Is the wind a problem (Passenger safety; am I going to get blown away; aircraft configuration)?
  Keep the plane inside or outside hanger?

- **Concurrent Tasks in all Phases of Flight**
  [These issues may be present during all phases of flight, but are they always equally important considerations? Are there some times when these issues are more critical and therefore require more apparent decision support?]
  Is the Wx affecting my aircraft performance? What are my limits before I act, related to Wx (*e.g.*, route, fuel, altitude, speed, schedule, safety, comfort, aircraft performance)
  Icing considerations?

7.5 Appendix E: Phase 2 Interview Guide

Conduct the Simulation Interview using the ACTA Simulation Interview Guide

Knowledge Audit Probes

- Anomalies - New pilots don't know what is typical, so they have a hard time identifying what is atypical. Experienced pilots can quickly spot unusual events and detect deviations. And they are able to notice when something that ought to happen, doesn't.

  Can you describe an instance when you spotted a deviation from the norm (either in weather information on the flight deck or out the window), or knew something was amiss, that a new pilot wouldn't notice? Example: After takeoff a pilot immediately noticed that the winds were not in the forecast direction on which his flight plan was based . . .

- Equipment difficulties / unreliable information - Equipment and information sources can sometimes mislead. Information received from sources such as distanced operators is sometimes unreliable. New pilots often believe whatever the equipment or other information source tells them; they don't know when to be skeptical.

  Have there been times when weather-related equipment (weather information and/or weather-compensating equipment, e.g., deicing boots) pointed in one direction, but your own judgment told you to do something else? Or when you had to rely on experience to avoid being led astray by weather information or weather-related equipment? Example: While enroute to his destination, a pilot became concerned about the reliability of the radar image he was getting on the flight deck . . .

- Big Picture - New pilots may only see bits and pieces. Experienced pilots are able to quickly build an understanding of the whole situation – the big picture view. This allows the experienced pilot to think about how different elements fit together and affect each other. This can allow them to anticipate problems that might develop in the future.

  Can you give me an example of what the Big Picture looks like for this task? What are the major elements of the weather that you need to know about and keep track of ? How does this help you know where things are headed? Example: A pilot needed to fly around a hurricane to get to his destination, which had an uncertified AWOS operating. He had to rely on a variety of different sources of information to build his understanding of the weather situation including his past experience with similar airfields and other weather information.

- Noticing - More experienced pilots are able to detect cues and see meaningful patterns that less-experienced pilots may miss altogether.

  Have you had experiences where you noticed things going on that indicated a potential weather problem that others didn't catch? Example: When he was descending through a cloud, a pilot noticed a drop in temperature and the presence of precipitation. This pattern of cues alerted the pilot to potential icing conditions—normally he would expect temperature to <u>in</u>crease as he descended.

Elicit an incident using the Critical Decision Method

"You can probably remember some flights in which you had to make difficult decisions due to the current weather conditions. We would like you to describe an incident in which your experience made a difference in how you handled the situation—a situation in which a less-experienced pilot might have made a different decision than you did." *Note: If participant has difficulty recalling an appropriate incident—use the Scenario from Hell technique below.*

- Construct incident timeline, relating the timeline to stages of flight operations
- Review the timeline to verify the content and sequence of events
- Identify key decision points involving weather
  - *Did you consider other alternatives?*
  - *Might someone with less experience have responded differently?*
  - *To what degree was your decision based on past experiences, on formal training, on other's experiences?*
- Situation Awareness probes
  - *What was it about this situation that let you know what was going to happen?*
  - *What led up to this decision?*
- Cue probes
  - *What were you noticing at this point (visual-external, visual-instruments, auditory, aircraft response)*
  - *Did you actively retrieve any additional information?*
  - *Did you retrieve any additional information for the purposes of validating information you had?*
- Knowledge probes
  - *What information did you use in making this decision?*
  - *Did you have any information that you didn't trust enough to use it in making this decision?*
- Goal probes
  - *What were the specific goals you hoped to achieve by making this decision?*
  - *What were you hoping to accomplish?*
  - *Besides weather, what other factors were concerns?*

Elicit a "Scenario from Hell"

"How would you design a weather-related "scenario from hell" for pilot simulation testing that would be difficult, but not impossible for another pilot. In particular, we are looking for weather-related events that are difficult to detect, ambiguous, insidious conditions, or conditions that, in conjunction with some other event or system failure, may result in an unsafe condition if not considered."

- Review the incident to verify the content and sequence of events
- Identify key decision points involving weather
  - *Might someone with less experience have responded differently?*
- Situation Awareness probes
  - *What about this situation that would let a pilot know what was going to happen?*
- Cue probes
  - *What would an experienced pilot have noticed at this point (visual-external, visual-instruments, auditory, aircraft response)*
- Knowledge probes
  - *What information would an experienced pilot use in making this decision?*
- Goal probes
  - *What would the pilot be hoping to accomplish?*
- Besides weather, what other factors would an experienced pilot be concerned with?
- Why would this situation be difficult for a less-experienced pilot? Where might they go wrong?

7.6 Appendix F: Simulation Interview Scenario and Material

Mission:

Current time is 4:00 pm. You have a pop-up trip taking the CEO and four other passengers to Jacksonville, FL. You arrange to depart from Norfolk airport at 5:30 pm. There is an evening meeting 10 miles from the terminal at 8:00 pm that the passengers must make. You will also need to make a return trip the following morning to be back in Norfolk for a noon meeting. At the meeting, the CEO will discuss the bonus plan for the pilots and you must be there to collect.

You are on the runway and making final preparations for take-off. Outside your window you see a windsock flying horizontal indicating that winds are gusting out of the Northeast at about thirty knots. It has been drizzling off and on during the day, however, you see no drizzle on the runway. Visibility is about seven statute miles and it is slightly overcast with a low ceiling at about one thousand feet. Current temperature is two degrees Celsius with a dew point of one degree Celsius.

As you ascend to cruising altitude at flight level three five zero you're flying in and out of patchy clouds. The weather outside your window is clear now, but there are t-storm cells to the South forming large convective cumulonimbus clouds. The temperature outside is about negative forty-seven degrees Celsius. The flight is getting a little bumpy and passengers are beginning to make comments about the uncomfortable ride.

You are listening to pilot frequencies to try to get a feel for what's ahead. You hear, "Charleston Northward at two two five zero, moderate turbulence at flight level three three zero, B757."

Above flight level two four zero, you can see towering cumulous cells along your flight path Northwest of Wilmington, approximately 25nm South of Wilmington, a large system due East and 50nm from Charleston, and a smaller cell almost directly over Charleston International.

Another pilot report indicates, "Dash Eight reported moderate mixed icing, forty miles East of Brunswick between six thousand and one zero thousand feet at two three one zero Zulu."

When you start your descent towards Jacksonville, a pilot report conveys, "Moderate turbulence at two three two zero Zulu, on approach to runway 31 inside VOR at Jacksonville International, reported by DC8."

Current conditions at Jacksonville indicate winds out of the Northwest at thirteen knots and gusting to twenty-one knots. There is a light rain and visibility is about two statute miles. Cloud ceiling is at one thousand two hundred feet. Current temperature is five degrees Celsius, with a dew point of four degrees Celsius.

Materials Provided:

Preflight	Enroute	Approach	Charts
Scenario Mission	PIREPS - ride reports	ATIS recordings	Approach Charts
Aircraft Description	Visual descriptions	PIREPS - terminal area	Airport Diagrams
Standard Briefing (DUATs encoded text)	FW scripts	METARS	IFR enroute low alt.
Weather Graphics:			IFR high altitude
Current Surface			Sectional charts
24 Hour Surface			
48 Hour Surface			
Current Flight Rules			
Doppler Radar			
Lifted Index			
Satellite Image			
Weather Hazards			

7.7 Appendix G: Post-Experiment Questionnaire

Dear Participant:

This questionnaire complements the interview process in which you have just participated. Your responses on this questionnaire will help us interpret the results of your interview data and help us address some issues that we didn't have time to cover in the interview process.

The questionnaire has the following sections: 1) Characterizing Business Jet Operations, 2) Personal Limits, 3) Weather Flying & Aircraft Characteristics, 4) Weather Training, 5) Use of Weather Products, and 6) Weather Information Requirements for Business Jet Operations. The *Characterizing Business Jet Operations* section will help us get a better feeling for your operations and allow us to better interpret your interview results. In addition, it will help us define the special requirements and challenges of the business jet community. The *Personal Limits* section will help us understand how you might constrain how you fly as a function of weather and atmospheric conditions. The *Weather Flying & Aircraft Characteristics* section will help us understand how you use your knowledge of your aircrafts' capabilities, and the equipage of your aircraft to make decisions in challenging weather situations. The *Weather Training* section will help us interpret your interview and questionnaire responses. In addition, we will better understand the breadth and depth of weather-specific training provided to business jet pilots. The *Use of Weather Products* section will help us understand the weather products (services, PIREPS, AIRMETS, graphics, …) you use, and the degree to which you find these products reliable and useful. Finally, the *Weather Information Requirements for Business Jet Operations* section will be used to complete a study of pilot weather information requirements by adding the needs of business jet pilots to those compiled for Commuter, General, and Transport pilot populations.

Please complete this survey and mail it back to me in the attached self-addressed and postage-paid envelope. I hope to receive all responses back by February 29. If you are unable to return the survey before then, please simply call me and tell me when you think you will be able to return it.

We are looking forward to developing prototype concepts for improving weather decision-making based on the interview and questionnaire results. We hope to see you again in the development and evaluation phases of these concepts. Thank you again for your participation in this study. Your time and efforts are much appreciated.

Sincerely,

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7.7 Appendix G: Post-Experiment Questionnaire

1. Characterizing Business Jet Operations

1.1 Owner/Operator Characteristics:

1.1.1 Size of Fleet: _________ aircraft owned _________ leased

---

1.1.2 Frequency of fleet use: _________ trips per _____________

1.1.3 Support structure (circle those you have in-house):
dispatcher, initial training, recurrent training, maintenance, procedure/ checklist development

---

1.1.4 Would you characterize the aircraft you fly as: < 20,000lb 20,000-40,000lb > 40,000lb

---

1.1.5 Do you share aircraft with other organizations? Yes No

1.1.6 Pilots are: Owners/Low Time Professional Crew

1.1.7 FAR Operations (circle all that apply):

121 135 91

1.1.8 Typical crew: ________ pilots + _______ non-piloting crew

1.2 Pilot Perspective:

1.2.1 Advantages of being a *business* jet pilot:
1.2.2 Disadvantages of being a *business* jet pilot:
1.2.3 Tasks you do beyond those of a commercial pilot:

7.7 Appendix G: Post-Experiment Questionnaire

1.3 Mission Characteristics:

1.3.1 Typical types of passengers:

1.3.2 Typical reasons for flights:

1.3.3 Amount of notice usually given for a flight: _____ to _____ (range), usually around ______

1.3.4 How often are last minute changes to the trip? every time 1/2time never

---

1.3.5 Typical trip length > 300nm, > 1000nm, > 2500nm

1.3.6 What % of your trips are to a novel destination? < 1% < 10% ~ 50% > 75%

1.3.7 To how many different "typical" destinations do you fly: _________________

1.3.8 Do you fly international trips? NO / YES: To where? _____________

1.3.9 Do you fly over water trips? NO / YES: How long over water? _________

1.3.10 Add any goals that are missing from the following list, and rank order these goals according to how important they are for your typical mission (*i.e.*, more important goals may be attained by sacrificing less important goals).

_____ precision of ETA at remote destination

_____ precision of ETA on return to home base

_____ fuel economy

_____ aircraft operating costs

_____ company transportation costs as a whole

_____ flexibility in mission

_____ passenger comfort

_____ ________________________ (other)

7.7 Appendix G: Post-Experiment Questionnaire

1.4 Operational Elements

1.4.1 Factors you consider in planning a flight (especially any unique to business operations):
1.4.2 Define a "good weather day."
1.4.3 What is the ratio of flights that you fly in bad weather days (less than "good weather days").
1.4.4 What would be "normal" bad weather? (you'd go, you think you'll be fine, it's just unpleasant).
1.4.5 What would be "alerting" bad weather? (you'd go, but think you might be coming back).
1.4.6 What would be the lower end of "prohibitive" bad weather (you wouldn't go)?

1.5 Problems

1.5.1 What are the biggest problems associated with business jet operations within your operational center?
1.5.2 Please describe the biggest problems associated with the aircraft you usually fly.
1.5.3 What are the biggest problems of business jet operations as part of the NAS?

7.7 Appendix G: Post-Experiment Questionnaire

2.0 Personal Limits

Personal limits are constraints on whether you fly, how you fly (*i.e.*, manage the aircraft), as well as how you would perform other pilot duties during a mission (*i.e.*, communications, systems management, task management). As such, when the conditions of a Personal Limit are met, a pilot will operate at a point inside the boundary established by "possible operations" (*i.e.*, those permitted by FARS, those made possible by aircraft capabilities). Personal limits can be expressed in terms of IF/THEN rules: the "IF" describes the conditions under which you would exercise this limit, the "THEN" describes how you constrain your behavior because of this limit. Personal limits can be distinguished from "Organizational Limits." A Personal Limit is one that you have determined through your own experience, by listening to others' experiences, or that you have derived from your basic knowledge of weather and atmospheric phenomena, and aircraft performance characteristics. An Organizational Limit is one that has been provided to you through formal training, company procedures, aircraft pilot operating handbook.

Please use the following table to describe the Personal and Organizational Limits that constrain your behavior beyond what is aerodynamically possible and permissible by regulatory agencies: 1) Indicate whether the limit is Personal (P) or Organizational (O), 2) Describe the task or decision that the limit affects, 3) Describe any Weather/Atmospheric Conditions that pertain to this Limit, 4) Describe how this Limit alters whether or how you conduct a mission.

