Air Carrier Training Recommendations to Address Limitations of Pilot Procedures during Unexpected Events in NextGen Operations

Task 3: Pilot Needs Analysis

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16. Abstract We present the results of a Subject Matter Expert knowledge elicitation study conducted with US Air Carrier pilots, instructor pilots, and evaluators through a semi-structured interview process. The goal of the study was to support or refute the body of research on pilot performance in responding to unexpected events presented in Task 2 from this research program. The objective of this phase was to obtain experts' input on the current level of pilot performance in line operations as well as what might be done to improve pilots' reactions to unexpected events. The analysis of the information elicited from the experts shows support for the concepts, procedures, and challenges of training to respond to unexpected events. The participant narratives were detailed in their descriptions of constructs associated with resilience and were in line with previously identified procedures, methods, and in some cases shortcomings of the pilot training as currently deployed. This study also suggests that more research is needed to determine how these constructs could be promoted during training in a way that elicits resilient behaviors during any unexpected events.		
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Executive Summary

Objective

The overarching aim of this project was to provide recommendations for researchers and training instructors to train air carrier pilots on how to manage unexpected aviation events. To this aim, four tasks were completed, and Tasks 2-4 resulted in technical reports. The tasks were as follows:

- *Task 1: Research Plan:* Research team met to create project plan of research.
- *Task 2: Relevant Research Assessment:* Synthesized the extensive literature on pilots' behaviors and responses to unexpected events.
- *Task 3: Pilot Needs Analysis:* Gathered expert input on current pilot performance and feedback to improve responses to unexpected events.
- *Task 4: Training Development Plan:* Recommend training interventions to increase pilot performance during unexpected events.

The present report presents the work of Task 3: Pilot Needs Analysis.

We present the results of a Subject Matter Expert knowledge elicitation study conducted with US Air Carrier pilots, instructor pilots, and evaluators through a semi-structured interview process. The goal of the study was to support or refute the body of research on pilot performance in responding to unexpected events presented in Task 2 from this research program. The objective of this phase was to obtain experts' input on the current level of pilot performance in line operations as well as what might be done to improve pilots' reactions to unexpected events.

Background

Resilient responses are needed to resolve uncertain prospective challenges in aviation. To further identify these capacities, we conducted interviews with air carrier pilots active in day-to-day operations. We were interested in what events they found surprising or unexpected, how they and other pilots handle the unexpected, and what more could be done to bolster positive performance and good outcomes when the unexpected arises in flight operations.

Method

Two human factors researchers conducted semi-structured interviews with 50 airline pilots. Each session lasted approximately one hour and entailed 10 questions which had additional prompts to elicit the expert knowledge from the participants. The responses from the interviews were coded by two researchers using a grounded theory framework. Categories emerged from the responses that were combined into themes associated with the resiliency needed to deal with unexpected events. It is important to note that the data obtained is limited by the nature of the method (pilot survey/interview data) and not measured pilot performance.

Results

The analysis of the information elicited from the experts show support for the concepts, procedures, and challenges of training to respond to unexpected events. The participant narratives were detailed in their descriptions of constructs associated with resilience and were in line with previously identified procedures, methods, and in some cases shortcomings of the pilot training as currently deployed.

Conclusion

The results of this study show the need to enhance pilots' abilities in dealing with the unexpected whether it is an event new to them or a situation that has never occurred before (i.e., a rare event not experienced by anyone). The significance of finding avenues to strengthen human (and system) resilience lies in the unknown consequences of future aviation activities. Below is a summary of the findings.

- The top three surprising or unexpected events were (1) aircraft systems events (e.g., engine, hydraulic, or gear failure); (2) environmental events (e.g., icing, wake turbulence, or weight and balance events); and (3) human events (e.g., events caused by a crew member and/or passenger behavior).
    - Given that pilots found these types of events to be the most unexpected or surprising, designing HITL scenarios with such events may provide the best path forward for evaluating the effectiveness of training interventions.

- When faced with unexpected events, pilots used the strategies of "aviate, navigate, communicate," following checklists and procedures, "winding the clock" (i.e., slowing down and taking time to think before acting), maintaining situation awareness, and utilizing their team both within and beyond the flight deck.
    - The identified strategies should be included as independent or dependent variables in the HITL. As independent variables, we may test their effectiveness at improving performance during unexpected events. As dependent variables, we may test *if* and *how* the training intervention bolstered the use of these beneficial strategies.

- When faced with unexpected events for which there is no known procedure (or the procedure/checklist is incomplete or incorrect), pilots reported adapting known procedures and using their system knowledge. Pilots also reported leveraging past experiences for use in the current unexpected situation. That is, if the pilot has experienced a similar situation in the past, they might apply their knowledge of the event and/or strategies that were helpful in overcoming that previous event to the problem at hand. For example, one pilot in the interviews reported diagnosing smoke as being caused by an electrical fire based on having experienced an electrical fire in the past.
    - These behaviors may be valuable to include as dependent variables in the HITL study.

- In general, pilots claim they handle unexpected events well, though some better than others.
    - The method of assessing performance in the HITL must be sensitive as to capture even subtle differences in performance of the unexpected event.

- Training on handling unexpected events included Crew Resource Management (CRM), Line Oriented Flight Training (LOFT), Advanced Qualification Program (AQP), expanded envelope training, and leadership training.
    - The HITL study ought to test the effectiveness of interventions *other* than what is currently being used.

- Crew procedures found useful when faced with unexpected or surprising events were maintaining flight deck discipline, employing active and open communication, and reaching consensus among the flightcrew.
    - Teamwork and communication are crucial for responding successfully to unexpected events, thus, they ought to be included as dependent variables in the HITL study.

- Overall, pilots believed that more simulator, ground, and LOFT training would help improve responses to unexpected events. Regarding simulator training, they emphasized that training on unexpected events and/or events that impart startle and surprise would be particularly beneficial. They also believed that more training on events found to be unexpected in the past would be beneficial for handling unexpected events in the future.
    - Simulator training involving unexpected or surprising events should be considered as a training intervention for the HITL study.

The results of Task 3 suggest that more studies are still needed to determine how these constructs could be promoted during training in a way that elicits resilient behaviors during any unexpected events.

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1. Task 3: Pilot Needs Analysis Task Overview

The purpose of the Pilot Needs Analysis was to obtain experts' input on the current level of pilot performance in line operations as well as what might be done to improve pilots' reactions to unexpected events. The analyses considered crew member procedures, procedural gaps, and associated knowledge and training requirements suggestions for responding to unexpected events. A diagram of the Task process is depicted in Appendix B.

1.1 Theoretical Basis

The Relevant Research Assessment (Task 2) presented recommendations and guidance to the FAA for which they can reference in developing resilience training for novel, unexpected, ill-defined, and surprising events. The primary purpose of Task 2 was to understand and synthesize the extensive literature surrounding pilots' behaviors and responses to unexpected events in order to determine how to better prepare pilots to respond with a positive outcome to future aviation events. Table 1 summarizes the findings from Task 2.

Table 1. Summary of Task 2 Relevant Research Assessment Findings

Literature Review Finding	Throughput from Task 2	Output to Next Study Tasks
Prevalence of the construct of resilience in different domains (business, finance, transportation, psychology, engineering, etc.)	Limited perspective to aviation context	Narrows the scope of the construct
Plethora of definitions for concepts related and integral to resilience	Determined study definitions of key terms	Provides consistent terminology for next study tasks
Concepts related to resilience are intertwined	Addressed similarities and differences in terms susceptible to misinterpretation (e.g., surprise/startle; resilience/adaptability)	Operationalization of study variables will be specific to the appropriate concept
Challenges of studying the construct of resilience due to the complexity of the surrounding factors	Investigated ways to clarify factors involved in resilience such as concept mapping or a Principal Components Analysis	The output of such activities would show how each factor contributes to overall individual (and system) resilience
System versus individual resilience	Focused on individual resilience	Structure study questionnaires and scenarios to focus on pilot responses to the system, not on system resilience
Very few studies specifically use resilience as a variable	Identified variables used as indicators of resilience (i.e., metacognition, cognitive flexibility, decision-making strategies, adaptive expertise)	Will consider previous research variables when analyzing interview and scenario data
Most useful studies focused on unexpected events (Pruchnicki et al., 2019; Field et al., 2018;	Noted study designs, variables, scenarios, method, apparatus, data	Lessons learned from previous specific research studies (successes, challenges, and

Literature Review Finding	Throughput from Task 2	Output to Next Study Tasks
Landman et al., 2018; Kochan, 2005;)	collection, data analysis, and results of related studies	failures) contribute to our task designs

2. Task 3: Pilot Needs Analysis Research Plan Development

Task 3 involved interviewing pilots and analyzing incidents in which pilots have encountered an unexpected event. The researchers interviewed 50 Subject Matter Experts (SMEs) using a semi-structured interview as displayed in Appendix E. The interview session lasted approximately 60 minutes. The interview was structured to elicit information regarding, (a) examples of events the participant found unexpected; (b) their current procedures regarding responding to unexpected events; (c) how desired behaviors of the flight crew are compared with the current behaviors of the flight crew; (d) where gaps in procedures or checklists may exist regarding unexpected or ill-defined events; and (e) what kind(s) of training might improve responses to unexpected events. The results of these interviews will begin to inform what other training and methods might be useful to aid in building a more resilient pilot.

The Pilot Needs Analysis, was a process to identify where training is needed for air carrier pilots to better respond to unexpected events. This was proposed to be accomplished by looking at the training that is now being deployed and what needs to be changed or added. We considered the output from the assessment of prior relevant research (Task 2 report), particularly the gaps in the knowledge, when constructing this plan. The outline below describes this process, and the process is depicted pictorially in Appendix B.