P/O*	Your Personal/ Organizational Limit ("IF")	Weather / Atmospheric Conditions	If weather/atmosphere is worse than limit, what do you do? ("THEN")

3.0 Weather Flying & Aircraft Characteristics

3.1 Please describe equipment (standard or special) that is on your aircraft that allows you to fly more safely in different weather conditions.

Weather / Atmospheric Condition	Aircraft Equipment

3.2 Please describe how performance characteristics of the aircraft you usually fly affect how you fly in weather conditions.

Weather / Atmospheric Condition	Aircraft Performance Characteristic

7.7 Appendix G: Post-Experiment Questionnaire

4.0 Weather Training

It is important for us to be able to interpret your responses during the interview and on this questionnaire in terms of your knowledge of weather flying. In the areas below, please list the formal classroom training, instructional videotape, computer training, and readings from which you have acquired skills and knowledge for flying in weather, for using weather services, and for using onboard weather-related equipment (in particular, onboard weather radar).

	classroom training	videotapes	computer-based training	readings
flying in weather				
using weather services				
using onboard weather radar				
using other onboard equipment				

5.0 Your use of Weather Products

The purpose of this questionnaire is to survey how biz-jet pilots use weather products (*e.g.*, surface-level charts, the weather channel, internet) and weather resources to make decisions during flight missions. We want to know which products and resources biz-jet pilots use, where they get access to these products and resources, what information pilots look for in the products and resources they use, and in which stage of the mission the information is useful. The next page shows a table with six columns and multiple rows underneath. At the top of each column is a specific question related to specific weather products that you as a biz-jet pilot would use before or during a mission. These columns are:

1. Wx **product.** This could be a specific product (*e.g.*, pressure charts for the entire U.S.) or specific resources of where you get your weather products (*e.g.*, a weather internet site, on-board radar, ATIS).
2. What **information** does this product/resource provide? How do you use this product/resource?
3. **Where** do you get this product (from the internet)? **/ When** is it used (during pre-flight)?
4. How **credible/trustworthy** is the information provided?
5. How **current** do you need this information to be?
6. How **important** is this information? What impact does it have on your decisions?

Please start by identifying each weather product or resource you use during a typical mission, and then answer all subsequent questions about that specific product or source. We define a mission in the following order: General planning (24-48 hrs prior), Specific planning (1-2hrs prior), Taxi out and take off, Climb, Cruise, Descend, Approach and Landing, and finally Taxi in and deplane. We recognized that this may not be exactly what you define a mission to be, but would like you to focus on these stages.

7.8 Appendix H: Individual Cognitive Demands Tables

Subject 1 - Cognitive Demand Table

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	General planning—24-48 hours ahead--What will wx be like enroute and at destination?		Wx channel On-line wx sources		
	Specific planning—12hours ahead—what are current conditions at destination?	Wx affects altitude, route selection and fuel requirements	NWS forecasts On-line wx sources Report from FBO at destination	Contact FBO at destination	May not contact FBO at destination and just rely on FAA briefing May not be able to interpret local Wx information if he's never been to destination airport before May not know the depth of information available
	Preflight planning—1-2 hours ahead—should I brief Passengers about likely delays?				
Take-off			Runway conditions, winds, ceiling, visibility	Gets ATIS report before he starts the engines	
Climb					
Cruise	Do I need to adjust my speed?	Wx affects aircraft performance (depends in part on aircraft capabilities); Wx information obtained during specific planning may be "old;" On long flights, winds aloft affect fuel consumption and route selection	Fuel consumption Forecast winds Distance left to travel	May call FSS (for longer flights) Speed across ground is different than air speed; he uses headwind instruments to determine his ground speed When necessary to avoid refueling stop, he will slow down to reduce fuel use	May have to stop and refuel (and lose more time than if he had just slowed down)
	How do I avoid t-storm cells?		On-board radar		

7.8 Appendix H: Individual Cognitive Demands Tables

Descent/Landing	Which frequency should I use to get Wx information?			Uses ATIS information or AWOS He will change his radio freq to get different sources of Wx info	
	Is wx okay for landing at destination?	Landing at small, uncontrolled airports is challenging (because there may be no one to provide wx update); Airport may have uncertified AWOS operating	Pireps Wind speed Wind direction Capabilities of his air craft	Contact tower or FBO for Wx update (for airfields w/o tower he uses AWOS or UNICOM frequency) When flying to uncontrolled airport he does more in the specific planning stage In bad wx, he sets more restrictive limits on wind speed/direction He considers the capabilities of the AC he is flying; Thinks about landing at similar airports in the past (Ex: Hilton Head and St. Simons Is)	May lack confidence in his flying abilities
	Do I need to change destination?			Keeps alternate destinations in mind	
	Should I go into a holding pattern or divert?		Fog at original destination Passengers needs	If diverting, need to rearrange ground transportation	Novice may give in to pressure from passengers to land at original destination
	Will I be able to see to taxi?		Moderate to heavy rain on the ground His flying skills	Rely on non-flying pilot to monitor Wx situation (although "chief" pilot makes the decision)	Novice may not know how to separate his flying skills from weather factors (skilled pilot will know if a missed approach should be attempted again because the wx may change or if it is a limitation of his piloting skill

7.8 Appendix H: Individual Cognitive Demands Tables

Subject 2 - Cognitive Demand Table

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	What's the wx at my destination?			Watches Wx channel or gets NOAA radar and satellite images on internet Gets forecast for destination from FSS for his flight plan	
Takeoff	Can I take off?	Wind sheer (downbursts) Icy runways		Gets information from ATIS	
Cruise	Avoiding turbulence		Jet stream Vertical clouds	Look out the window Listen to determine what other pilots are doing	
	Avoiding t-storms		Onboard radar Vertical cloud formations	Look out the window Listen to determine what other pilots are doing-HIWAS Took a course on how to interpret on-board radar pictures—at certain elevations you can pick up ground returns (from his experience)	
	Is there an icing problem at low altitudes?		Low cirrus clouds Aircraft capabilities	Look out of window	
	Should I slow down to see if Wx at destination will clear?			Call ATIS 100 miles out Go into holding pattern or just reduce speed	
Descent/landing	Can I land?	Wind sheer Icy runways Ceiling, visability		Observes from about 100 miles out. Uses ATIS via radio Check wx at airports near his destination. Call FBO at destination Rearrange when on ground transportation if diverting	Novices fail to anticipate –might not rearrange ground transportation until he arrives at different destination
	Is there an icing problem?		Aircraft capabilities		

7.8 Appendix H: Individual Cognitive Demands Tables

Subject 3 - Cognitive Demand Table

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	Is the route safe?	Wx is changeable and forecasts have limited accuracy (in terms of resolution and shelf-life)	Wx briefing; wx channel, internet wx		
	Is the destination safe?	Wx is changeable and forecasts have limited accuracy (in terms of resolution and shelf-life)	Wx briefing; wx channel, internet wx		
	Is destination close to minimums?	FSS not reliable because they rely on automated weather obs equipment and don't have eyes on; need to check regularly in case they change, esp. if the ATIS has a lot of amendments (*i.e.* Wx changeable)		Check more frequently if numbers are close to minimums; check after the hour for the latest updated ATIS	Novice probably would not fly if numbers are close to minimums
	Determining take off time	Weather may cause delays		Leave an hour earlier if weather is a possible factor (rule of thumb: if severe Wx approaching, leave one hour before its predicted arrival)	
	Will aircraft performance be an issue?	A/c performance impacts fuel consumption and ETA	Temps (hot and cold)		
	Do I try to go through the gap in the Wx that I see on my radar?	Don't always know how bad the weather is in that "gap"; don't always know what's on the other side of the gap	Radar picture; sensitivity of the passengers		

7.8 Appendix H: Individual Cognitive Demands Tables

Concurrent	Will windshear be a problem?	If you misjudge the possibility of windshear, the consequences are severe. No direct indication of severity of wind shear.	Wind speed, direction, changeability; GPWS indications; FMS indications (estimated fuel consumption based on winds aloft forecast is off); t-storm activity increases likelihood; FW; ATIS, PIREPs; visual cues (trees blowing, rain direction, waves on water)	Carry extra speed to overcome loss in lift due to change in wind direction; add power; recalculate fuel usage; change altitude for better winds	
	Will icing be an issue?	In clouds it's hard to visually see icing; no direct indications of icing; if there's a temperature inversion, you may get unexpected icing on descent; esp. tricky if flying slow (in a hold or on descent) because lift is impacted by icing on wing surfaces	Temp; precipitation or moisture (clouds, rain, fog);	Look for ice on windshield, on wings, on boots; if skimming or going through clouds (and temps are appropriate 10 degrees C or below) put deicing on as a ROT; disconnect autopilot (so that it doesn't compensate for loss of trim, with-out pilot realizing it)	
	Can I trust my radar picture?	Sometimes it "paints" ground clutter and that can be confused with precipitation	Angle of tilt on the radar	Adjust tilt of radar; don't trust it beyond 100 miles	May not know how to use radar properly

7.8 Appendix H: Individual Cognitive Demands Tables

Subject 4 - Cognitive Demand Table

Phase of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	How much fuel to carry, Do I want to carry "bingo fuel" - extra fuel to give me options of different destinations.	Constrained by aircraft performance; aircraft doesn't fly well at high altitude with warm air – poor speed It is difficult to predict winds aloft It is difficult to predict if pilot will need to hold/divert Have to be able to plan accordingly so as to land with a min. amount of fuel	Temperature and winds at specific altitudes Number of people flying Distance of flight	Don't carry "bingo fuel" if doesn't need it – adds extra weight, which means restricted to certain altitudes	Carry too much fuel, can't change to higher altitude
	Fly in poor visibility conditions (e.g., 300ft, ½ mile)	Difficult to see runway or other objects	What are the ceiling and visibility readings What is the temperature if going thru clouds – icing problems	Set cockpit for emergency return Turn on anti-ice before takeoff	
	Route planning	Universal service gives most direct flight, which could go right thru storm center – have to be aware of that	Where are storms, how are they moving, what speed are they moving? Where are fronts, squall lines, and pressure cells?	Call Universal Flight Service to speak with experienced meteorologist – more reliable Fly around bad wx. Summer time watch for wx in "tornado alley"	
	Looks at general wx forecast concerns (departure and destin.)		Satellite, surface maps, Knowledge of Land Topography	Compare 10 minute-old data to own big picture Compare own numbers with flight plan; if	Misinterpret wx data or what wx might be in future – which leaves pilot unprepared

7.8 Appendix H: Individual Cognitive Demands Tables

			What are Minimums? Tops of clouds and height of tropopause?	anomalies spotted, look deeper Call Universal Flight Plan Service – more reliable talking to real wx forecaster Build big picture – with radar summary and graphics.	Don't develop big picture
Takeoff **"business attitude" approach**	Consider a "rejected takeoff" prior to decision speed	Hot weather – thermals coming off runway create easier lift, and therefore less decision time and room for correction Short runway – less time for decision to be made Winds in terminal area	Convection in terminal Spontaneous lightning Mechanical issues		"can do" attitude can cloud good reasoning
	Checking for contaminated runway (ice, deer)	Flying into an unfamiliar airport, perhaps no FBO on ground Short runways are a problem – may have to change numbers manually in own head if icing on runway Need more runway when anti-ice is on	Ambient air temp Traction is poor Braking action reports Altitude of runway PIREPS	Visually inspect Use anti-ice for takeoff Use Field Length Regulation Tables	
	Check that configuration of aircraft and cockpit is set [This is procedural]		Flaps up, gear up/down, etc…	Look out window, use gauges	
Climb	Looping around inbound traffic	Sound abatement			

7.8 Appendix H: Individual Cognitive Demands Tables

	Set radar scale	Low watt radar is not functional beyond 50miles, it paints too much, doesn't discriminate well between precip and other clutter	Have to play around with power level to get good setting and useable picture T-storms pop-up quickly and they can be difficult to pick-up with low-watt radar	Keep on same setting and look for changes	Jump back and forth between settings
	Above FL250, ask for direct route	May have to change route because of wx ahead	Knowing where poor weather is	Stay on upwind side of the storm	
Cruise	Check to see if wx at destin. is poor, may call FSS to check for current wx	Some FSS have live radar, some don't	What are current trends; getting better or worse?	Check to see if they should slow down, change destin., reassess fuel, estimate hold time Talk to FSS just after the hour – FSS amends the ATIS if wx is getting worse or better during the hour Talk to another airport	May rely on earlier forecast data instead of updating along the way
	Watching for turbulence	Can't see it, clear-air turbulence - happens after a front has passed through or due to mountains disturbing air flow Weight of plane and amount of fuel affect how to react	Eddies are formed on each side of jet stream Tops of t-storms, overall cloud tops Turbulence also found at converging jet streams Land topography – mountain ranges create turbulence Wind and temp at each altitude	Ask ATC what altitude is smooth Listen for PIREPS	Ignore PIREPS at different altitudes Stay at wrong altitude Not inform passengers of bumpy ride

7.8 Appendix H: Individual Cognitive Demands Tables

	Request wx avoidance, change in altitude	Aircraft performance restrictions	Looking for thunder heads Avoid icing conditions Temps under 10 degree Celsius	Don't want to go too high, may stall out Use de-ice through "soggy clouds" Try to get 25-30 miles downwind of convective wx or stay on the upwind side of wx cell	
	Reroute	Difficult to anticipate changing wx	Poor weather en route (t-storms, icing, turbulence and winds)	Decide early if you think you want to change route	May not petition ATC soon enough for reroute
Descent/Landing	Call for auto wx report at destin. to see if they can initiate landing			Perform this 150-180 miles out (get sky conditions, precip., pressure)	
	Non-precision approach at unsupported airfield	No help on the ground Don't know what runway conditions are	What are minimums? Temp and dewpoint spread, and wind (direction and speed)	Conducts visual inspection of runway "fly by" Better to fly on autopilot, better SA	
Taxi	How long to stay at destination?	If no de-icing capabilities, deplaning can be tricky			
Taxi/Deplane	How long to stay at destination?	If no de-icing capabilities, deplaning can be tricky			

Other	T-storms		Deep Low cell indicates lots of turbulence Backside of a low, has residual effects Looking for thunderheads, if there is growth or dissipation- is towering then they are at mature stage and have much energy What's the distance from the plane	Listen or look for severe wx reports PIREPS Change altitude or go around	

7.8 Appendix H: Individual Cognitive Demands Tables

Subject 5 - Cognitive Demand Table

Phase of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	What's my route?	Need to know where any weather is, also any special airspace restrictions; may be a pop-up trip with only a couple of hours notice	WSI Wx briefing; Wx channel; look out the window	Route upwind of the weather, behind the fronts; carry extra fuel in case need to hold or divert;	Misjudge the severity of the weather
	How much extra fuel will I need?	Need to anticipate potential delays for holding en route and at the destination; need to anticipate aircraft performance based on payload and use of anti-icing	Wind; Payload; Potential delays at destination due to Wx; Icing forecasts (precip and temps); Icing PIREPs and radio chatter	Carry extra fuel (half hour or 500lbs)	Not understand impacts of weather on aircraft performance (e.g. deicing equipment)
	Are there any weather concerns today?	Depends how recent the forecast is; PIREPS can be unreliable; forecasts can be unreliable	WSI Wx briefing; pilot chatter on radio and PIREPs	Look for key information in Wx forecasts (e.g. use of the words "severe"), anything relating to departure or destination fields, or en route; fast changing weather; wx near minimums	Not recognizing the "key" aspects of all the information provided
	Is the destination viable?	Have to anticipate Wx at the destination at arrival time; forecasts are unreliable	METARS for destination; AIRMETs/SIGMETs for destination; PIREPs for destination; delays at destination	Read Wx briefing, listen to radio chatter	
	What additional precautions do I need to take?	Don't know all the possible problems			

7.8 Appendix H: Individual Cognitive Demands Tables

Taxi/Takeoff	Can I handle the crosswind?	Hard to anticipate gusts or wind shear; crosswind component is dependent on angle &/ speed of winds (no direct crosswind component indicator)	Wind direction, wind speed, pilot and ATC reports of crosswinds (chatter and PIREPs); can I see bad weather (dark menacing clouds)?	Request different runway; know aircraft limits and personal limits; use "split" controls procedure (one pilot has throttle and rudders, the other has the yoke)	Novice may not be familiar and/or comfortable with split-control procedures (esp. if flying with a crew member for the first few times)
	Should I turn on the anti-icing equipment?	Turning on anti-icing can affect aircraft performance and make your ascent slower, thus providing more opportunity for icing, it's trade-off	What is the temp?; Is there precip/moisture? Length of runway; is windshield icing up (look at windshield icing light reflector)	Use radar to look for precipitation in the area, use FMS or TAF to get air temperature; listen for PIREPS, or ATC reports of icing; add .5hour (500lbs) fuel	Novice may not realize the impact of the deicing equipment on climb performance; may not realize to check if still have enough runway to take off
	Can I taxi out in this?	Potential for damaging brakes, wheels, flaps; potential for loss of braking ability	Snow, slush, or standing water on the tarmac	Taxi with flaps in; listen to PIREPs and braking reports	Novice may not realize that slush and snow can damage external aircraft parts
	Do I need to be careful of runway contamination?	Can't see standing water; no direct indication of length of runway and aircraft performance limits	Airport facilities directory for runway length; look for standing water; get PIREPS and listen to radio chatter concerning snow, slush, water, other contaminants)		
Climb	Should I turn on the anti-icing?	Anti-icing impacts aircraft performance (see above)	Temp? Moisture? Aircraft performance characteristics and feel; length of runway;		Novice may not realize the impact of the deicing equipment on climb performance; do not check to see if still have enough runway to take off
	Do I need to deviate immediately to avoid a Wx cell?	Requires clearance from ATC to get a quick deviation	Does radar or ATC indicate close t-storm cells/severe weather (wind shear); WSI;	Request (before take off) detour for immediately after take-off	May not want/know to make a request for deviation so early

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			onboard radar; stormscope		
	Will wind shear be a problem?	There is no direct indicator of windshear in any Wx forecasts or indicators on the aircraft (GPWS provides some information)	Wind direction, speed; sudden or dramatic changes in these values; convective weather systems in the area (t-storms) from FMS, looking for ominous clouds, feel, and windsock	Watch wind indications very closely for sudden changes or shifts (FMS provides crosswind component); use split control procedures	Novice may not be familiar and/or comfortable with split-control procedures (esp. if flying with a crew member for the first few times)
Cruise	How should I avoid any Wx cells?	Hard to know the range of the Wx (lateral and vertical) and the extent of the Wx around the main cell; squall lines may require a large detour; radar cannot always penetrate Wx cells and may not provide an accurate image of the extent of the cells; hard to estimate cloud heights	Radar indications (from preflight, onboard, and ATC); look outside; listen for PIREPS and radio chatter;	Estimate the height of cloud tops; manually manipulate radar to estimate cloud heights; ask FW for tops; 10-20 miles lateral clearance, 2000ft vertical clearance; look for “steep” gradients on the radar, avoid these areas.	May not be able to manually manipulate the radar to estimate cloud tops and required altitude for clearance
	How can I make the ride as comfortable as possible for the passengers? (i.e., avoid turbulence)	You cannot see turbulence and there are no direct indicators of turbulence in the weather forecasts or from indicators in the aircraft; AIRMETs/SIGMETs and PIREPs are unreliable	PIREPS; radio chatter; feel; ATC reports; AIRMETs/SIGMETs (not very reliable)	Request ATC reports; listen to chatter; slow air speed; deviate around clouds/ sources of turbulence	May not consider passenger comfort
	Is my destination still viable?	Requires anticipation and projection, plus interpretation of PIREPS and radio chatter around the	Radio chatter for destination; delays and holds at destination; ATC reports; FW reports	Listen to ATIS asap; contact FW; slow down, reroute, hold	

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		destination			
	Do I still have enough fuel to make the trip? How am I doing?	Headwind component may be different than forecast; delays at the destination may require holding; aircraft performance is affected by anti-icing equipment turned on	FMS; length of delays and holds at destination; distance to alternate; length of detours to avoid weather; look for changes in wind and impact on speed and ETA (on FMS) esp. compared to expectations/planning	Slow down, reroute, hold; change altitude to reduce headwind (especially over 25-30kts)	May not constantly check for unexpected headwinds or changes in ETA and available fuel status
Descend	Do I need to turn on my anti-icing equipment?	Hard to tell if icing will be a problem	METARS at destination; PIREPS; radio chatter	No cost for aircraft performance by turning it on (it's almost a non-decision)	May not realize there is no cost to turning it on on descent
	Is there a possibility of windshear that I should prepare for?	Windshear is hard to predict/anticipate and there is no direct indicator of it on the aircraft and you cannot see it	Sudden or dramatic changes in wind speed and wind direction over time	Use radar to find convective weather; if crew disagree on severity, "go conservative route"; watch GPWS	
	Do I need to brief Passengers for a rough ride? Will there be turbulence?	Not difficult!! Usually easy to do it, be conservative and don't get caught out	Is the ride getting bumpy? Will Passengers comfort be affected? Will destination be affected? Will schedule be affected?	Always keep passengers informed, for comfort and safety. Inform them if more turbulence than expected. Also, if there's a need to divert, they may want to help make that decision	
Approach/Land	Is my assigned runway OK?	Need to check several sources of info: braking reports, runway contaminations, airport facility directory and NOTAMS	runway direction; wind direction/speed; wind shear indications; length of runway; runway equipment (ILS); visability and ceiling conditions	Check runway direction and crosswinds. Limits are 25 knots crosswind component	May not check runway direction versus wind direction
	How is the visibility? Do I need an ILS approach?	Visibility and ceiling can be dynamic and changeable and are hard	runway equipment (ILS); visibility and ceiling (MVFR/IFR	Check airport facilities for landing; check ATC for current vis and	

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		to forecast and ambiguous to report	conditions??)	ceiling	
	Is the runway contaminated? Is braking going to be a problem? (wet runway)	Need to check NOTAMS, listen for or request PIREPS	PIREPS; braking reports; ATC; precipitation	Check ATC for braking reports, and runway condition	
	Is Wx changing/changeable at the destination field?	Hard to anticipate/project what the destination Wx is, esp if info is sparse	ATIS; ATC; PIREPS; radio chatter	Listen to ATIS and figure out how many amendments have been made in previous hour	
	Will windshear be a problem? (crosswind)	No indicators, hard to predict, cannot see it	PIREPS; ATC reports; radio chatter; FMS readouts	Use radar to find convective weather; if crew disagree on severity, “go conservative route”; watch GPWS; Check runway direction and crosswinds. Limits are 25 knots crosswind component, 10-15kt discrepancy in speed changes, and rapid shifts over ~ 20 degrees	GPWS is less accurate or useful the further you are from the field; it’s a gray area as to how to interpret the significance of GPWS alerts further out
	Do I need to think about anything specific for a possible missed approach?	Need to judge how likely a missed approach could be based on the weather and other factors (e.g. something on runway)	Severe Wx indicators?	Listen to radio chatter and PIREPS for other recent missed approaches	
Taxi/Deplane	How are my brakes?	No indicator	Braking reports;		
	How are the ground conditions?	Hard to tell by looking, hard to see black ice, or depth of standing water.	PIREPS; braking reports; ATC reports	Listen to PIREPS	
	Do I need to make a quick turnaround?	aircraft must be kept “alive” while the passengers deplane, and reduce wing icing etc.		Keep the engines alive while on the ground, so they don’t get cold	May not be thinking that far ahead

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Concurrent	Do I need to brief the passengers?	Easy	Is the schedule in jeopardy? Will the Wx impact comfort? Will I have to divert to a new destination/alternate	Ask for input if schedule, destination, or comfort may be affected, if their safety may be affected	May not communicate or ask for input for alternate destinations
	What's the buzz from other traffic?	What do others report?	Radio chatter; PIREPS	Listen to radio chatter on your route and at your destination	
	What's the destination like, will I have to hold?	How busy is the destination, is it likely that I will have to hold?	PIREPS; ATC reports; ATIS; reports of holds and/or delays; call FW	Get forecasts from WSI; radar (onboard and WSI); listen to chatter at destination; listen for hold/delays at destination	Not paying attention to chatter

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Subject 6 - Cognitive Demand Table

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	Determine best route to destination	Must continually get updated info and possibly revise plan enroute	Radar Departure and destination Wx Cloud tops, winds aloft, SIGMETs, turbulence	He builds his big picture of Wx starting with radar and satellite of US He looks at movements of fronts and locations of t-storms He then reads hard text readouts to check Wx at departure and destination and 3-5 stations "behind" the Wx to see what's moving in his direction	May be too mission oriented, press on or over extend in bad Wx; May not plan for contingencies
Take-off	Should I delay takeoff?	Have to plan around hold over times	Winter: freezing rain, snow Summer: squall lines, t-storms Wind sheer, crosswinds Runway condition	Wait awhile before take off, because wind sheer tends to move quickly Determine if immediate return is possible Brief passengers about turbulence	Fail to get wind sheer reports Not plan for immediate return Not know limits to his flying ability (not the AC's ability)
Take-off	Which direction do I take off from?		Cross winds Wind sheer		
Climb	Avoiding turbulence	Weather is dynamic Corridors may be saturated with other AC	Reports of t-storms Reports of icing	Builds big picture (in his head) of Wx ahead Checks for proximity of convective activity and how it is moving Uses TCAS to determine how other AC are moving around Checks Pireps Ask ATC for reroute Looks for leverage points if he has to return soon	Not build picture of Wx ahead Not turn on anti-ice Improper use of radar

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Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Cruise	Avoiding turbulence/storms	Usually it's not difficult, he can fly over it Sometimes there is a pressurization problem so he has to fly at a lower altitude and go around the Wx	Cloud lines Mountain "waves" Radar—turbulence indicator Pireps Fuel state Green clouds indicate hail	Fly over the Wx Call tower for change in altitude or vector Don't fly under cloud "anvil"	Staying VFR Fail to detect embedded t-storms on radar Miss subtle visual cues out the window (like green clouds) Let fuel run too low Be less proactive Let mission requirements dictate rather than safety
	Thinking about approach/destination change if weather is bad				
Descent	Should I put on the anti-icing or wait for the automatic de-icing to start?			He plans for the worse and starts the anti-icing if he thinks icing may be a problem	Trust the computer to start the de-icing when necessary
	Convective activity?		location of activity, width, height of convective activity? Comma shaped convective activity Reports from other pilots (from AFIS or over radio)	Checks radar for convective activity May fly around convective activity Ask Center where other pilots have gone through in last 30 minutes	

7.8 Appendix H: Individual Cognitive Demands Tables

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Landing	Should I hold? Divert? Or Land?	Wind sheer Down bursts Runway conditions Potential for hydroplaning if excess water on runway	Wind direction on runway Wet runway Gusty winds Dew point spread	He carries an extra hour of fuel He won't land on less than 5000ft runway He finds out about the availability of deicing equipment and hanger space during planning Waits until someone tries to land Lands "hard" to avoid hydroplaning on wet runway May hold at higher altitude to wait out turbulence	Won't check for wet runway Not ask for windshear report May not de-ice engine (just wings)
Taxi/deplane	Should I put the plane in a hanger?		Icing Hanger space Departure time		
Other	Should I brief Px about wx conditions				