The first step was to ensure that the research team was using nomenclature that is consistent with industry terms and consistent among the team members. We developed a working list of terms and definitions. Our next step was to identify the study variables (Task 3.1) and confirm the variable selections (Task 3.2) from our Safety II based analysis of unexpected event accidents that had positive outcomes (see Task 2 report).

Next, we developed the protocol for the SME Knowledge Elicitation Study (Task 3.3). The purpose of the protocol was to gather more insight into how experts respond to unexpected events and where SMEs see the gaps in training for such occurrences. We developed a demographic questionnaire (Task 3.3.1), surveys to measure the constructs involved in judgment expertise (Task 3.3.2), and interview questions for a semi-structure interview (Task 3.3.3). The study materials for the SME Knowledge Elicitation Study are provided in Appendix F (demographics and interview questions) and Appendix B (judgment expertise surveys). Once the study materials were constructed, they were pre-tested on a retired US air carrier captain (Task 3.3.4). Minor edits and changes were made to the materials and the protocol.

The next step was to recruit and select participants for the SME Knowledge Elicitation Study (Task 3.3.5). This was accomplished through personal contacts, emails, and direct references from known SMEs. The pilot recruitment email is shown in Appendix G.

Task 3.4 involved conducting the SME Knowledge Elicitation Study. The purpose of the study, which was conducted remotely online with individual pilots, was to (a) collect the demographic data (see Appendix

C); (b) administer the SME Judgment Expertise Surveys electronically (Appendix D); and (c) conduct the semi-structured interview using the interview questions in Appendix E.

First, a group of ten SMEs that were current instructor or evaluator pilots employed by a US 14 CFR Part 121 air carrier (Task 3.4.1) completed the study. The data from this initial group was analyzed to further refine the study protocol, though no changes were found to be necessary. Then, 40 additional pilots were interviewed. These participants did not need to be instructors or evaluators (Task 3.4.3), but many were. The data from the additional 40 pilots was combined with the initial pilot participants' data.

Data sources for the study were the participants' demographics, verbal protocol analysis of the answers to interview questions, and the judgment expertise surveys. All data was entered into SPSS v. 27 for analysis.

Data collection was accomplished by review of the recorded interviews/transcripts and interviewer notes. Each participant's report was analyzed and categorized based on the "nature" of the surprising or unexpected event. We did not use any pre-existing taxonomy to characterize or categorize the pertinent variables. Specifically, information in the reports was not "fit" into pre-conceived categories as in many error classification systems (Dekker, 2003). Rather, as the reports were read, the reviewer made note of what factors were involved in the described unexpected events. As variables were noted, categories were created via manual tabulation of similar situations. Thus, categories of variables were determined based on what was found to be surprising or unexpected (the trigger event) and circumstances surrounding the event and resolution (the response).

Once categories were discovered, they were consolidated as described in the section on Concept Collapsing and Coding (Figure 1), and the frequencies of the final categories were tallied. If a report contained detailed information fitting more than one category, an entry was made in all applicable categories. At least two researchers reviewed each report and inter-rater reliability was checked.
The results from this analysis provided, (a) categories of events the participants found to be unexpected; (b) procedures regarding responding to unexpected events; (c) examples of behaviors associated with flightcrew response; (d) where gaps in procedures or checklists may exist regarding unexpected or ill-defined events; and (e) what kind(s) of training might improve responses to unexpected events. The results of these interviews will begin to inform what other training and methods might be useful to aid in building a more resilient pilot.

The results from the analyses are to help add to the body of knowledge on how to assess and improve pilot responses to unexpected events.

3. Terms and Definitions

This section provides the terms and definitions used in this study. From Task 3.1, we adopted consistent construct definitions. Here we also define the terms that we will use in referring to tasks and activities of the study to ensure our consistency and promote the understanding of our work to readers and reviewers.

Table 1 summarizes the current definitions of the primary constructs of interest in this phase of the study. Note that these definitions are based on current literature, but they have been modified to

ensure a well-operationalized variable for adequate measurement. We also created simplified references for use with participants in the study for pertinent constructs:

"Unexpected Event" - An unexpected event is any event that takes someone by surprise, which can violate a pilot's expectations and can affect the mental processes used to respond to the event. This includes situations that are difficult to identify, do not have known procedures to respond, or appear to not fit into a specific checklist.

"Ill-defined Event" - This would be a situation where there is no annunciation and/or checklist. It might be a combination of factors that do not seem to make sense.

"Pilot Resilience" - The ability to adapt and respond to a situation that is unexpected or ill-defined.

Table 2 presents the construct indicator variables (that can be measured) with definitions and operationalization of the indicator variables of interest.

Table 2. Primary Research Constructs of Interest

Construct of Interest	Current Definition Used
Adaptability	We define adaptability as, "*being able to strategically return to an original state after an unexpected event*" after Hancock & Cruit (2020). Through post scenario interviews with pilots, we can assess what strategies were used to return to their original state after an unexpected event.
Brittleness	Woods (2015) definition of brittleness has been adopted as "*a rapid fall off or collapse of performance that occurs when events push a system beyond its boundaries for handling changing disturbances and variations.*"
Cognitive Flexibility	According to Spiro (1995), "*cognitive flexibility is the ability to spontaneously restructure one's knowledge in many ways, in adaptive response to radically changing situational demands"* and has been adopted as our working definition.
Decision-Making	We consider decision-making as a *systematic approach to the mental process used to consistently determine the best course of action in response to a given set of circumstances.*
Metacognition	Metacognition is the ability to monitor one's current level of understanding and decide when it is and when it is not adequate. In other words, it is the awareness of one's knowledge and is a skill which can be used to control and manipulate cognitive processes.
Monitoring	The working definition for monitoring is adopted from the FAA's Crew Resource Management Advisory Circular (AC 120-51E) is "*the observation of the aircraft's flight path and systems and actively cross-checking the actions of other crewmembers."*
Novelty	Novelty is considered to be "*a property of a stimulus that has not been previously presented to or observed by and is thus unfamiliar to the subject*" per Gordon & Luo (2011).
Recognition	The working definition for recognition in the context of this project is, *identifying something totally with sense, perception, awareness and/or behavior.*

Resilience	Our definition of resilience has a specific focus on the system states. Thus, we define resilience as "*the capacity of a system to exhibit a new state of operational stability when adaptation to recover the prior base state has now failed*." In addition, we also consider a definition of resilience that pertains directly to the human in the system: "*the ability to adapt to changing circumstances by attaining a differing form of operational stability through situation assessment, self-review, decision making, and action."* By focusing on the human in the system, we can consider human behavior and implications for training these qualities of resilience as outlined in the definitions.
Robustness	We will use the definition from Hoffman & Hancock (2017) for robustness as, "*the ability of the system to operate within its normal operating boundaries when it is perturbed*."
Safety	The working definition of safety is from the ICAO, "*the condition where risks are managed to acceptable levels*."
Startle	For the purposes of this study, we define startle as, "*a physiological reflex reaction to a sudden, intense stimulus triggering an involuntary physiological response to include eye blink, increased heart rate, and increased tension of the muscles*."
Stress	"*Stress is a response to threatening situations that involves biological, cognitive, behavioral, and emotional components*" is adopted as our definition of stress from Dismukes, Goldsmith, & Kochan (2015).
Surprise	Surprise is defined as, "*an emotional and cognitive response to unexpected and difficult to explain events*" as described by Landman et al. (2017).
Unexpected Event	An unexpected event is *(a) An event incongruent with expectations as determined by base rate probabilities (average probability of event occurring) and the contextual information available; may be normal, abnormal, or emergency in nature; it may also be frequent, infrequent, or novel; or (b) the absence of an expected event.*

Table 3. Research Constructs of Interest with Measures

Judgment Expertise Construct of Interest	Indicator Variables of Construct	How to Measure
Vertical Thinking	Cue usage	Key words/terms in the SME/Pilot Survey responses
	Script shifting	Key words/terms in the SME/Pilot Survey responses
Strategic Knowledge	Decision-making strategies	Key words/terms in the SME/Pilot Survey responses
	Application of facts and procedures	Key words/terms in the SME/Pilot Survey responses
Metacognitive Skills	Scenario rehearsal	Metacognitive Survey
	Imagery	Metacognitive Survey
Cognitive Flexibility	Generate and consider alternatives	Cognitive Flexibility Survey
Adaptive Expertise	Apply knowledge to novel situations	Key words/terms in the SME/Pilot Survey responses
Self-Efficacy	Confidence in actions	Self-Efficacy Survey Generalized Self-Efficacy Survey

Resilience	Anticipating	Key words/terms in the SME/Pilot Survey responses
	Monitoring	Key words/terms in the SME/Pilot Survey responses
	Responding	Key words/terms in the SME/Pilot Survey responses
	Learning	Key words/terms in the SME/Pilot Survey responses

4. Task 3: Pilot Needs Analysis Research Method

4.1 Institutional Review Board and Informed Consent

This study was conducted with an exemption from regulation on human subject research by the University of Central Florida Institutional Review Board. The participants were provided with an informed consent document. See Appendix A for exemption document and informed consent statement.

4.2 Participants

Participants were recruited via email solicitations to known crewmembers meeting the criteria of 14 CFR Part 121, Part 135, or Part 91K. The recruitment email is shown in Appendix G. Each participant was scheduled at their convenience and compensated with a $150 gift card from a nationally known pilot shop. Demographic data were collected via Qualtrics (i.e., an online platform designed to collect and analyze survey data) at the beginning of the interview sessions.