7.8 Appendix H: Individual Cognitive Demands Tables

Subject 7 - Cognitive Demand Table

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	Where am I going? (domestic or international)	International flights are usually long and have different wx patterns Difficult to anticipate international wx; during long flights the wx changes more frequently Language barrier and airspace laws are specific to certain countries; may not be able to reroute over or land in certain areas	Find out what tops of clouds are	Call flight control (ATC) to see how other aircraft are doing and what they are doing (jammed up) Try to get live wx radar before takeoff Look at cloud top report Fill aircraft full of fuel on international flights – can come in handy for unexpected events	Don't get PIREPS Don't get SIGMETS, which could suggest a route change
	What is the wx doing at destination, departure, and along the route?	Air traffic congestion (in and out of East Coast)	How much moisture is out there? Tight groups of t-storms indicating pop-up t-storms, fast growing – may be hail Winds and especially gusts of wind at departure and destin.	If domestic, gets briefing over the phone from FAA on conditions at departure and destination, NOTAMS, and forecast. If wx looks bad call another wx service to get more information or call FAA the night before Use Universal Wx in Houston or Global Wx in Seattle (real forecasters) FAA relies on NWS for general forecast info (private pilot service provides more specific	Rely too much on static information Don't get PIREPS

7.8 Appendix H: Individual Cognitive Demands Tables

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
				info) May speak to a meteorologist from (can do this on the ground or enroute) Puts radar on while still on ground and points his plane in direction of takeoff so can see what's out in front	
Takeoff	Where do I go if there is a problem on takeoff (can you get back?)	Turbulence Contaminated runway Windshear concerns (how will aircraft perform) T-storms close to field make it difficult to turn back	Direction and speed of winds Temperature (if low temps potential for icing). Temp-Dewpoint spread Turbulence reports Wet runway	Takeoff with anti-ice on Turn continuous ignition on so engine won't flame out if fly through a small t-storm	Try to take off in impossible conditions
	What should I set takeoff power setting to?	Gusty winds Aircraft performance constraints (how will it affect fuel load?)	Icing, winds		
	Is the runway too contaminated?	Some part of the runway may be more slippery than others, tough to see this	Are the runways clean and dry? What part of the runway is slippery?	Look out window	
	Will the de-icing fluid last long enough? Do I need anti-ice on?	Delays caused by ice and snow and sleet, build up on wings Different fluids last			No knowledge of icing fluids

7.8 Appendix H: Individual Cognitive Demands Tables

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
		longer/shorter.			
Climb	Can I go around or over t-storms or will I have to penetrate?	Frontal systems move fast in summer Usually lightning associated with storms May have delays (unable to go around) Embedded t-storms, can't see them Hail – very dangerous Warm air drafts above t-storms can affect aircraft performance	How high are t-storms Color of clouds (dark-dark, half dark, white) Flat, anvil shapes or peaked, growing, mature Clouds lined-up in a row or are spotty Visual assessment of color on bottom of cloud Radar images: symmetrical cells are not as dangerous as "hooks"	Uses radar to spot them, Run radar down so that he knows where bottom of beam is, then angles up. Talks to ATC If t-storm is at 40,000, then give 40 miles distance; if at 30,000, then give 30 miles distance	May not consider delays, which impact how much fuel to bring If you start radar at high level, may not detect a low t-storms Put radar on automatic Try to move around things you can't see
	Where are the strongest winds and will they be a problem?	When you penetrate jet stream lots of turbulence	Strongest winds in jet stream are during the winter months Jet is somewhere near 30,000, and around 120 knots of wind	Listens to other aircraft who have gone through jet stream Talks to enroute ATC about jet stream activity	
	Is there icing?	Build up of ice reduces lift on aircraft	Rime ice occurs between 0 and minus 10 degrees C.	Turn Anti-ice on before takeoff	Don't use anti-ice
Cruise	Can I stay at this altitude?	Too much fuel or extra weight will affect ability to move to higher altitude	Weight of aircraft makes a difference What are the winds, steady or changing? Are they favorable? Location of frontal crossings and t-storms	Checks with ATC to see what other pilots are experiencing	Fly too high
	What kind of land/water	Crossing mountains can	High wispy clouds with		

7.8 Appendix H: Individual Cognitive Demands Tables

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
	will I be crossing?	be dangerous Airport in the valley may be reporting little wind and not have any idea what winds are like over the mountain tops – may give false impression	somewhat circular rolls (linticular clouds) indicates winds/instability		
	Do I need to stop to refuel?	International flights over ocean	High winds and temp affect aircraft performance	Find best route for fuel consumption Fill up on international flights, never know when you may have to hold or reroute	
	Do I need to slow down to fit ATC's guidance?	Difficult to time when to get to a certain lat/long to fit into ATC flow	High winds and temps will affect speed		
	For international flights, what wx information do I need?	Communication with ground can be difficult, may not be willing to provide pilot with necessary info; bad radar or hostile country. May need to go way out of the way because of ill-communication, remote airports	Middle East, Eastern Block, and South America are difficult places to fly into	Use own Flight Service	Unfamiliar with international wx and what to plan for
Descent	Do I have to fly through a storm system? How do I do this?	Turbulence associated with storms Windshear and downbursts in summer time	Ceiling and visibility, temps Low level fronts – produce turbulence	Listening to destination airport wx information Listening to what other planes have done that have been flying in the area from the enroute ATC	Fail to listen to other reports from planes that have flown in the area

7.8 Appendix H: Individual Cognitive Demands Tables

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
				Listen to ATIS for wind information Have one pilot on short range radar and one on long range May hold to wait for wx to pass	
	Is there freezing rain or ice?	Weighs down aircraft, can't get lift when needed Runways are slippery, won't be able to stop	Runway breaking action reports	Use anti-ice equipment before get into icing conditions	Don't use anti-ice
	Do I have enough fuel? What is alternate destin.?	Difficult overseas – not a lot of alternatives in some remote areas	What are the passengers doing? – being dropped off and leaving again, or are they staying on the ground for a while	Planning for possible contingencies	May assume that traveling international is similar to traveling domestic – could be a big mistake in thinking
	How many runways are at destination?	Fuel considerations may be impacted if they have to hold or divert Can only land in one direction in one runway – consider crosswinds	What direction the winds are coming from, are they aligned with runway	Check ahead in advance for number of runways, especially if landing at a new airport	
Approach/Landing	What are the minimums and can we land in them?	In the winter can get blowing snow, ice, gusty With strong crosswinds the runway may not be exactly where you expect it to be.	Where will plane break out Turbulence at field	Listens to pilots ahead of him Check to see if anyone else has landed at that airport today	May not be able to handle different flying situations (e.g., make the aircraft land forcefully)
	Will I have to go somewhere else after I land?	May be on the ground long time, and if icing will have to de-ice		Might not land if wx is bad	Complete the current mission without thinking about next stage

7.8 Appendix H: Individual Cognitive Demands Tables

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
		Gusty winds, lots of turbulence			
	Will I have to change destination at last minute?	At this point in the mission, may already have been committed to a destination and not planned to divert	Forecast is different than what current wx is: winds, icing, turbulence, t-storm activity that quickly develop	Get update on current conditions at destination, contact FSS	Not consider options
	Are winds too heavy to land in?	Passengers start to get concerned, causes more stress May get better, may get worse Can't always see the winds coming	Getting banged around a lot, heavy turbulence	Start to talk about other options with 1st pilot	
Other	Do I have to fly to an airfield with no tower?	Flying without vital information about the destination		Do not want to do this in the evening when there is low visibility and low ceiling – affects decisions throughout flight	
	Don't know how to fly around or near certain wx systems (e.g., hurricanes, tornados)	Little knowledge about how the wx system works creates more uncertainty, don't know what to expect		Call experienced meteorologist to find out about what particular system is doing and what the best route is to go around it	

7.8 Appendix H: Individual Cognitive Demands Tables

Subject 8 - Cognitive Demand Table

Phases of Flight	Cognitive Demand	Why Difficult?	Cues & Factors	Strategies/Actions	Novice Errors
Planning	What's the general weather picture, what's the situation? What are my "problems of the day"?	The weather picture is based on what aircraft he's flying, therefore has to interpret the picture with respect to the aircraft's capabilities; DUATS format is very hard to interpret (he likes pictures/graphics)	WSI Severe Wx briefings; Wx channel synopses, outlooks and graphics; route relevant info; convective AIRMETs/SIGMETs; Where are the pressure areas, where are the fronts, which way are they moving? Where will they be when I want to fly?	Call FSS for NOTAMS; if the weather is cruddy, carry extra fuel.	
	Who's going to fly this leg?	May not know experience level of copilot and the extent of the Wx problems		If it looks like a cruddy day, he will want to fly the leg	Less experienced may be more concerned by crosswinds
	How much do I need to brief the copilot?	Doesn't always know capabilities/experience of copilot	Level of copilot experience; degree of concern for weather based on airmets, sigmets, icing and turbulence reports	He briefs the copilot if he is not familiar with him/her - otherwise doesn't, necessarily.	
	How will I fly this route based on the weather?	Not an issue of whether to go, but how to do it; wx is a challenge to him, not a problem; has to be safe.	Severe weather; feasible destination; aircraft type; copilot	Because his aircraft (Citation X) is high powered and has AFIS, he can fly through anything; he just has to find a good route and a place to land and he can be much more flexible than the airlines.	
	What kind of approach will I need, ILS or visual?	Hard to know what the conditions will be on arrival, but need to know if ILS facilities are available at the destination	Current and forecast ceiling/vis at destination; Airport Facilities Directory for landing facilities	Check forecasts and facility directory	
Taxi/Take-off	Will icing be a concern?	May be an issue for runway contamination,			

7.8 Appendix H: Individual Cognitive Demands Tables

		depending on the type of airport			
	Will Wx affect takeoff?	Need to find t-storm cells in take-off path, hard to do especially if the cells are embedded	Storm cells; ceiling; turbulence reports		
	What will I do if I get an engine out?	Wx impacts the handling characteristics of the aircraft differently for different conditions	Crosswinds; turbulence; storm cells; wind-shear reports	Anticipate the problem and generate potential contingency plans	
Cruise	Will I be able to maneuver around the weather?	May be embedded cells, hard to tell severity by looking and sometimes from radar	Use radar and eyes to weave through storm cells (Stormscope, radar) and listen to PIREPS	Listens to PIREPS but doesn't trust them too much, just use as a guide; request info from ATC; choose route that avoids major fronts, or t-storm activity (fly behind a moving front, upwind of it)	May put too much faith in PIREPS and forecasts
	Will I need anti-ice en route?	A/c self-deices at speed, but hard to tell how severe the icing conditions are and if you really need to switch deicing equipment on (aircraft performance goes down when deicing is on, uses more fuel)	If aircraft is flying fast, the airframe warms up and automatically de-ices, depending on how severe the icing is (temp and moisture)		
Approach/Landing	Will icing on approach be an issue?	Forecasts for icing and PIREPS for icing are unreliable; can't always see icing conditions	As aircraft slows down, it cools down and is more susceptible to icing	Request icing reports from tower	
	Will I need to shoot an ILS approach? On which runway?	Need to assess ceiling and visibility conditions, and integrate with knowledge of runway facilities, as well as personal capabilities			
	Will I need to carry	Wind-shear hard to	Call tower for wind	Inform passengers of	

	extra speed for landing to avoid wind-shear problems?	recognize or see	reports; listen for PIREPS	bumpy ride if turbulence is expected; carry 20kts over normal approach speed	
	If I need to go around, which way will I go?	Need to assess where the weather is	Radar, ATC reports; Where are t-storm cells, are they moving? Which way? How fast?; Which runway am I using?		
Concurrent	How can I make this flight the most comfortable for the passengers?	Need to be aware of turbulence and its impact on passengers; can't see turbulence or always anticipate it	PIREPS; tower reports	Request turbulence reports from tower; fly at a slower speed in turbulence	

7.9 Appendix I: Summary Cognitive Demands Tables

Information Requirements and Goals Table

Phase of Flight	Cognitive Demand	Information Requirements[1]	Goals[2]
Planning	**How much extra fuel do I need with regard to wx?**	Knowing if there are re-fueling facilities at destination – (not specified) Airmets – (DUATS, ATIS, FSS, ATC) Sigmets – (DUATS, ATIS, FSS, ATC) Pilot reports – (ATC, HIWAS frequency, DUATS) Aircraft performance – (own experience with flying a particular aircraft and with restrictions in the Aircraft Flight Manual)	Efficiency Safety Passenger Comfort
	What's the general wx picture? Will it be affecting my flying in the next few days?	International and Nationwide forecast – (Internet, Wx Channel, NWS, FSS, Private wx provider, FAA phone brief, DUATS)	Safety Passenger Comfort Efficiency
	What are the wx problems for this flight – departure? **(what time do I leave, go/no go?)**	Forecast Wx– (Internet, Wx Channel, NWS, FSS, Private wx provider, FAA phone brief, DUATS) Current Wx – (Nexrad radar on internet and TV, FSS, Private wx provider)	Safety Passenger Comfort Efficiency
	What are the wx problems for this flight – en route?	Airmets – (DUATS, ATIS, FSS, ATC) Sigmets– (DUATS, ATIS, FSS, ATC) Turbulence – (DUATS, ATC, FSS, onboard radar)	Safety Passenger Comfort Efficiency

[1] Information Requirements are pieces of information a pilot uses to build a "big picture" of the weather, and are related cognitive demands during a specified phase of flight. Pilots use various sources to retrieve weather information. The sources that were directly linked to information requirements in the raw data are identified in parentheses, and sources that were not directly linked to an information requirement are identified as "not specified."

[2] Mission goals are prioritized and sometimes compromised during a mission. The purpose of this column was to prioritize general mission goals (safety, passenger comfort, and efficiency) based on order of their importance for each cognitive demand specified in the table.

7.9 Appendix I: Summary Cognitive Demands Tables

	What are the wx problems for this flight – en route? (cont)	Icing reports – (ATC, DUATS, FSS) Pilot Reports – (ATC, HIWAS frequency, DUATS) Height of cloud tops – (not specified) Winds aloft – (Wx channel, DUATS, internet, FSS, ATC, ATIS) Fronts – (Wx channel, private wx provider) Pressure cell movement and development – (Internet, DUATS) Topography – (Maps, own experience, look out window) Jetways/Airways – (Flight Charts) Current Conditions – (Nexrad radar from TV and Internet, FSS, Private wx provider) Forecast Conditions – (Internet, Wx Channel, NWS, FSS, Private wx provider, FAA phone brief, DUATS)	
	How much confidence do I have in the other pilot?	Experience flying with other pilot	Safety Efficiency Passenger Comfort
Taxi/Takeoff	**Can I taxi/takeoff in this wx? (crosswinds, windshear, runway conditions, icing; go or no-go)**	Wind and crosswind direction, speed - (ATIS) Takeoff limitations (aircraft manual) METARS – (not specified) Temperature/Dewpoint spread – (not specified)	Safety Passenger Comfort Efficiency

7.9 Appendix I: Summary Cognitive Demands Tables

		Precipitation – (onboard radar) Visibility – (ATIS, look out the window) Windshear – (not specified) Pilot Reports – (not specified) NOTAMS – (not specified) Runway contamination, braking action reports– (ATIS, look out the window) Icing – (visually inspect plane)	
	Do I need to consider a rejected takeoff?	Temperature - (not specified) Humidity - (not specified) Pressure – (not specified) Length of runway and altitude – (not specified) Wind speed and direction - (ATIS) Runway contamination - (ATIS, look out the window)	Safety Passenger Comfort Efficiency
	Do I need to delay takeoff?	Severity reports - (not specified) METARS - (not specified) Current wx - (not specified) Forecast wx - (not specified) Ceiling - (ATIS, look out the window) Visibility - (ATIS, look out the window)	Safety Efficiency Passenger Comfort

7.9 Appendix I: Summary Cognitive Demands Tables

		Crosswinds - (ATIS) Windshear – (ATC) Runway contamination - (ATIS, look out the window) Icing - (visually inspect plane) Lightning – (not specified)	
	Do I need to consider post- takeoff alternatives? **(e.g., engine failure, wx cell blocking route, can't get back)**	Severity reports - (not specified) METARS - (not specified) Ceiling - (ATIS, look out the window) Visibility - (ATIS, look out the window) Crosswinds - (ATIS) Windshear – (ATC) Runway contamination - (ATIS, look out the window) Icing - (visually inspect plane)	Safety Efficiency Passenger Comfort
Climb	Anticipating icing problems	Temperature, forecast and current – (ATC) Pilot Reports – (not specified) Precipitation – (onboard radar) Icing – (look out the window) Cloud location – (onboard radar)	Safety Efficiency Passenger Comfort
	Anticipating wind-related problems (turbulence, windshear, crosswinds)	Forecasted wx – (FSS) Winds aloft, speed and direction – (look	Safety Passenger Comfort Efficiency

7.9 Appendix I: Summary Cognitive Demands Tables

		out the window, onboard sensors FMS) Jet stream level – (enroute ATC) Turbulence – (enroute ATC, PIREPS)	
	Determine how to avoid wx obstacles (t-storms, hail, lightning)	Locating t-storms activity – (onboard radar, enroute ATC, PIREPS) Pilot reports – (not specified) Cloud color and alignment – (look out the window)	Safety Passenger Comfort Efficiency
Cruise	Is my destination still viable?	Ceiling – (FSS, DUATS, ATC) Visibility at Destination – (ATC, FSS, DUATS, ATIS) T-storm activity – (Call ATC, look out window, onboard radar) Surface winds – (ATC) Turbulence – (DUATS, ATC, FSS)	Safety Efficiency Passenger Comfort
	How am I doing in general? (Do I need to refuel? Am I on schedule?)	Wind speed and direction – (ATC, FMS) Fuel considerations – (FMS) ETA - (FMS) Upper air Temperature – (FMS) Delay information – (ATC)	Efficiency Safety Passenger Comfort
	Provide passengers with comfortable ride	Airmets – (Not specified) Sigmets – (Not specified) Turbulence – (DUATS, ATC, FSS) Topography – (personal knowledge of region, out the window)	Passenger Comfort Safety Efficiency

7.9 Appendix I: Summary Cognitive Demands Tables

	Determining how to avoid wx obstacles (t-storms, hail, lightning)	Clouds tops – (onboard radar, FW) T-storm activity – (onboard radar, ATC) Cloud color – (look out the window)	Safety Efficiency Passenger Comfort
	Anticipating icing problem	Moisture – (look out window, onboard radar) Temperature – (FMS, ATIS) Icing – (ATC, DUATS, FSS)	Safety Passenger Comfort Efficiency
Descent/ Approach/ Landing/Taxi	Dealing with wx obstacles in descent	Wx avoidance – (ATC, look out window, listen to radio frequencies, onboard radar)	Safety Passenger Comfort Efficiency
	Anticipating Wx: Icing, windshear, turbulence, runway conditions, crosswinds, visibility	Icing – (look out the window, ATIS, ATC) Turbulence – (not specified) Cross winds/windshear – (radio chatter, ATC, PIREPS, GPWS) Visibility – (ATC, FBO)	Safety Passenger Comfort Efficiency
	What kind of approach: ILS or visual? Which runway?	Select runway – (ATC, ATIS) Winds/Windshear – (look out the window, ATIS, radio chatter, PIREPS, GPWS, ATC) NOTAMS – (not specified) Visibility – (ATC, FBO) Ceiling – (ATC) Temperature Runway length restrictions – (ATC)	Safety Passenger Comfort Efficiency
	What kind of landing – hard or gentle?	Wind/windshear – (radio chatter, PIREPS, GPWS, ATC, ATIS, window)	Safety Passenger Comfort

7.9 Appendix I: Summary Cognitive Demands Tables

		Breaking action reports – (ATC) Runway conditions – (ATC, look out the window)	Efficiency
	Do I want to hold? Should I divert to alternate destination?	Ceiling – (ATC) Runway conditions – (ATC, look out the window) Visibility – (ATC, FBO) T-storms – (ATC, look out the window, listen to radio, onboard radar) Temperature – (ATIS) Wind – (ATIS, look out the window)	Efficiency Safety Passenger Comfort
	Will this aircraft have quick turnaround for next trip?	Wx avoidance – (ATC, look out the window, listen to radio, onboard radar) Icing – (look out window, ATIS, ATC)	Efficiency Safety Passenger Comfort
	Anticipate missed approach, go around	Runway conditions – (ATC, look out the window) Windshear – (radio chatter, PIREPS, GPWS, ATC) Select runway – (ATC, ATIS) Visibility – (ATC, FBO) Ceiling – (ATC) T-storm avoidance – (ATC, look out window, listen to radio, onboard radar)	Safety Efficiency Passenger Comfort

7.9 Appendix I: Summary Cognitive Demands Tables

Cognitive Demands and Indicators of Expertise

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
Planning	How much extra fuel do I need with regard to wx?	Winds aloft are difficult to predict There are trade-offs by carrying extra fuel Wx conditions at destination are difficult to predict Wx conditions en route may cause problems (divert, reroute) for fueling considerations	Reallocate "payload"/passengers Carry extra fuel (up to max) Don't carry too much fuel Check destination for delays/holding Route selection/flight plan determines fuel load	May carry too much fuel (limit altitude availability) May not account for how wx impacts aircraft performance
	What's the general wx picture? Will it be affecting my flying in the next few days?	Depends on aircraft Depends on reliability of forecast (difficult to predict, wx is dynamic) Is it a multi-day, multi-leg trip?	Watch the wx – TV, internet, *etc.* Form a "big picture" "Forecasting" (generate expectancies) Call FSS for briefing the night before	Misinterpret general wx Don't form big picture of wx or look ahead
Planning (cont)	What are the wx problems for this flight – departure? (What time do I leave, go/no go?)	Have to plan ahead: Schedule departure for passengers, what are scheduling constraints Difficult to predict wx	Change departure time – move up or back Change passenger schedule/itinerary	Feel too constrained by passenger schedule "Can do" attitude
	What are the wx problems for this flight – en route? (What route?)	Limited shelf-life of forecast data Limited accuracy of forecast data	Get briefings Look at internet, TV Look at graphics: -Radar	Misjudge severity of wx Rely too much on static information

7.9 Appendix I: Summary Cognitive Demands Tables

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
		Planning is based on forecast (*e.g.*, fuel, route) Restrictions on possible routes and altitudes (*e.g.*, altitude/direction, special use airspace) Given flight plan is not optimized for wx avoidance Wx is dynamic Aircraft limitations (equipment, performance)	-Satellite -Synopsis Plan route behind (upwind) of fronts/severe wx Talk to experienced meteorologist at the FSS or personal wx provider Account for season and region (based on experience) Consider carrying extra fuel as contingency Share SA/brief non-flying pilot	Not plan or prepare for contingencies
	What are the wx problems for this flight – destination? (Is it viable, do I consider alternatives, which?)	Limited shelf-life of forecast data Limited accuracy of forecast data Planning is based on forecast (*e.g.*, fuel, route) Destination may have limited facilities and equipment (ILS, icing, snow removal, VFR field, uncontrolled, foreign language, *etc.*) – more uncertainty Difficult to predict wx – related traffic and delays Wx is dynamic Aircraft limitations (equipment and performance)	Get briefings Look at internet, TV Look at graphics: -Radar -Satellite -Synopsis Talk to experience meteorologist at FSS or wx provider Call destination (*e.g.*, FBO) Account for seasonal and regional wx (based on experience) Consider carrying extra fuel as contingency Share situation assessment/brief	Misjudge severity of wx Rely too much on static information May not plan or prepare for contingencies More concerned about minimums May not get local "eyes on" report Interpretation of local wx based on experience and knowledge (may not have it) May not utilize all relevant resources

7.9 Appendix I: Summary Cognitive Demands Tables

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
		If too close to minimums	non-flying pilot Check for wx upwind of destination (severity, rate and direction or movement) Check Airport Facility Directory Compare forecast to own expectancies If too close to minimums, check ATIS more frequently	
	How much confidence do I have in the other pilot?	Don't know how much experience or how capable other pilot is to deal with wx related to flying issues (In terms of judgment, decision making skills, flying skills, and exposure to difficult wx situations)	Discuss situation between both pilots – share assessment of situation and agree on course of action If in doubt, be conservative Share duties – "split control" Coordinate duties and control	"Can do" attitude May not discuss/consult /share SA
	Can I taxi/takeoff in this wx? (crosswinds, windshear, runway conditions, icing) Go or no go?	Wx hazards are difficult to predict and detect Wx poses hazards to the flight/takeoff Taking off out of uncontrolled airport – lack of facilities and wx support data	Use radar (on board) Check ATIS Check with ATC (radar and PIREPS) Request a different runway Delay takeoff Expedite takeoff Visually inspect aircraft and runway conditions	Uncomfortable with split control procedures (especially in crosswinds) May not check length of runway if runway is contaminated or aircraft has anti-icing on (loss of aircraft performance) May damage flaps by not retracting while taxiing Fail to get pilot/ATC reports of specific wx hazards

7.9 Appendix I: Summary Cognitive Demands Tables

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
			Put on anti-ice Use airport de-icing facilities Taxi out with flaps not fully extended (reduces damage from slush, snow, and ice) Increase takeoff power setting	Fail to recognize own flying capabilities Don't recognize severity of wx hazards
	Do I need to consider a rejected takeoff?	Wx impacts aircraft performance, which can change amount of decision time available Need to judge aircraft performance factors that are wx dependent No direct indication of how wx will affect the aircraft	Awareness of the wx factors impacting aircraft performance	No awareness of factors impacting aircraft performance
	Do I need to delay takeoff?	Passenger schedules and constraints add pressure to make the mission happen Judging when the wx will be a problem is difficult Costs: -Lose takeoff slot -Need to de-ice again	Brief passengers Gather current and forecast wx from ATC and ATIS Use on-board radar to judge movement of wx cells (rate and direction) Use knowledge of local wx conditions & terrain (experience)	Misjudge speed and direction of wx Do not predict or anticipate changes appropriately
	Do I need to consider post- takeoff alternatives?	Likelihood of engine failure or malfunction increases at this stage	Determine if immediate action is possible Brief passengers	Fail to consider alternatives to flight plan

7.9 Appendix I: Summary Cognitive Demands Tables

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
	(*e.g.*, engine failure, wx cell blocking route, can't get back)	Aircraft performance is degraded by wx conditions Hard to judge severity of wx	Consider alternate course of action Get prior ATC clearance for immediate deviation around wx Turn on continuous ignition to avert engine flame out in case of t-storm/lightning	
Climb	Anticipating icing problems	No direct indicators of icing Use of anti/de-ice equipment impacts aircraft performance	Turn on anti-icing before takeoff Avoid flying through clouds	Don't realize the impact of anti-icing equipment on aircraft performance during climb
	Anticipating wind-related problems (turbulence, windshear, crosswinds)	Winds are very dynamic and difficult to forecast Need to provide smooth ride for passengers No direct warnings of turbulence	Avoid t-storms, menacing clouds Talk to ATC and FSS: -PIREPS -Jet stream update Use TCAS to determine how other aircraft are maneuvering around wx	Not comfortable with "split control" cockpit Fail to use radar effectively to locate storms
	Determine how to avoid wx obstacles (t-storms, hail, lightning)	Wx is very dynamic Difficult to know the magnitude or intensity of wx obstacle Requires ATC clearance for quick deviation Embedded t-storms are difficult to detect Hail is difficult to detect Warm air drafts above t-storms affect aircraft performance	Manipulate radar to determine cloud heights Request immediate reroute from ATC Avoid menacing clouds Talk to ATC and FSS – PIREPS Use TCAS to determine how other aircraft are maneuvering around wx	May not request reroute early enough Fail to use radar effectively to locate t-storms and assess cloud top heights Fail to anticipate embedded t-storms