4.3 Interviewers and Reviewers

Two interviewers holding PhDs in human factors conducted the study sessions. One interviewer is a retired airline pilot and currently flies as an FAA Designated Pilot Examiner. Two other researchers, one a retired airline pilot, conducted reviews on the video recordings to check for consistency of transcription of the sessions.

4.4 Study Procedure

As detailed in Appendix F, the study protocol was conducted virtually via a Zoom conference call with the participant. The sessions were audio and video recorded. After the brief introduction to the study, the participants used a Qualtrics link to complete demographic questions and self-assessment questionnaires. They returned to the Zoom call and the interviewer conducted a semi-structured interview consisting of ten questions found in Appendix E. The sessions lasted approximately one-hour. Participants received their gift card information after completion of the session.

4.4.1 Measurement Instruments

Five pilot self-assessment questionnaires were administered during the session. The purpose of the questionnaires was to obtain measures of four factors (human traits/states/behaviors) found in the literature that contribute to the construct of resilience which has been found to influence the ability to respond to the unexpected. The instruments with references are presented in Appendix D.

4.5 Data Preparation and Analysis

Data were entered into SPSS version 27 (IBM Corporation, 2020) for analysis. The demographics and questionnaire data were imported from Qualtrics. Analyses included descriptive statistics, frequency analyses, and analyses of variance.

4.5.1 Interview Data: Concept Collapsing and Coding

The interview data were prepared by first having at least two interviewers and/or reviewers view the recorded interviews and code "key concept(s)" for each question. The concepts were then grouped and categorized in an Excel spreadsheet. A snapshot of a segment of the spreadsheet showing the main category (e.g., Crew Management Resource Concepts), the sub-category (e.g., "Workload/Situation Awareness"), and then the "key concept" that contributed to the sub-category (e.g., "Task Switching," "High Workload") is shown in Figure 1. Frequency distributions of the concept categories for each question were created data visualization.

Figure 1. Concept Collapsing and Coding of Interview Data Example

Technical Skills Concepts		Crew Resource Management Concepts			
Domain Expertise	Training	Workload/Situation Awareness	Communication	Teamwork	Decision Making
1	2	1	2	3	1
Procedural Knowledge	Training	Situation Awareness	Communication	Leadership	Rushed Decision Making
Expertise	Training for procedures	Tunneling	Task delegation	Teamwork	Complacency
Expert vs Novice	Train critical thinking	Mental Workload	Nonverbals	Having a team	Decision Making Under Time Pressure
Knowledge of resources	Lack of training for skydivers	Task switching	Lack of communication	Trust in others	Decision making strategies
Lack of experience with aircraft	Standardized training	Heads Down	Communication event	Trusting in teamwork	Time-sensitive decision making
Knowledge of environment at airport	Type rating training	High workload	Inconsistent communication	Rapport	Prioritizing options under time pressure
Knowledge of basics	Relied on training	Distracted	Sound recognition	Shift Turnover	Expert vs novice decision making
Knowledge of procedures	Learning	Recognition		CRM	Prioritizing tasks
Amount of experience/training will help you make decisions		Recognition based on past experiences		Interpersonal conflict	Expectation bias
QRH		Recognition based on physiological changes		Calming the crew	Sunk cost effect
Memory Items		Responding		Emergent teaming	Primacy Effect
event did not result in mishap		Monitoring		Brainstrom	Quick decision making
		Unsure where the issue was			Decision error
					Pressure from passengers

5. Task 3: Pilot Needs Analysis Results with Discussion

Section 5 presents the results and discussion of the Pilot Needs Analysis including demographic information, Pilot Self-Assessments, and findings from the SME interviews.

5.1 Participant Demographics Results with Discussion

Figures 2 through 5 summarize the demographic data from the 50 study participants, including data on age, gender, type of operation, and years flying. The sample in the study was consistent with the parameters found in the reference pilot population.

Figure 2 shows the distribution of age groups in the sample. The majority of participants were between the age of 51 and 60 years. Participants had an average age of 46.46 years (*SD* = 11.11). Figure 3 presents the gender distribution of the participants. The study sample is consistent with FAA and airline personnel data (link to 2019 Active Civil Airmen Statistics). Figure 4 presents the distribution of operation group types, while Figure 5 shows the distributions of participant flight hours. The majority of participants met the criteria of 14 CFR Part 121. The majority of participants also had over 30 years of flight experience, with 25.31 years of flying (*SD* = 13.00) on average.

Figure 2. Participant Age Group Frequencies

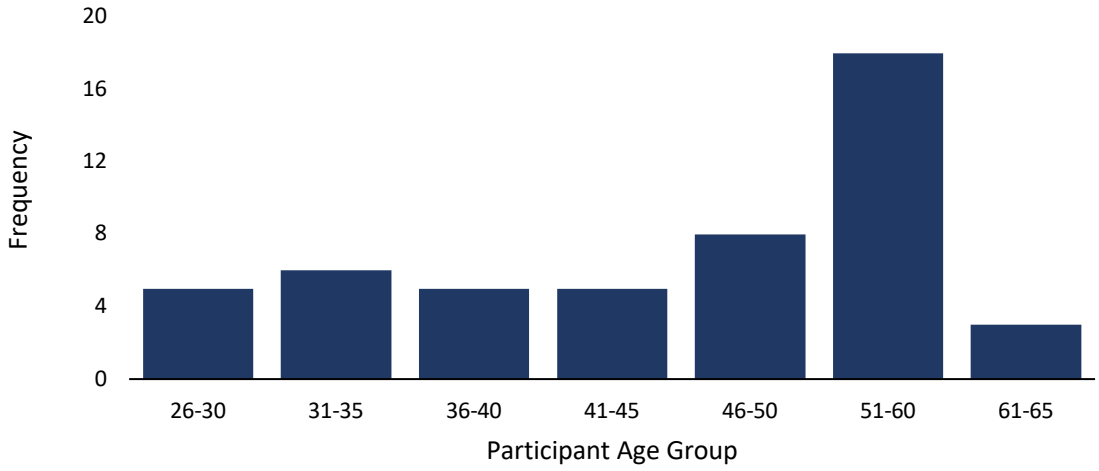
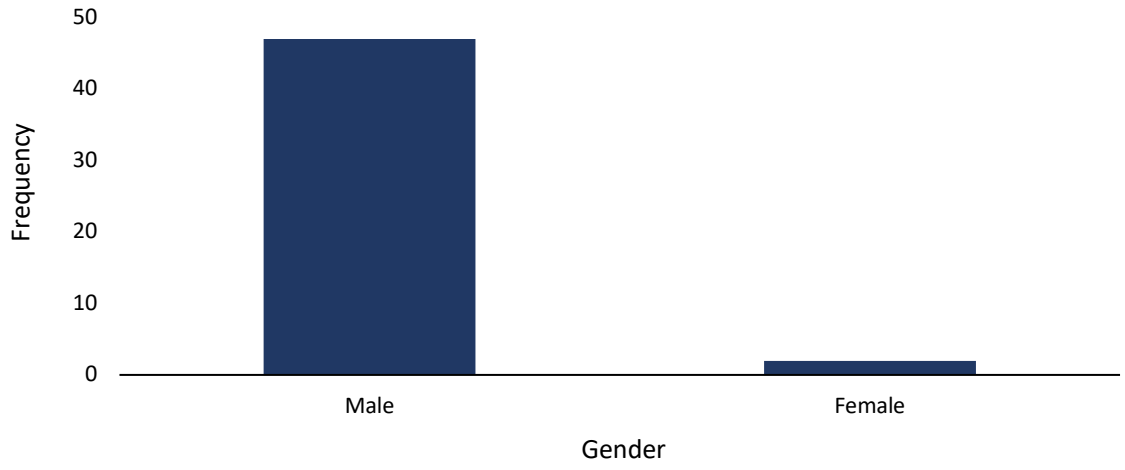


Figure 3. Participant Gender Group Frequencies



Note. Gender data was missing from one participant.