7.9 Appendix I: Summary Cognitive Demands Tables

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
	Is my destination still viable?	Lack of real time data Requires pilot to project/anticipate wx from stale data Requires pilot to project/anticipate wx from radio chatter at destination At an uncontrolled airport there is a lack of information, reliable information	Listen for delays/holding at destination Judge trends in wx at destination – Getting better? Getting worse? Get ATIS just after the hour (latest reports at destination) Slow down, hold, reroute to destination Reroute/divert to alternate (having assessed wx at alternative)	Not get wx updates for destination, rely on old forecast data
	How am I doing in general? (Do I need to refuel? Am I on schedule?)	The flight plan is based on forecast wx which may be unreliable (especially winds aloft) Delays at destination are difficult to predict It is difficult to assess aircraft performance due to wx (headwinds, de-icing equipment)	Slow down to avoid holding Change altitude and/or route for better wind Slow down to conserve fuel – avoid refueling	Not check planned vs. actual: -Winds -Fuel -ETA
	Provide passengers with comfortable ride	Can't see turbulence, no direct indicators Hard to predict turbulence Shelf life of turbulence reports is unreliable, also unreliable due to subjective nature (depends on aircraft and pilot perception) Embedded t-storms are difficult	Listen to radio chatter about turbulence Ask ATC for smoother ride (different altitude) Listen to PIREPS of turbulence Fly around sources of turbulence Slow down/reduce airspeed =	May not consider passenger comfort May not request alternate altitude May not understand reliability/relevance of PIREPS to their situation/location

7.9 Appendix I: Summary Cognitive Demands Tables

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
		to detect on radar May need to trade-off direct, bumpy ride with an indirect, smooth ride that takes you low on fuel	more comfortable ride Brief passengers about turbulence	
	Determining how to avoid wx obstacles (t-storms, hail, lightning) Determining how to avoid wx obstacles (t-storms, hail, lightning)	-Wx is very dynamic -Difficult to know the magnitude or intensity of obstacle -Requires ATC clearance for quick deviation -Embedded t-storms & hail are difficult to detect -Warm air drafts above t-storms affect aircraft performance	-Manipulate radar to determine cloud heights -Request immediate reroute from ATC -Request different cruising altitude -Avoid menacing clouds -Talk to ATC and FSS – PIREPS -Use TCAS to see how other aircraft maneuver around wx	May not request reroute early enough Not use radar effectively to locate t-storms and assess cloud top heights Fail to anticipate embedded t-storms
	Anticipating icing problem	No direct indicator – requires inference or visual detection (difficult to see at night or low visibility) Autopilot corrects for ice build-up	Look out the window, periodic visual inspection of wings and boots Turn on de-icing before icing accumulates Disconnect autopilot so it doesn't compensate for loss of trim	Use de-icing boots to early – may not work again when needed Over-reliance on autopilot
Descent/ Approach/ Landing/Taxi	Dealing with wx obstacles in descent	Less room to maneuver (approach/landing)	Call ATC for good routes through wx into airport One pilot on short range radar, one on long range	Fail to listen to other planes navigating through obstacles
	Anticipating wx: Icing, windshear, turbulence, runway conditions, crosswinds, visibility	Specific to landing /approach Sudden changes, rapid deviations have more impact – fewer options and less space to play with, especially altitude Similar issues as previous	Fly over airfield ("fly by") Call ATC Listen to ATIS Activate de-icing Hold until wx passes	May not be proactive anti-icer May not de-ice engine when needed

7.9 Appendix I: Summary Cognitive Demands Tables

Phase of Flight	Cognitive Demand	Why Difficult?	Strategies/Actions	Novice Errors
			Listen for PIREPS/chatter	
	What kind of approach? ILS visual? Which runway?	No single source of rwy/wx information Ceiling, visibility, and wind hard to report accurately (especially if changeable)	Check airport facilities Talk to ATC for ceiling, visibility	Lack confidence or overconfident in ability to land close to minimums
	What kind of landing – hard or gentle?	Need to anticipate wind and runway conditions	If gusty/windshear or excess water carry extra speed, land a little harder, brief passengers, get runway reports, wind reports	Don't adjust for conditions
	Do I want to hold? Should I divert to alternate destination?	Pressure to land – fuel, passengers, Conditions may be marginal, info may be unclear, ambiguous, or unavailable	Get updated info from ATC, FSS Discuss options with pilot-not-flying Listen to PIREPS/chatter Brief passengers Do a fly by of runway Keep alternate airport in mind Reschedule ground transportation for passengers	Confidence in ability when close to minimums May not consider options
	Will this aircraft have quick turnaround for next trip?	Need to keep plane "alive" -> Ensure airport has facilities for quick turnaround	Keep engine warm & aircraft deiced May not land if can't turn around	May not be thinking very far ahead
	Anticipate missed approach, go around	Requires pilot to think ahead and anticipate how wx may impact approach/landing / missed approach	Go around to avoid t-storms or other obstacles Listen to radio chatter and PIREPS for other approaches	Doesn't look that far ahead

7.10 Appendix J: Simulation Interview Summary

Decision	SME 4	SME 5	SME 6	SME 7	SME 8
Planning Phase					
Route planning	What is the best route?			Where am I going? Domestic or international?	
Will icing be a problem?	Will icing be a problem?	Should I turn anti-ice on during climb and descent? When should I initiate anti-icing? Aircraft performance considerations.		Is there going to be icing?	Will icing be a problem?
Should I carry extra fuel?	Should fuel load be heavy or light?	Will I need to carry extra fuel?			How much fuel should I carry?
What are the significant weather concerns?	Where are the wx concerns?	What are major weather concerns (destination, cruise and departure)? Icing?	What are major wx concerns? Departure and destination	Should I call Flight Service to speak with meteorologist?	
Which runway should I use?	Which runway to takeoff from – cross winds are heavy	Should I request alternate runway on takeoff – crosswinds;			
Takeoff concerns			Should I ask tower about windshear? Should I wait for windshear to pass? – tends to move quickly	How do I handle wx in the terminal? – gusty winds, visibility Should I takeoff with anti-ice?	What are my takeoff concerns?
Takeoff in cross winds?	Do I fly into the wind or battle the crosswind?	Am I within crosswinds limit? Should I split controls with co-pilot – crosswinds.	How am I going to deal with gusty winds and crosswinds?		
What are the cloud tops?		What are the cloud tops?		What are cloud tops?	
What altitude should I fly at?	What is the best altitude to fly at?	Should I request for higher altitude to get above turbulence?			
T-storms			How am I going to avoid t-storm and turbulence?	How am I going to avoid t-storms?	

7.10 Appendix J: Simulation Interview Summary

Decision	SME 4	SME 5	SME 6	SME 7	SME 8
Turbulence			How am I going to handle turbulence? Should I alert passengers about turbulence?		How can I make this flight more comfortable?
Misc		Am I within personal limits?			How much do I brief my copilot?
Takeoff problems				Where do I go if there is a problem in takeoff? Can I get back?	What do I do if an engine goes out?
Talk to ATC?				Do I need to call ATC for flow control? What are other planes doing? Should I change vector?	Will ATC allow me to do deviations I may want to do enroute?
Destination		Which runway should I use at JAX?	Should I make call ahead to change meeting times with clients? – may have to vector or hold		What is going on in JAX? What does the alternate look like? Should I call FSS for NOTAMS? – JAX and MCO
Climb/ Cruise					
Turbulence	How do I handle turbulence and convective activity?	Do I need to listen to PIREPS – turbulence reports	How do I handle turbulence on climb out? Do I need to call ATC to see what other aircraft have been doing?	How do I handle clear-air turbulence?	
Altitude	Is this a good altitude?	Should I request altitude change?		Do I ask ATC for altitude change?	What is the best altitude? Should I call ATC for change?
Brief px	Do I need to brief passengers for rough ride?	Do I brief passengers/copilot – windshear?			
Avoid t-storms	Where are the thunderclouds? How to avoid them?	How should I deviate around clouds?	What is the convective activity like?	How do I avoid storms? Are there embedded storms?	Can I pick through weather?
Contact ATC	Do I need to call ATC to see what other aircraft have been doing?	Should I call ATC for rerouting information?	Should I talk to ATC for vector/heading change? Fly West?		

7.10 Appendix J: Simulation Interview Summary

Decision	SME 4	SME 5	SME 6	SME 7	SME 8
Fuel			What is my fuel state? Do I have enough for holding/divert?	How's my fuel?	
Icing		Should I turn anti-ice on early – no cost in performance in cruise and not much on descent	What are my de-icing/anti-icing capabilities?	Is there icing?	Will I need to anti-ice enroute? Will there be icing on approach?
Speed				Should I fly faster? - Winds are heavy	
Misc				When should I retract the landing gear – let water runoff gear? Should I turn continuous ignition on?	
Destination				Is the runway contaminated? Is JAX plugged up? What's going on for wx at JAX?	
Approach/ Descent					
Which runway		Which runway should I choose? What is runway length?		What is the best runway for landing? Is the wind direction aligned with runway?	Which runway should I use?
Icing	Do I turn anti-ice on for approach/ descent?		De-ice wings and engine?		
Brief px			Should I brief flight attendant about turbulence?	How's the ride quality for passengers?	Should I brief passengers?
Approach speed/landing	How do I pad my approach speed?	How much approach speed should I carry?	How am I going to handle landing? – wet runways/ hydroplaning	How should I handle the landing?	
What have other planes done?			Should I talk to tower to find out what other planes have done?	What have other planes done?	

7.10 Appendix J: Simulation Interview Summary

Decision	SME 4	SME 5	SME 6	SME 7	SME 8
Visual vs insturment		Is this an instrument or visual approach?			Will I need to shoot an ILS approach? Can field support it?
Check ATIS		Should I get ATIS?		What is ATIS reporting?	
Destination wx			What is the wx like around destination?	Is my destination runway contaminated?	
Other			Should I hold at higher altitude to wait out turbulence?	Will I need to change flap settings?	What's my Vref? What's my descent rate?
				Will I need to ask for different approach?	

7.11 Appendix K: Critical Decision Incident Tables

Incident 1 - Subject 2.

SME 2 and his co-pilot were scheduled to fly into Elizabeth Town, NC from Norfolk, VA on a Cessna 525. They knew before takeoff that Elizabeth Town was a small, uncontrolled airport (sometimes they can't even get an ATIS report from there) with a 500ft minimum. They also knew that the approach into Elizabeth Town would be non-precision.	Critical cues: small, uncontrolled airport; non-precision approach; 500 feet minimum ceiling
The weather out the window was cloudy en route. In fact, at a distance of about 200 miles out the pilots could not see Elizabeth Town, where on a clear day Elizabeth Town would have been visible. They listened to the ATIS reports (a specific radio frequency for every airport) for weather conditions at Fayetteville, an alternate airport in the Elizabeth Town area, with the intentions of finding a better place to land. The weather at Fayetteville reported marginal conditions so they decided to check other local airports to compare weather reports. Relying on his experience and understanding of weather and many years of flying, SME 2 also considered that the weather in Elizabeth Town might not be as bad on the ground as it looked from the sky, and may even have better weather than the surrounding airports. The biggest concern for SME 2 was the overcast, cloudy conditions. Clouds usually have turbulence associated with them and they wanted to avoid that.	Cognitive demand: What are the weather problems at my destination? Information sources: ATIS, pilot's eyes, pilot's experience with local weather conditions Critical cues: cloudy, destination not visible at 200miles; Cognitive demands: Is my destination viable? How will I deal with potential turbulence during descent? Actions: check weather at alternate destination Why difficult? Weather is dynamic and available weather information often is not current
SME 2 continued to listen to ATIS reports from the other surrounding airports as he approached Elizabeth Town. However, before a decision to land was made SME 2 performed one more check. He called the FBO on the ground at Elizabeth Town to get real-time observer perspective. The FBO reported to SME 2 that he was unable to see across the airport, which indicated to SME 2 that he needed to find an alternate airport to land at. A call to the FBO on the ground is preferred over a call to the tower. A call to the tower usually indicates a strong commitment to land at that specific airport and if you are just checking the weather, there is no need to call the tower.	Actions: continue to monitor ATIS reports; call FBO at destination Cues: FBO at destination couldn't see across air field; weather at alternative destination better Information sources: destination FBO; ATIS
SME 2 called ATC in Fayetteville and arranged to land there as they were reporting better weather and were the closest alternative. He also arranged for ground transportation to pick his passengers up at the Fayetteville airport.	Actions: arrange to land at alternate destination; arrange alternate ground transportation for passengers

7.11 Appendix K: Critical Decision Incident Tables

Incident 2 - Subject 1.

SME 1 was scheduled to fly into the St. Simons, Georgia airfield, a small island off the coast of Georgia, out of Norfolk, VA. SME 1 waited until the day of the mission to make his final decision about flying into St. Simons because of a hurricane watch in the area. He thought that conditions might change overnight. He knew that one trip in particular, out of the three he had to make to St. Simons that day, was going to be difficult because of the timing and proximity of the hurricane. He used a one-page FAA briefing and the internet to assimilate his forecasted weather data.	Cognitive demand: What's the general weather picture? What are the weather problems for this flight? Critical cues: hurricane watch for destination Information sources: FAA briefing; internet
This was the first trip into St. Simons but was confident with his knowledge of local weather conditions. SME 1 also had experience flying into other airfields (Hilton Head and Brunswick) that are similar to St. Simons, and in similar weather conditions. SME 1 knew that the AWOS at St. Simons was uncertified in handling weather reports. SME 1 also had alternative airports in mind (Savannah, Brunswick) before leaving.	Information sources: pilot's experience with local weather conditions; AWOS report from destination Why difficult? AWOS at destination known to be uncertified; threatening weather at destination Cognitive demand: Is my destination viable?
Before taking off, SME 1 set more restrictive limits on wind speed and direction than he usually does. If winds surpassed the limits SME 1 set, he would immediately reroute to an alternative airport. In fact, in some airplanes SME 1 would not have even attempted to make this trip. He contacted the FBO at St. Simons to get a real-time assessment of the situation on the ground, and received near real-time data from Brunswick (15 minutes old).	Actions: consider alternative destinations Cognitive demand: How will I deal with weather obstacles on descent? Actions: set more restrictive limits on permissible wind speed and direction for landing; contact FBO at airport near destination airport; listen for weather updates for other nearby locations
On final approach, SME 1 prepared himself by using Hilton Head as a template for landing on St. Simons. The features were virtually the same: a small island, the climate was similar, and SME 1 knew it had to be a precision approach. He landed with no problems.	Cues: wind speed and direction at destination Information sources: FBO at airport near destination Cognitive demand: What kind of landing do I need to make? Why difficult: he'd never landed at this airport before Information sources: pilots' knowledge of other similar airports

7.11 Appendix K: Critical Decision Incident Tables

Incident 3 - Subject 6.