Figure 4. Participant Type of Operation Group Frequencies

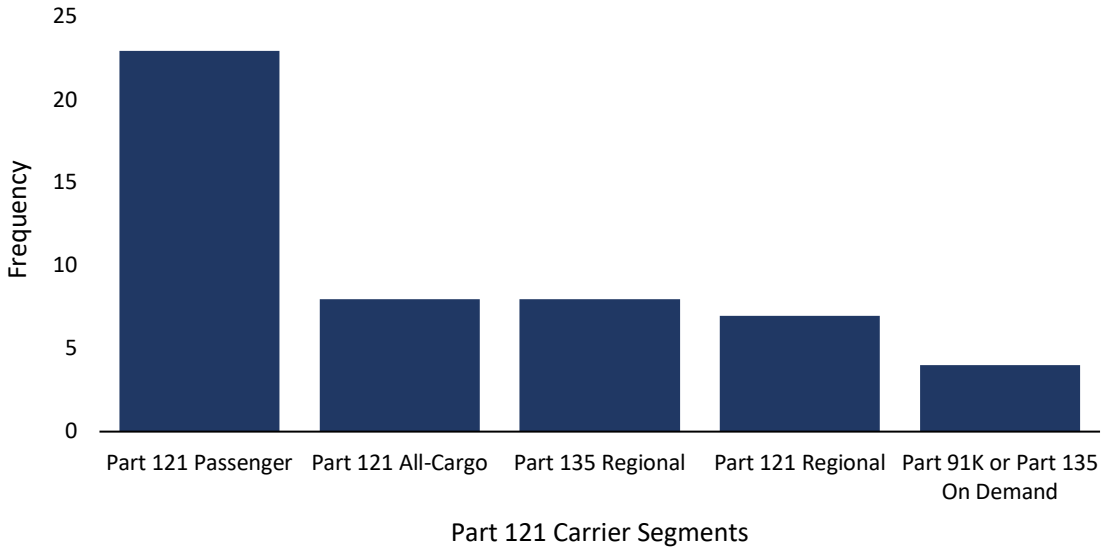
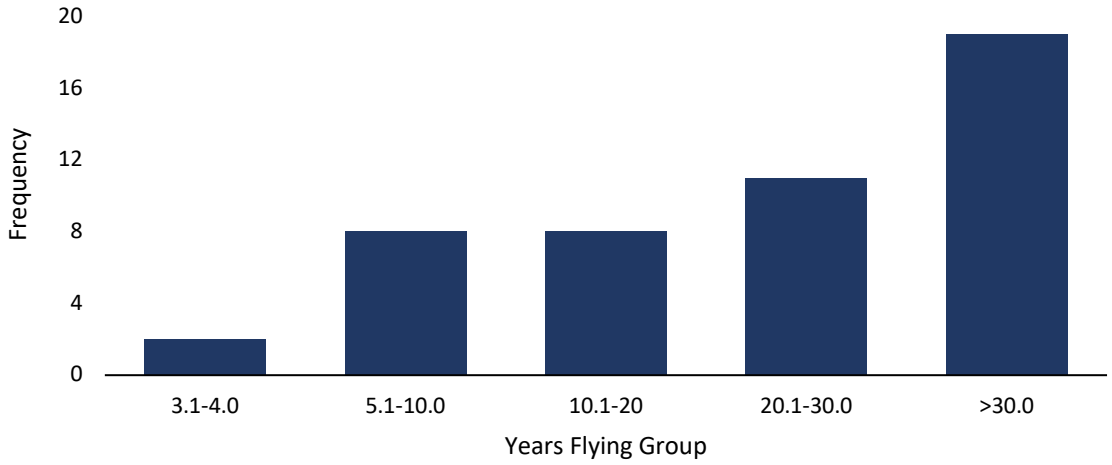


Figure 5. Participant Years Flying Group Frequencies



Note. Years flying data was missing for two participants.

5.2 Pilot Questionnaire Results with Discussion

Table 4 presents the results of the four Pilot Assessments (i.e., Self-Efficacy and Metacognition, Generalized Self-Efficacy, Trust in Automation, and Cognitive Flexibility). The purpose of these assessments was to obtain measures of four factors (human traits/states/behaviors) found in the literature that contribute to being able to best respond to unexpected events. See Appendix B for the complete list of items for each survey.

In the Self-Efficacy and Metacognition survey, participants indicated the extent to which they agreed with statements relating to their self-efficacy and metacognition. For example, “I'm certain I can handle the most difficult situations that arise in flying.” The survey consisted of ten items, and participants responded to each item on a five-point Likert scale (Strongly Disagree to Strongly Agree).

In the Generalized Self-Efficacy survey, participants indicated how true statements about their confidence while flying was for them. For example, “If I am in trouble, I can think of a good solution.” The survey consisted of ten items, and participants responded to each item on a four-point Likert scale (Not at all True to Exactly True).

The Trust in Automation survey asked participants to indicate the extent to which they agreed with statements regarding aircraft flight management systems. For example, “I understand the limitations of the system.” The survey consisted of nine items, and participants responded to each item on a five-point Likert scale (Strongly Disagree to Strongly Agree).

Cognitive Flexibility survey asked participants to indicate the extent to which they agreed with statements regarding their cognitive flexibility when dealing with an unexpected event in aviation. For example, “I consider multiple options before making a decision.” The survey consisted of 20 items. Participants responded to each item on a five-point Likert scale (Strongly Disagree to Strongly Agree).

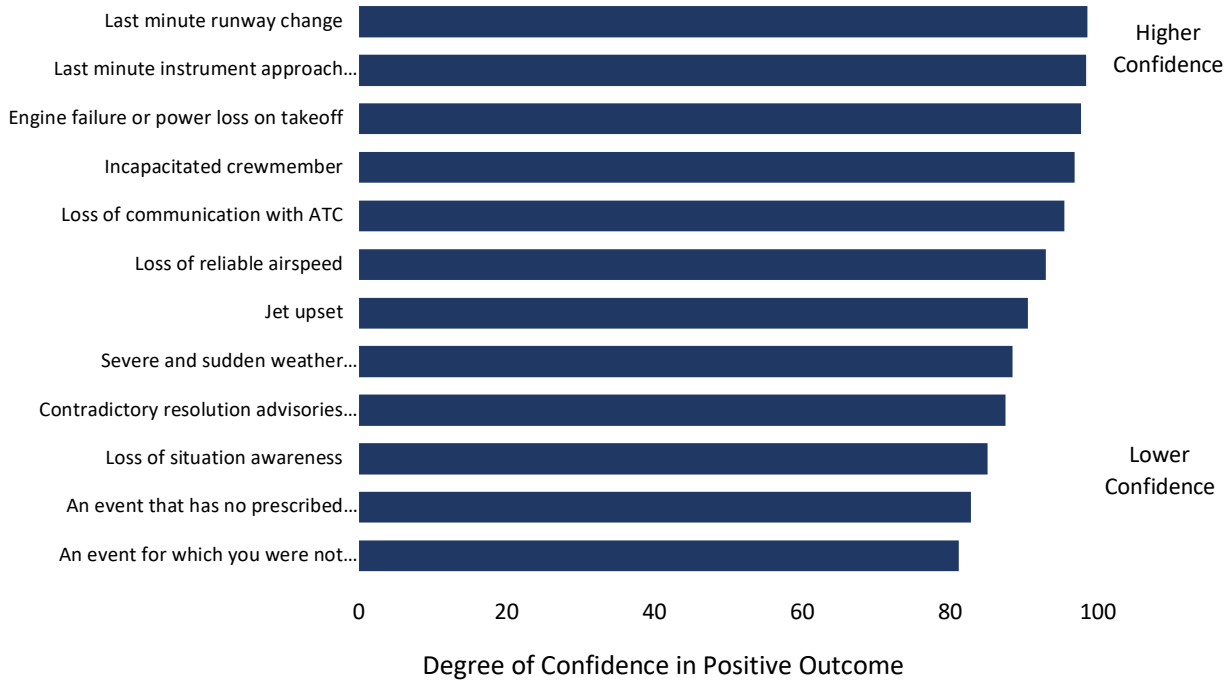
For each survey, the average, median, minimum, and maximum scores were calculated. Larger scores reflect higher degrees of the respective trait(s)/behaviors that were assessed by the survey. In general, all survey data were positively skewed in that most pilots scored high (with a ceiling effect) on all assessments. This suggests that pilots tend to have high degrees of self-reported self-efficacy, metacognition, trust in automation, and cognitive flexibility.

Table 4. Pilot Assessment Questionnaire Results

Assessment	*Mean*	*Median*	*Standard Deviation*	*Min*	*Max*
Self-Efficacy and Metacognition	4.25	4.3	0.58	1.5	5
Generalized Self-Efficacy	3.36	3.35	0.37	2.5	4
Trust in Automation	4.31	4.33	0.45	3	5
Cognitive Flexibility	4.36	4.4	0.33	3.7	5

Figure 6 presents the results of the Pilot Self-Efficacy Questionnaire. Participants were given a list of unexpected/surprising situations that might occur while flying (e.g., a last-minute runway change) and were asked how confident they were that their decisions in each type of event would result in a positive outcome. Participants indicated their confidence on a scale from 0 to 100, with higher scores indicating higher self-efficacy. Overall, participants reported a high degree of confidence in their ability to handle unexpected events.

Figure 6. Pilot Self Efficacy Questionnaire Results



5.3 Subject Matter Expert Interview Results with Discussion

This section presents the results of the analyses of the ten questions presented on the semi-structured interview.

5.3.1 Question #1

Describe the two most surprising or unexpected events that you have experienced in aviation and what

5.3 Subject Matter Expert Interview Results with Discussion

5.3.1 Question #1

Figures 7-10 reflect the results from Question #1: “Describe the two most surprising or unexpected events that you have experienced in aviation and what were the outcomes to these events? (When did these occur?)”

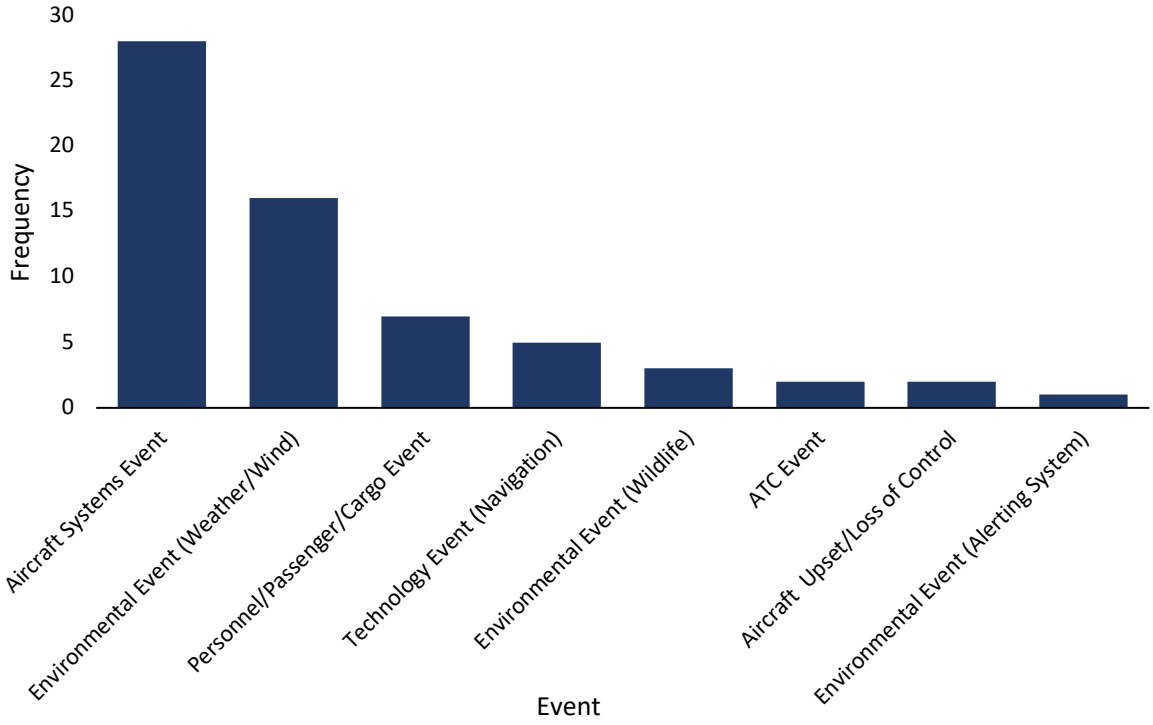
There were eight categories of events identified in the responses to this question. Aircraft systems events involved the of the mechanical systems of the aircraft (e.g., engine, hydraulic, and gear failures), whereas technology events involved the aircraft’s computer/automation and avionics systems. Environmental events included events caused by or relating to elements of the environment surrounding the aircraft. Environmental events are further classified as either weather/wind events (e.g., icing), wildlife events (e.g., a bird strike) or altering system events (e.g., terrain avoidance warning). Additional categories of unexpected events included personnel/passenger/cargo events (e.g., an event caused by a crewmember or passenger), unexpected events involving ATC, and events involving aircraft upset or loss of control.

Figure 7 presents the frequency of events reported as surprising or unexpected. The top three surprising or unexpected events were aircraft systems events; environmental events; and personnel, passenger, or cargo events.

Figure 8 shows how often each type of technical skill was mentioned in participant responses to this question, while Figure 9 shows how often each type of CRM skill was mentioned in participant responses. Participants mentioned domain expertise skills more often than training while discussing the unexpected or surprising event. Communication was the most common CRM skill mentioned in conjunction with the unexpected event.

Figure 10 presents how often each type of judgement skill was mentioned in participant responses to Question 1. Participants frequently reported decision-making skills, followed by cognitive flexibility and metacognitive skills.

Figure 7. Types of Events Reported as Surprising or Unexpected



5.3.2 Question #1

Figure 8. Technical Skills Reported for Surprising or Unexpected Events

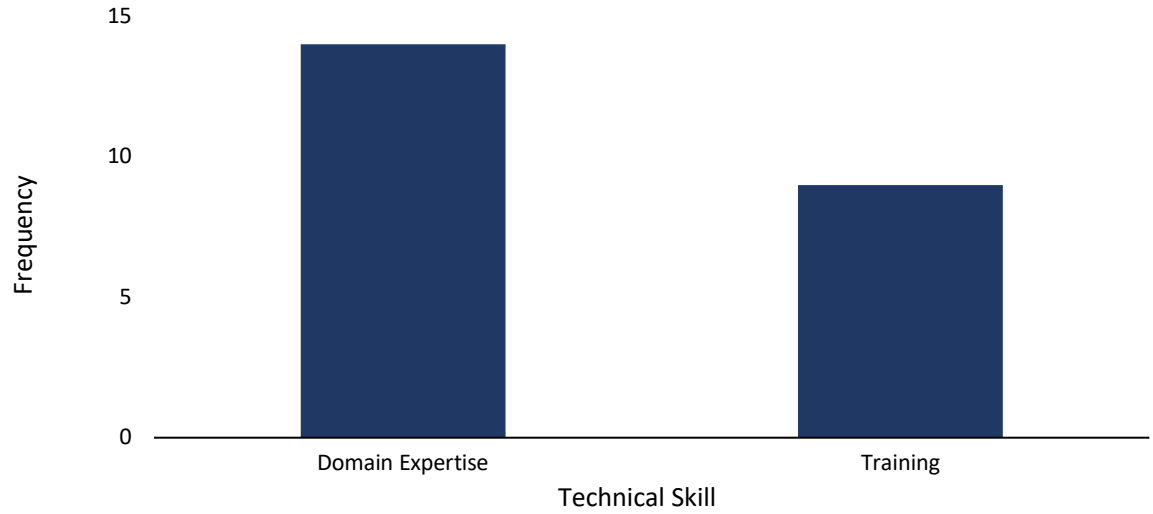


Figure 9. Crew Resource Management Skills Reported for Surprising or Unexpected Events

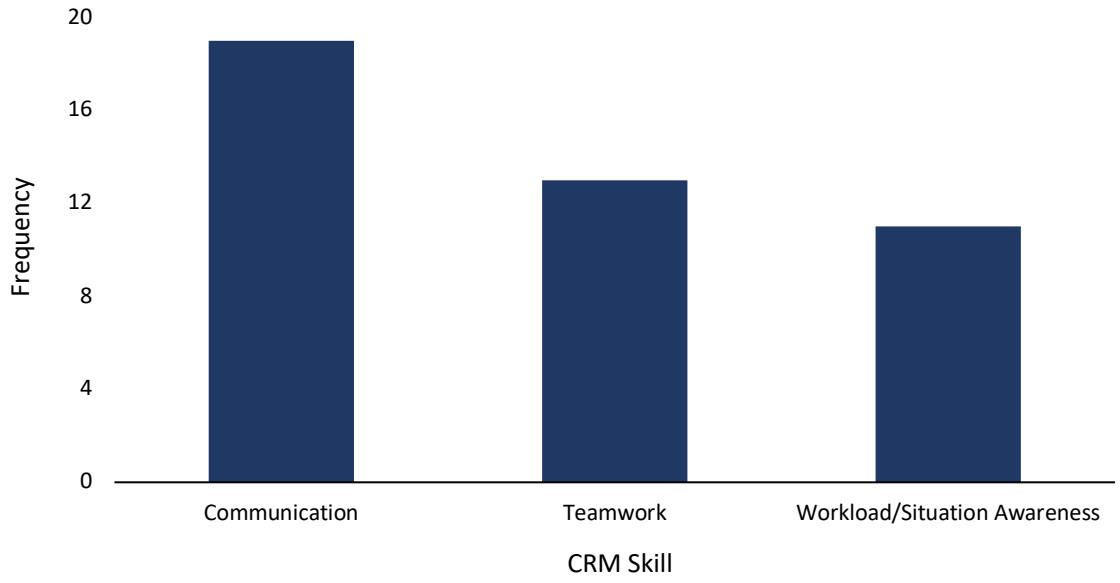
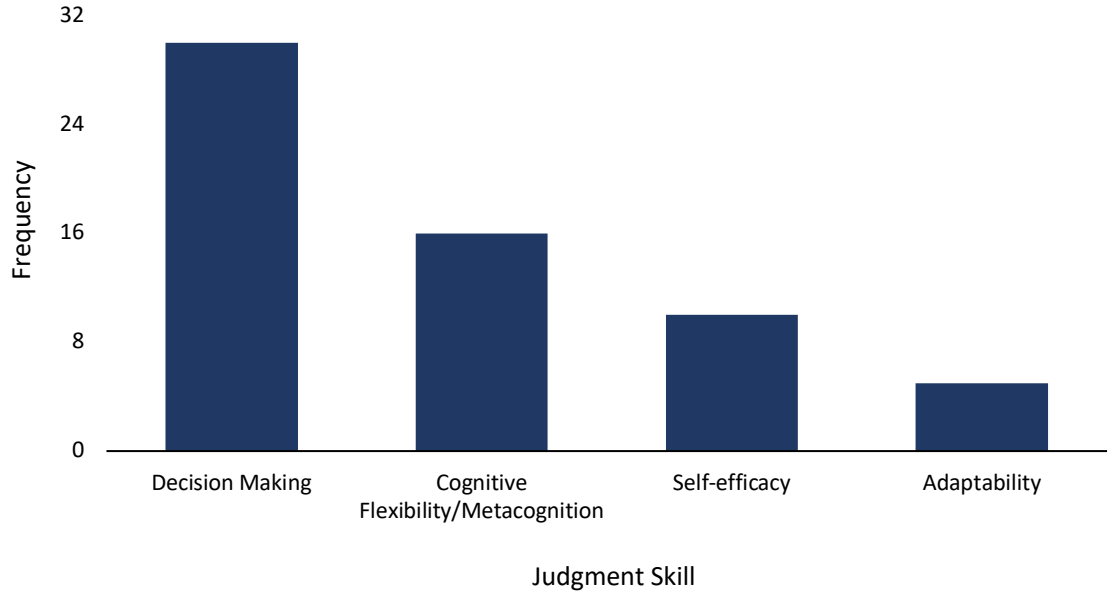


Figure 10. Frequency of Judgment Skills Reported for Surprising or Unexpected Events



5.3.2 Question #2

Figures 11-12 reflect the results of Question #2: “Have you ever had an unexpected event occur because of technology or a particular Instrument Flight Procedure? If so, explain.”

Figure 11 lists frequencies of types of unexpected events involving technology or instrument Flight procedure. The most frequently type of technology unexpected event involved navigation/the navigation system, though other types of technology events included those relating to trust in the automation and one’s knowledge of the technology. Other, less-frequently reported technology events involved an additional causal factor (i.e., relating to personnel/passenger/cargo, weather/wind, ATC, or the aircraft system,).