SME 6 was scheduled to fly to London, Ontario out of St. Paul at 5:00pm in a Gulf Stream 4. Total flight time is 90 minutes, about 450-500 miles. From about 4:00 – 4:45, SME 6 gathered pre-flight weather information for departure and destination airports. He primarily uses KAVOURAS, a weather service based in St. Paul. The service provides verbal briefs, including the ability to file a flight plan, it provides a radar picture, and provides weather for departure city and state. The only problem with this service is that it doesn't provide the big picture. After collecting initial weather reports, SME 6 had a discussion with the 1st officer about the trip in which the 1st officer voiced his concern and thought they shouldn't go. SME 6 felt otherwise, and asked the 1st officer to call the ATC tower in London. The conditions at St. Paul were rainy, foggy, below minimums, and temperatures were about 3 to 4 degrees Celsius. London was reporting conditions below minimums but they had improved to 100 ft and ¼ mile visibility. They were also reporting the cloud bottoms were ragged. SME 6 knew that even though conditions might be below minimums when they arrived in London, he could at least go look (FAA Part 91 regulations).	Cognitive demands: What's the general weather picture? What are the weather problems at destination? Why difficult? 1st officer disagreed with pilot about viability of landing Information sources: private weather service; ATC at destination tower Cues: radar picture; temperature, ceiling, and visibility at destination and departure airports Action: discuss destination weather with 1st officer; call ATC at destination tower; plan to fly to destination and then make decision about landing
Before they left they called the tower in London once again, which reported conditions were down again, 200 ft and ½ mile visibility. They decided to go anyway and briefed the passengers on the situation. They devised several alternatives if they couldn't land in London and agreed that the best alternative would be to turn around and go back to St. Paul. Detroit could have been an option but required more logistical planning.	Actions: call ATC at destination tower (again) Cues: destination ceiling/visibility Actions: brief passengers; identify alternate destination which was to return to departure airport if unable to land
Because the reports out of London were "ragged," this meant conditions were up and down all day in SME 6's mind. From his previous flying experience, SME 6 knew that minimums at night were different than during the day. At night pilots can see the amount of light shining up through the clouds from the landing strip. Obviously, day conditions don't provide this cue. SME 6 knew he could always go back to St. Paul if the weather was bad, but he wanted to take a look anyway.	Cognitive demand: Can I anticipate and deal with significant weather at destination? Why difficult? Ceiling and visibility conditions at destination kept changing throughout the day and evening Cues: landing lights shining through low level clouds Action: fly to destination air field and look at lights
At about 6:00pm, during cruise, SME 6 checked with FW. They had enough fuel to play with several options: hold for a while, make a pass, or go back to St. Paul. On Approach/Descent, SME 6 briefed 1st officer (check frequencies, radios, minimums check, and initiated call-outs). They contacted ATC. ATC reported that other planes had landed that evening, which indicated to SME 6 that he would at least try to land. Minimums were 300 – 400 ft, and 1 mile visibility. SME 6 inferred this from the amount of light shining up through the clouds. They were able to land without any problems	Cognitive demands: Is my destination still viable? How am I doing on fuel? Action: contact ATC at destination tower Cues: ATC reported other planes had landed recently Action: attempt landing Cues: light shining through low level clouds Information sources: ATC at destination tower; pilot's eyes

7.11 Appendix K: Critical Decision Incident Tables

Incident 4 - Subject 5.

SME 5 and his co-pilot were scheduled to fly a group of Asian business-people from an airfield in Phoenix, AZ (Grand Canyon) to Morristown, NJ, in a Gulf Stream 4 at 4 pm (6pm EST). SME 5 was planning to stay over night in NJ, and then fly back to MN in the afternoon. At about 2 pm (4 pm EST) SME 5 and co-pilot began planning for the trip to the East Coast. Conditions on the ground in Phoenix were clear and beautiful. He called the Wx service before they left and they said there were no problems in the NY area. Current conditions in NJ at around 2pm were reporting marginal with some gusty winds.	Cognitive demands: What's the general weather picture? Are there weather problems at destination? Why difficult? Weather is dynamic and available information often is not current Cues: gusty winds at destination Information Source: private weather service provider
At about 8:30 EST SME 5 started his approach into Morristown. Prior to this point the ride had gone smoothly and they didn't expect any problems ahead. About 100-150 miles out SME 5 picked up the Morristown ATIS, which reported winds gusting from the NW at 15-20 knots. They were approaching from the Southwest and he concluded that runway 5, landing to the Northeast, was the only choice. The Morristown airport sits down in a valley surrounded by some terraced hills on the Southwest side and a swamp area to the East. He knew that there would be a significant crosswind. He was not thinking about alternatives because the weather was not that bad.	Cognitive demands: How do I deal with significant weather at destination (gusty winds)? Which runway should I use? Cues: winds speed and direction, runway direction, topography surrounding destination airport Information sources: ATIS, pilot's familiarity with runways and topography at destination airport
He started to descend to about 20,000 ft when he received notice from ATC that there was turbulence below 10-15,000. At almost 9pm EST, he could see Morristown 20 miles out. SME 5 was cleared for a visual approach. When he got down to 6000 ft the winds were worse there than they were higher up. He hadn't expected this. He got down to 4000 feet and it was quite rough. At about six miles out from the airport they started to get banged around a lot. The passengers were no longer talking. He had the aircraft on autopilot and auto throttle, but it was not handling the winds well, so he turned it off around 2000 ft. This caused a warning horn to sound. The passengers heard this and were very alarmed.	Cognitive demands: How do I deal with significant weather at destination (gusty winds)? What kind of approach do I need to make? Information sources: ATIS, pilot's visual & kinesthetic experience Cues: turbulence reported, cleared for visual approach, experienced high winds at lower altitude, turbulence experienced Actions: turn off autopilot&/throttle.
As he was coming over the hills the winds started getting violent, there were heavy gusts up and down, rolling and yawing. The normal approach speed was 130-140 knots, but they were flying 160-170 knots. His yoke control was going from stop to stop (*i.e.*, he was losing control of the aircraft). They had to abort the approach. He knew he could get the aircraft to the runway but he didn't think he could keep the plane on the runway when they landed.	Cognitive demand: What kind of approach do I need to make? What kind of landing do I need to make? Why difficult? Unexpectedly high winds made aircraft control difficult Cues: yoke control handing difficult Action: Abort the approach
It was very unusual to have these violent gusts. The plane didn't feel right. SME 5 now knew that runway 5 wasn't going to work so he looked at runway 30. This was too short and he was too heavy to land there. He decided to abort the landing.	Cognitive demand: should I try a different runway? Cues: High winds, runway too short, plane too heavy
They went back up and circled for 15-20 minutes so he could calm down and discuss his options with his 1st officer. All the NY airports were gusty, but they didn't all have the hills like Morristown. They checked with LaGuardia, but they were real busy. At around 9:30pm EST they tried to land again at Morristown. They had enough fuel to try again and if they couldn't land it this time they could still go somewhere else.	Cognitive demands: Is my destination still viable? How am I doing on fuel? Action: discuss options with copilot Information sources: checked with ATC at alternate airport
He did not get any new information on the winds. No one else had landed at Morristown since he had tried 15-20 minutes ago (but no one had attempted it either). The turbulence was much less on the second try and they were able to land.	Cues: alternate airport very busy, sufficient fuel to try again Action: try landing at original destination (again).

7.11 Appendix K: Critical Decision Incident Tables

Incident 5 - Subject 5.

SME 5 was waiting on the passengers who were late. His copilot was the most experienced pilot in the organization. The weather was beginning to turn nasty with a storm moving rapidly towards the field. They followed the weather on the internet and television in the crew room, and were getting updates from the tower for over an hour. The storm was moving in at about 30 knots and would hit the field soon, at least delaying their departure further.	Cognitive demands: What's the general weather picture? What are the weather problems for departure? Information sources: internet, TV Cues: direction and speed of storm moving towards departure airport
The passengers arrived and boarded the aircraft. The storm was moving in fast but current conditions at the field were good. No rain, good visibility, and the wind was not going to be a problem. They knew they would have to get up quickly and make a quick turn to avoid the storm. There was still a question of whether they would get off the ground in time, but ATC confirmed that they looked OK if they expedited their departure. They used their on-board radar to check the progress of the storm. They swung the aircraft 360 degrees on the ground to make sure that the weather was clear around the storm and that they could get out. The radar picture was helpful, although ground clutter made the picture a little ambiguous. However, the tower's radar picture was clearer, and the tower made the same assessment of the situation. The speed and intensity of the storm had worried the pilot. They had watched it move rapidly in their direction, and their departure was in jeopardy. Thirty miles away a tower had been abandoned due to the storm, so they knew it was severe. Both the pilot and the 1st officer agreed that they could make it, and their assessment matched the tower's assessment. They knew it was heading right for them because they could see from the weather reports and tracked its movement, and as they prepared for departure, they could see the growing, ominous clouds. The pilot was confident in the judgment of his 1st officer, an experienced colleague. Also, their assessment had been confirmed by the tower. If either of these other opinions had differed from the pilot's, he would have postponed the departure. If the 1st officer had been less experienced, the pilot may not have been so confident in trying to beat the storm.	Cognitive demands: do I need to delay my take-off? How am I going to avoid weather obstacles during climb? Cues: lack of wind and precipitation at departure airport; visibility at departure airport, pilot observations Action: track approaching storm on on-board radar; talk to tower to get their assessment of approaching storm Information sources: ATC at departure tower, on-board radar Cues: radar picture of approaching storm, speed and intensity of approaching storm, local tower abandoned Action: discuss options with 1st officer Cues: experience of 1st officer; agreement with destination tower ATC Action: take-off quickly before storm arrives
They took off, deviated immediately, and made it clear of the storm. Two minutes later the storm hit the field (according to reports from the tower at the field).	Action: turn aircraft immediately after take-off to avoid storm

7.11 Appendix K: Critical Decision Incident Tables

Incident 6 - Subject 4.

SME 4 had to miss an approach into a small, unsupported airfield near Traverse City, MI. He could not see the airfield even though the ASOS was telling him that the airfield was above minimums. SME 4 knew that the temperature and dew-point spread was close, and that the wind was in the "wrong direction." But the automated weather observation equipment was telling him that the airfield was within the limits. He said he "smelled a rat." He made the approach, but the visibility was only 2 ½ miles and the ceiling was under 700 feet. He could not see the runway, so he made a missed approach. He did not really know how the automated observation equipment worked, but he sensed that it might be wrong based on his assessment of the conditions, and his intuition proved him correct. He ended up flying to a close alternate airfield.	Cognitive demand: Can I deal with low ceiling and limited visibility at destination? Information sources: ASOS at destination; pilot's observation of conditions at destination, pilots' experience with similar weather situations Cues: temperature/dewpoint spread; wind direction Actions: attempt approach, observe ceiling and visibility Cue: couldn't see runway Action: abort approach, fly to alternate destination

7.12 Appendix L: "Scenarios from Hell" Incidents

Subject 3 -

- Windshear at takeoff or landing
- Add to workload at landing by changing runways (need to redo approach)
- Low ceilings encountered just after decision height (expert will prepare for missed approach)
- Forecast a close dew pt/temp spread
- Runway clear until rotate speed reached, then socked in
- Start flare on landing and runway in fog
- While in holding pattern, ice accumulates on the bottom (of wings?)
- Ice in clouds
  Any slow forming icing conditions (when flying slow, low altitude) [this is particularly difficult when on autopilot that continues to adjust for it until overloaded]

Subject 5 -

- Strong wind sheer, unexpected at takeoff or landing
- Engine failure on opposite side of cross-wind
- Icing during night flight
- Equipment failures that affect de-icing equipment (asymmetrical malfunctions are hard to control)
- Contaminated runways
- Pitot-static system failure with slow onset (altitude and airspeed indicators are affected)
- Radar clutter or misleading radar image (big cell behind the squall line)

Subject 6 -

- Destination is an uncontrolled airport, maybe no FBO
- Snow or frost on runway—no braking action
- Ceiling and visibility at minimums
- Forecast winds with gust from 10-20 knots
- Landing on runway at 3 degrees
- EICAS gives message for anti-skid failure after takeoff, but then this goes away
- EICAS message comes back on when pilot tries to put wheels down for landing [he should abort landing and look for alternate with dry runway]
- If fail to gear down, must fly at low altitude to alternate or retract them and do a belly landing
- When aircraft starts to descend the winds are up to 25-30 knots with a 90 degree crosswind
- Runway has blowing snow and anti-skid has failed
- Takeoff from south
- Have thunderstorms in the area
- Running low on fuel
- Runway 4500-5000 ft

Subject 8 -

- Forecast icing conditions (especially for night flights)
- Use a plane with no deicing equipment
- Forecast low visibility at destination
- Co-pilot that hinders (doesn't call out altitude or descent rate on approach)
- Wake turbulence can be tricky
- Strong wind sheer
- Strong cross winds at takeoff and landing
- Engine failure at takeoff with strong cross wind (makes physical control difficult)
- Bleed air failure (system that affects deicing equipment)
- Pitot-static system icing failure—slowly degrades validity in instruments

Subjects 1,2,4 and 7 did not receive this probe due to lack of time available in the interview.

7.13 Appendix M: Scenario Elements and Behavioral Markers.

CD- Incident 1	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Landing at small uncontrolled airport					x					x	Airport directory; pilot's own experience	
Cloudy, destination airport not visible			x	x			x				Visual observation out the window, usually able to see from this distance; ATIS; PIREPS; ATC; FBO on ground	Weather on the ground may be better than weather in the air. Need to check with alternate airports if weather in surrounding area is better or worse
Turbulence in clouds			x	x	x		x				Sensing the plane being jerked around	Find smoother air - need to consider how this will affect performance of plane (higher vs. lower altitude, fuel consumption)
Airport conditions on ground poor, FBO can't see across airport					x		x				FBO	
Temps decreasing to freezing level						x	x				ATIS	Need to consider how this may impact approach with precipitation in the area (how long they will have to fly through potential freezing rain)
Precipitation on radar				x	x		x	x			On-board radar	May be ground clutter, need to get multiple reports
Clear conditions at departure airport	x						x				Visual observation; ATIS, ATC	

7.13 Appendix M: Scenario Elements and Behavioral Markers.

Not able to land at destination							x		x		Call FBO for weather on ground at alternate	Make arrangements with alternate airport, don't call tower at alternate airport until ready to land there - if just checking for weather no need to call tower. Calling tower usually indicates strong commitment to land. Consider passenger needs

7.13 Appendix M: Scenario Elements and Behavioral Markers.

CD- Incident 2	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Hurricane approaching destination				x	x		x				FAA Briefing/Internet forecast	Should keep track of hurricane movement closely. Need to consider alternatives before beginning the flight as hurricane may change paths quickly
Landing on a small island				x	x				x		PIREPS, ATC	Should see if any other planes in the area have encountered problems; if any other planes have landed that day
Destination AWOS not certified for handling weather conditions										x	Own experience	
Wind speed and direction a concern for approach and landing				x	x		x				FBO on Ground at destination; ATIS, ATC; PIREPS	Should consider how conditions will impact landing, -check runway direction, crosswind severity
Precision approach				x	x						Pilot knowledge of airport, and experience landing on similar sized islands to this approach & landing	Try not to be overconfident, set limits for approach and landing

7.13 Appendix M: Scenario Elements and Behavioral Markers.

CD- Incident 3	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Departure Conditions rain, fog, below mins	x	x					x				ATIS; Pilot's own out window view; ATC	
Temperatures decreasing to 3 to 4 degrees C at departure and destination	x	x		x	x		x				ATIS	Pilot should recognize pre-cipitation in area of takeoff and landing - icing could begin to form and hinder aircraft performance
Conditions at destination below mins, however, changing and variable				x	x		x				KAVOURAS service; Called tower at destination	Pilot needs to con-stantly monitor dest-ination conditions, and be prepared for alternate plan if unable to land. Maybe determine this before take off.
Ragged clouds at destination				x	x		x				Called tower at destination	
Co-Pilot and captain disagree on course of action. Co-Pilot doesn't think they should go, 1st pilot feels otherwise						x	x	x			Forecast; ATC at departure and destination, ATIS	Have to be able to come to common solution for course of action, cannot have one pilot feeling unsure of the course of action - could impact safety of flight and cause other problems
Flying at night						x			x		Pilot able to see the amount of reflection of airport lights shining through ragged clouds.	Unable to see if ice is accumulating, more difficult to see clouds and other weather out window.

7.13 Appendix M: Scenario Elements and Behavioral Markers.

CD- Incident 4	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Destination ariport situated in a valley					x				x		Own experience landing at destination	Pilot must consider how terrain will affect aircraft performance, and how weather may be different in valley than at higher altitudes. Also surrounded by hills - less room for error.
Only one runway viable due to wind direction and speed					x					x	ATC; Pilot's knowledge of airfield; Airport Directory	Pilot should consider alternate landing if cannot land at single runway; also must determine if length of runway is long enough for Gulf Stream 4
Significant cross wind on approach				x	x		x				ATIS	
Violent gust and turbulence on approach, getting worse and worse as descend				x	x		x				ATIS; plane getting jerked around a lot; significant feeling of pitching and yawing	Switch off the autopilot; determine whether or not pilot can land and if the plane can land. Increases workload and calls for good teamwork between pilots
Passengers getting nervous, tense				x	x				x			Don't ignore passenger concerns, want to inform them of what is going on.
Surrounding airports reporting					x					x	Called La Guardia to check for a slot;	

7.13 Appendix M: Scenario Elements and Behavioral Markers.

same winds, and are busy											PIREPS	
Pilot losing control of aircraft				x	x		x					There is a tendency to panic, not recognize limits of own ability and aircraft ability
Severity of conditions were unexpected; pilot called ahead on departure - NY area reported no problems				x	x		x		x		Called Wx service; pilot and crew could feel the plane being jerked around	Pilot caught off guard, not expecting such a rough ride. May not be as alert as should be.
Departure weather was beautiful	x						x		x			
Flying from west coast to east coast						x			x		Pilot observation; using own knowledge and experience of flying this flight path.	Pilot should consider the effects that terrain plays on weather, and how that may affect the performance of aircraft.

7.13 Appendix M: Scenario Elements and Behavioral Markers.

CD- Incident 5	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Severe storm approaching field at 30 knots	x	x					x				On-board radar; ATC radar; look out the window	Pilot should consider direction of takeoff in relation to direction of storm path. May need to make a series of turns to avoid storm, weather may alter aircraft performance
Conditions at field are good despite approaching storm	x	x					x				Observation out the window; ATIS; ATC	
Expedited departure	x											Expedited departure doesn't mean skipping over normal preflight checks.
Decision of whether to take off or wait for storm to pass needed to be made quickly	x						x				Used knowledge of weather and flying experience to make assessment	Need to consider alternatives; pilot has to be prepared for alternate course of action, which will impact passeger needs (meeting times, transportation, rescheduling)

7.13 Appendix M: Scenario Elements and Behavioral Markers.

CD- Incident 6	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Automated observation equipment says weather is within limits					x			x			ASOS	Over-reliance on weather equipment
Pilot feels like conditions are worse than what automated weather equipment is telling him					x		x	x			Pilot's observation out the window	
Pilot can't see runway, visibility only 2.5 miles, ceiling < 700 ft				x	x		x					
Small, unsupported airport					x				x		Pilot has been there before, knows limitations of airport.	Fail to plan ahead of time; need to find alternate airport and arrange for ground transportation to pick up at alternate location (impacts passenger schedules) increases workload
Pilot unable to land at destination airport					x		x		x			Try to land in poor conditions, can't see if runway is contaminated

7.13 Appendix M: Scenario Elements and Behavioral Markers.

SH- Incident 1	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Destination is uncontrolled (may have a FBO)						X				X	Airport directory, experience	
Snow/frost on runway				X	X		X				FBO report	
Ceiling & vis at mins			X	X	X		X				FBO report, Automated reporting	
Forecast/actual winds gusting 10-20kts, crosswind			X	X			X				FBO, Automated reporting	
Winds increase to gusting 25-30kts, crosswind					X		X				FBO, Automated reporting	
EICAS gives anti-skid failure message, but then goes off	X							X			In-cockpit warning	
EICAS warning reappears when gear is deployed					X			X			In-cockpit warning	Should look for alternate, dry runway
Additional:												
T-storms in the area				X	X		X				On-board radar, Sigmets, HIWAS	Increases problems of selecting route to alternate
Low on fuel				X	X			X			Fuel indicator	Increases problem of selecting alternate
Runway short (4500-5000ft)					X				X		Airport directory, experience	Reduces possibility for error, increases risk

7.13 Appendix M: Scenario Elements and Behavioral Markers.

SH- Incident 2	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Night						X	X				Time of day, visual	Harder to look out the window and see ice build up, need to be more vigilant of other indicators *e.g.* aircraft perform-ance/ handling, air temperature and presence of moisture
Forecast icing	X	X					X				Forecast (DUATS)	Should be more vigilant for icing indicators (above)
System failures. - no deicing equipment, or bleed air failure; - pitot static failure						X		X			Bleed air failure inhibits ability to de-ice. Pitot-static failure - due to icing/blockage, instruments will cause inaccurate airspeed indications.	Icing becomes a larger problem with the loss of deicing equipment. The pilot should be more conservative, and if icing is a big threat, may want to reroute, or change the flight plan
Forecast low visibility	X	X					X				Forecast; current ATIS indicators of ceiling and visibility	Increases pilot workload, will need more help from copilot.
Unhelpful copilot (doesn't call out altitudes or descent rate)				X	X	X					Lack of call-outs by copilot; copilot distracted; copilot un-responsive	Pilot-flying must communicate to copilot if call-outs are required or additional help is needed.
Strong windshear	X	X		X	X		X				Forecasts, other PIREPS, radio chatter, windshear	Pilot should consider alternate runway if location or direction

7.13 Appendix M: Scenario Elements and Behavioral Markers.

											alert in cockpit, pilot observations of wind behavior in the air on indicators on the ground (trees blowing, gusts across bodies of water, windsock)	of windshear is known, or alternate airfield depending on severity of windshear.
Wake turbulence	X	X		X	X				X		PIREPS, windshear alert in cockpit	Pilot should consider alternate runway or delaying landing until wake turbulence has subsided.
Strong cross winds	X				X		X				See windshear indicators	Pilot should assess severity of crosswind and assess need for an alternate runway or alternate airfield

7.13 Appendix M: Scenario Elements and Behavioral Markers.

SH- Incident 3	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Strong windshear	X				X		X				Forecasts, other PIREPS, radio chatter, windshear alert in cockpit, pilot observations of wind behavior in the air on indicators on the ground (trees blowing, gusts across bodies of water, windsock)	See previous
Failure of upwind engine in strong winds	X						X	X			Yaw in direction of failed engine; master caution/warning lights; other flight deck indicator lights & system displays	Actuation to maintain directional control
Icing during night flight						X	X		X (night)		Aircraft has sluggish response to control inputs - loss of airspeed with not changes in power setting; may have icing indicator lights; see outside air temperature and moisture in the air (clouds)	Harder to look out the window and see ice build up, need to be more vigilant of other indicators *e.g.* aircraft performance/ handling, air temperature and presence of moisture
Equipment failures affecting de-icing equipment						X		X			Flight deck indicators for system malfunctions (e.g., electrical power, bleed air system)	Assesses risk of icing; change flight plan (altitude, course)
Contaminated runways and poor					X		X			X	PIREPS; tower reports; visual on	

7.13 Appendix M: Scenario Elements and Behavioral Markers.

braking action											airfield	
Pitot-static failure with icing conditions, slow onset						X	X	X			See indicators for icing and for pitot-static equipment failures above	Hard to spot indicators sometimes; requires added vigilance, cockpit coordination, watching the behavior of specific instruments over time…
Radar clutter, misleading radar image						X		X			On board radar	Pilot may ask copilot for a different read/opinion on the radar, may try to change radar settings (range, resolution, type of scan).

7.13 Appendix M: Scenario Elements and Behavioral Markers.

SH- Incident 4	Phases of Flight						Features Involved					
Challenging Elements:	Takeoff	Climb	Cruise	Descend	Land	All	Weather	System	Environment	Infrastructure	Information Sources	Behavioral Markers
Switch runways last minute				X	X					X	ATC request;	Pilot must assess viability of new runway wrt wind, contamination, length
Windshear potential or crosswinds on new runway				X	X		X				See information sources for windshear above	Check reliable sources: ATIS, ASOS/AWOS, wind sock, FBO, tower, other pilots, listen to radio chatter on approach
Low ceilings on approach				X	X		X				ATIS, visual, PIREPS, reports from tower	Pilot has to decide if the ceiling is below the minimum for the kind of approach s/he is using. Needs to decide whether or not to attempt approach, goaround, delay landing, or seek alternate (or all of the above)
Forecast a close dew pt/temp spread				X	X						Forecast, ATIS	Pilot should acknowledge the close dew-point/ temp range as a factor in assessing the weather conditions in this scenario
Reduced vis halfway down runway at decision point (reached	X						X				Visual cues	Recognize the potential in advance, generate plans for aborted takeoff

7.13 Appendix M: Scenario Elements and Behavioral Markers.

rotate speed)												
Ice accumulation while holding for runway [add a distractor task to take the pilot's focus away from flying the plane]			X	X			X				See indicators for icing	Requires the pilot to anticipate the potential for icing while holding, and to be aware of the indicators for icing (including how the plane looks, outside temp and moisture, how the plane handles, whether autopilot is compensating.
Icing in clouds			X	X			X				See indicators for icing	Pilot should detect the possibility of icing and act appropriately depending on whether s/he has deicing equipment.
Slow ice accumulation + autopilot + flying low and slow			X	X			X				See indicators for icing	See above for icing in clouds

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13. ABSTRACT (*Maximum 200 words*)
This report presents preliminary findings from a cognitive task analysis (CTA) of business aviation piloting. Results describe challenging weather-related aviation decisions and the information and cues used to support these decisions. Further, these results demonstrate the role of expertise in business aviation decision-making in weather flying, and how weather information is acquired and assessed for reliability. The challenging weather scenarios and novice errors identified in the results provide the basis for experimental scenarios and dependent measures to be used in future flight simulation evaluations of candidate aviation weather information systems. Finally, we analyzed these preliminary results to recommend design and training interventions to improve business aviation decision-making with weather information. The primary objective of this report is to present these preliminary findings and to document the extended CTA methodology used to elicit and represent expert business aviator decision-making with weather information. These preliminary findings will be augmented with results from additional subjects using this methodology. A summary of the complete results, absent the detailed treatment of methodology provided in this report, will be documented in a separate publication.

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