Figure 12 presents how often and what kind of judgment, CRM, and technical skills were reported in response to this question. The most frequently reported skill was cognitive flexibility/metacognition, followed by workload/situation awareness, and the reliance on training.

Figure 11. Types of Technology or Instrument Flight Procedure Unexpected Events

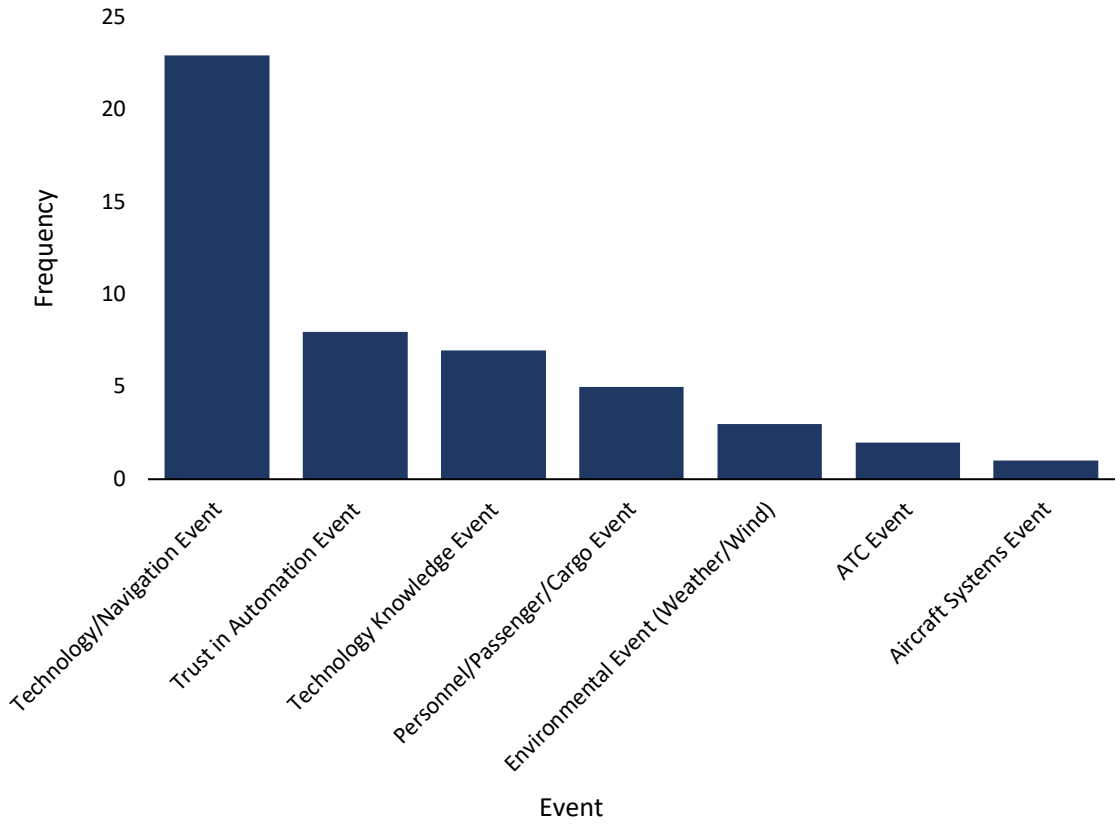
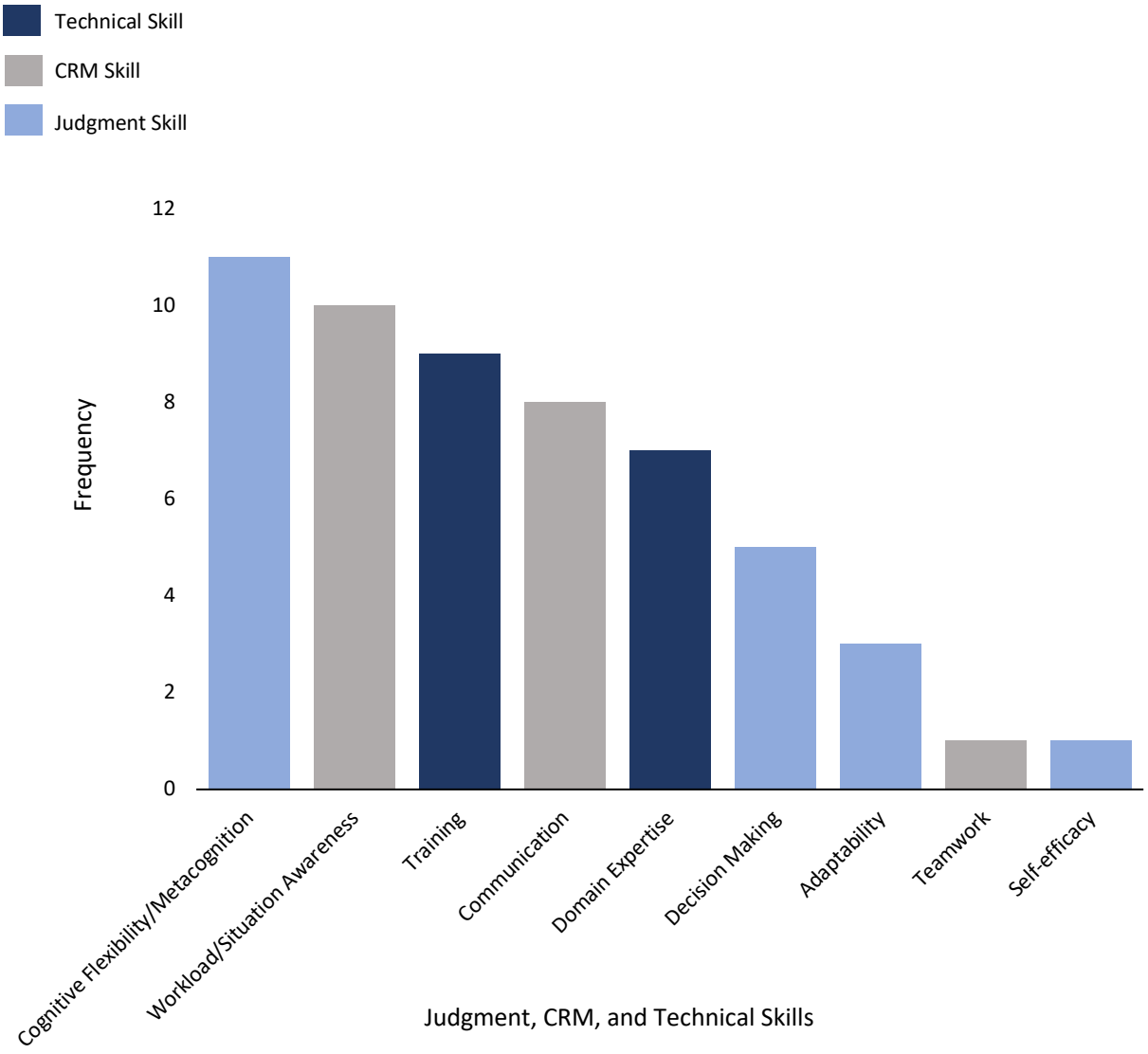


Figure 12. Frequency of Judgment, CRM, and Technical Skills Reported for Technology or Instrument Flight Procedure Unexpected Events



5.3.3 Question #3

Figures 13 and 14 reflect the results of Question #3: “In general, what do you consider the most surprising events that happen while flying.”

Figure 13 lists the frequencies of the types of events that participants generally found to be surprising, while Figure 14 reflects judgment, CRM, and technical skills reported by participants in response to the question. The most reported type of event was environmental events, followed by aircraft systems events and personnel/passenger/cargo events. Participants frequently mentioned workload and situation awareness when answering this question.

Figure 13. Frequency of General Impression of Surprising Events in Flying

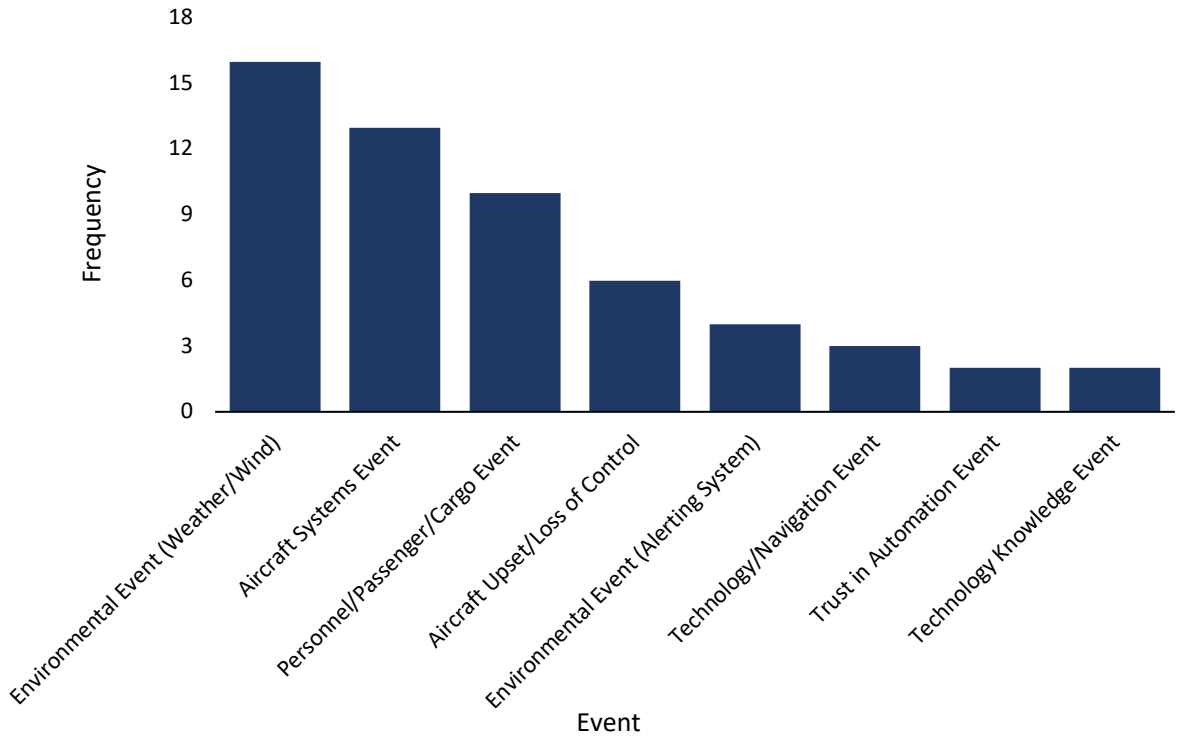
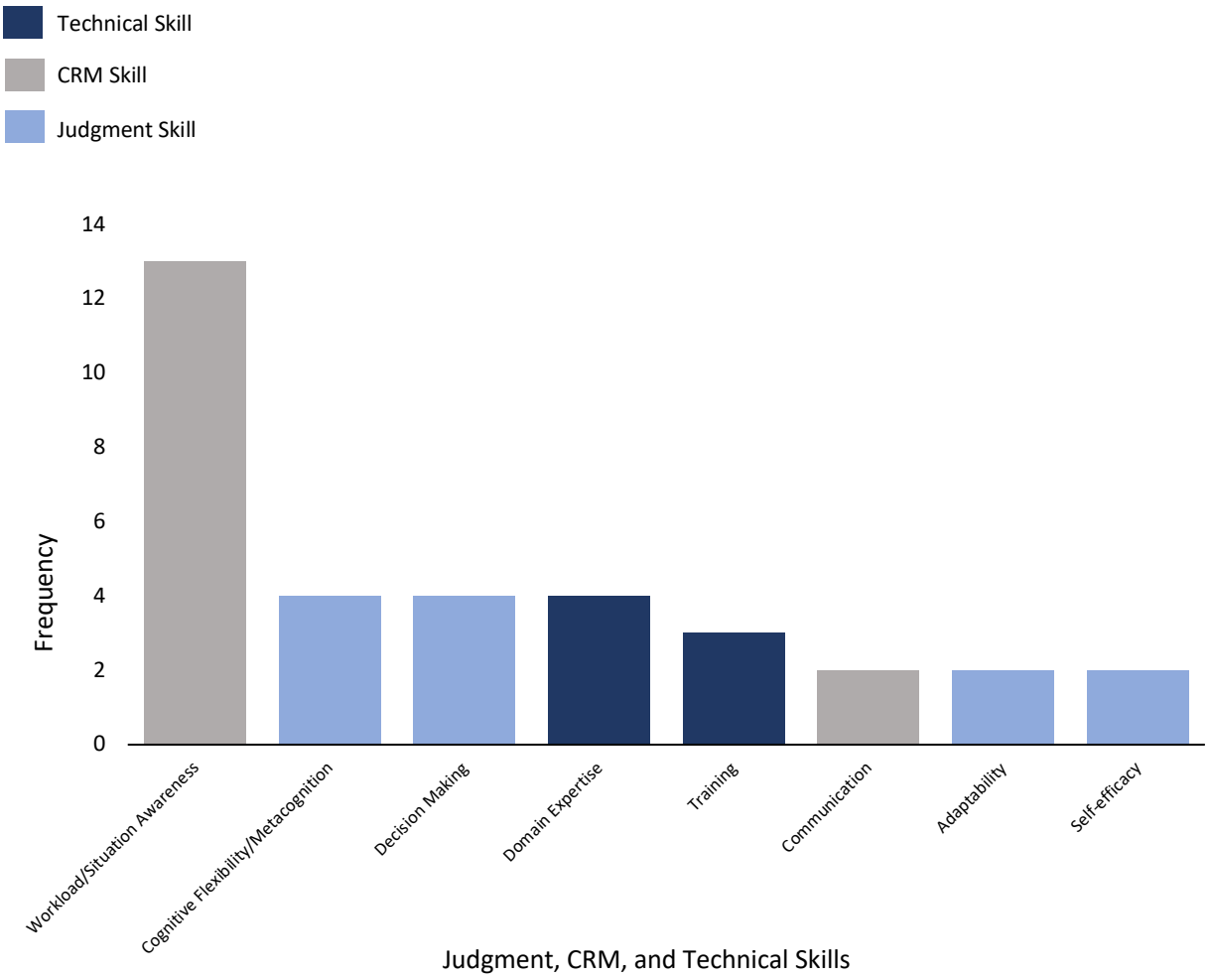


Figure 14. Frequency of Judgment, CRM, and Technical Skills Reported for General Impression of Surprising Events in Flying

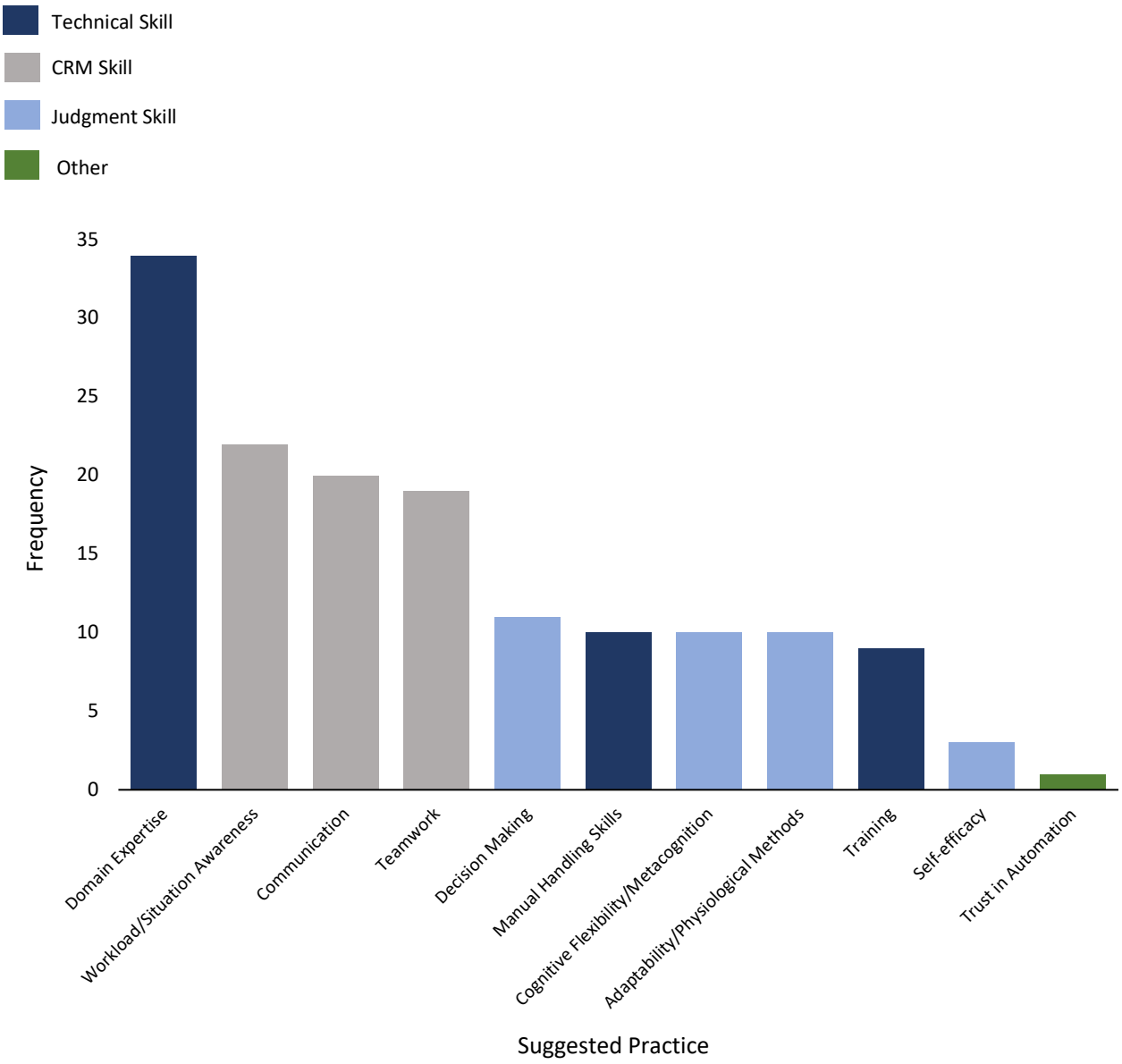


5.3.4 Question #4

Figures 15 reflects responses to Question #4: "What are the procedures, guidance, best practices, and/or habits that you use in dealing with unexpected events?"

The top three procedures, guidance, best practices, and/or habits used when responding to unexpected events were using domain expertise, managing their workload and situation awareness, and communicating with their crew. Some frequently reported, specific strategies included "aviate, navigate, communicate, following checklists and procedures, and "winding the clock" (i.e., slowing down and thinking through the process).

Figure 15. Frequency of Suggested Best Practices for Dealing with Unexpected Events



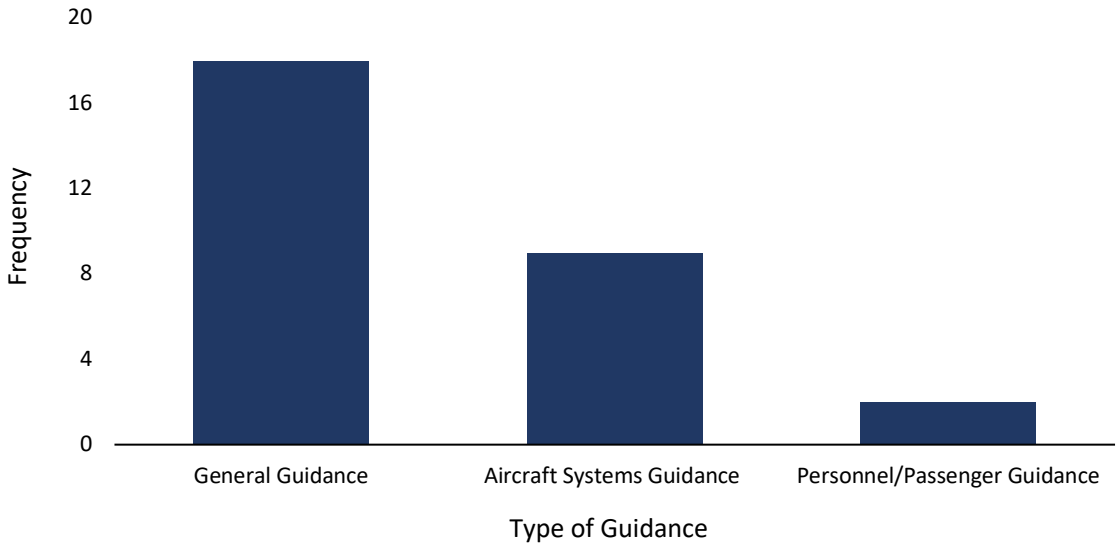
5.3.5 Question #5

Figure 16 reflects responses to Question #5: "Are there procedures or guidance that you have found missing or unavailable for a given event? If so, explain."

Participants most often reported that general guidance was missing. Participants also reported that aircraft systems guidance was often missing, followed by personnel/passenger guidance. Though, participants often reported adapting known procedures, using their system knowledge. Pilots also reported leveraging past experiences, which involves applying knowledge of event and strategies previously known to be helpful in dealing with the event to the problem at hand. For instance, one

participant recalled diagnosing smoke as being caused by an electrical fire based on having experienced an electrical fire in the past.

Figure 16. Types of Missing Guidance

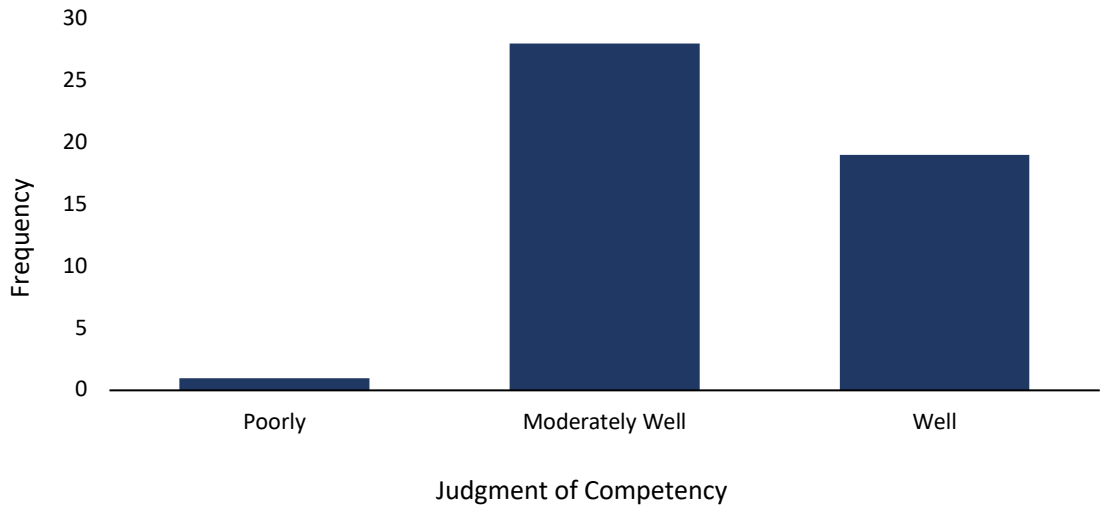


5.3.6 Question #6

Figure 17 reflects responses to Question #6: “In general, how well do pilots handle unexpected events?”

Overall, participants reported that pilots handle unexpected events well, though some handle them better than others.

Figure 17. Pilot Competency in Responding to Unexpected Events

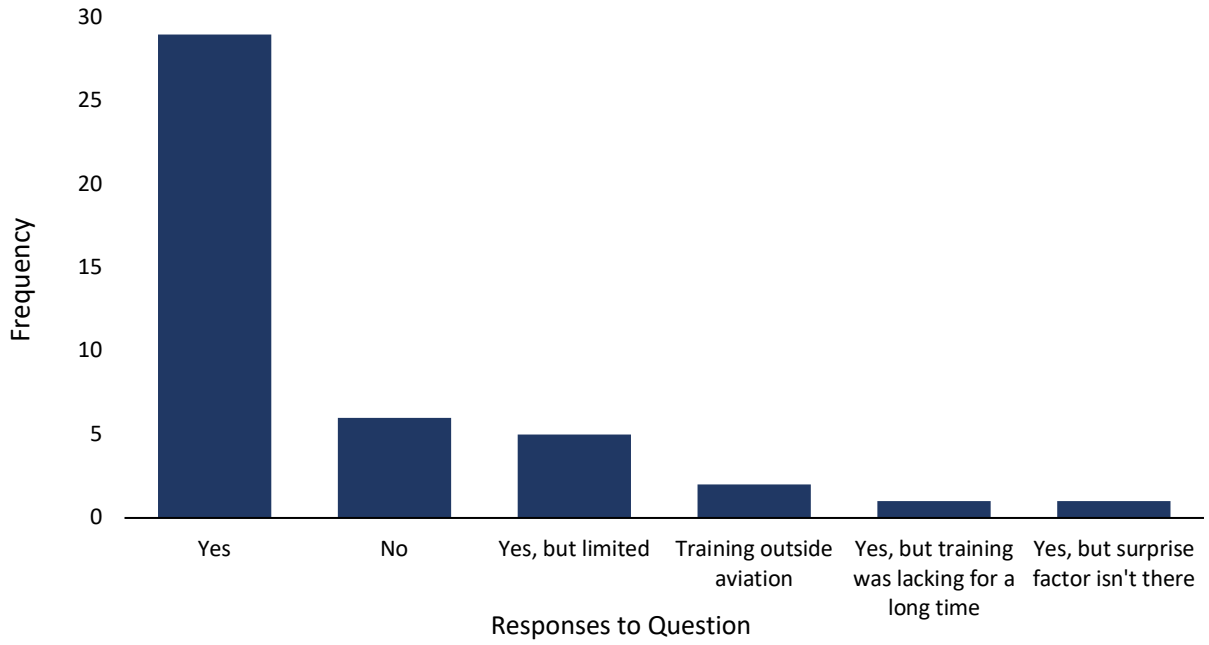


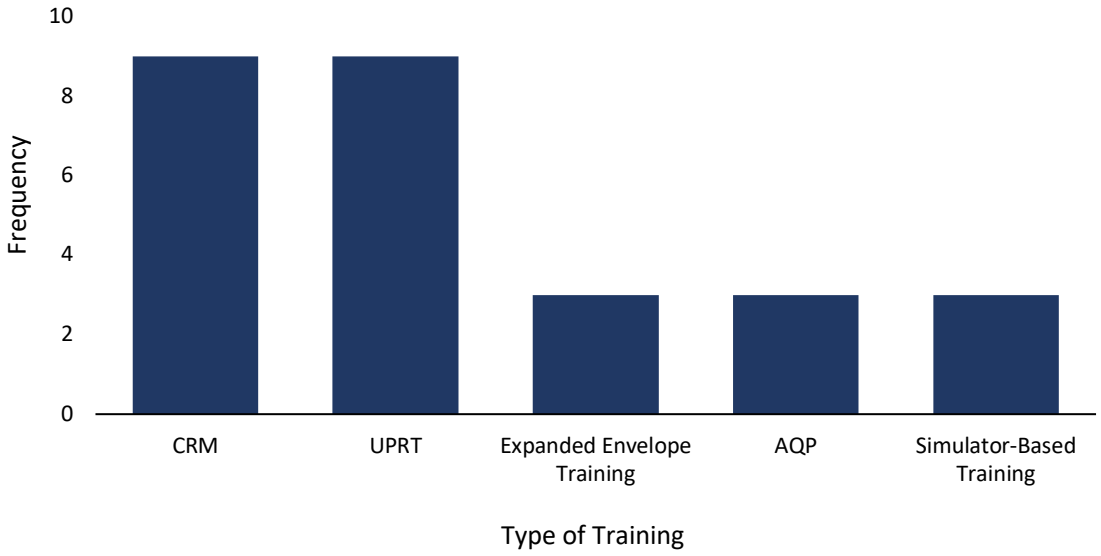
5.3.7 Question #7

Figures 18 and 19 reflect responses to Question #7: “Have you had any specific training on reacting to unexpected events in general (not for specific procedures), for example in Crew Resource Management (CRM) or Upset Prevention and Recovery Training (UPRT)? If so, describe the training.”

Figure 18 shows participant responses to the first part of Question #7 (i.e., “Have you had any specific training on reacting to unexpected events in general”), while Figure 19 lists the types of trainings reported by participants in response to this question. Most participants reported having some type of training regarding unexpected events. The most frequently reported types of training were CRM training and UPRT.

Figure 18. Pilot Training in Responding to Unexpected Events



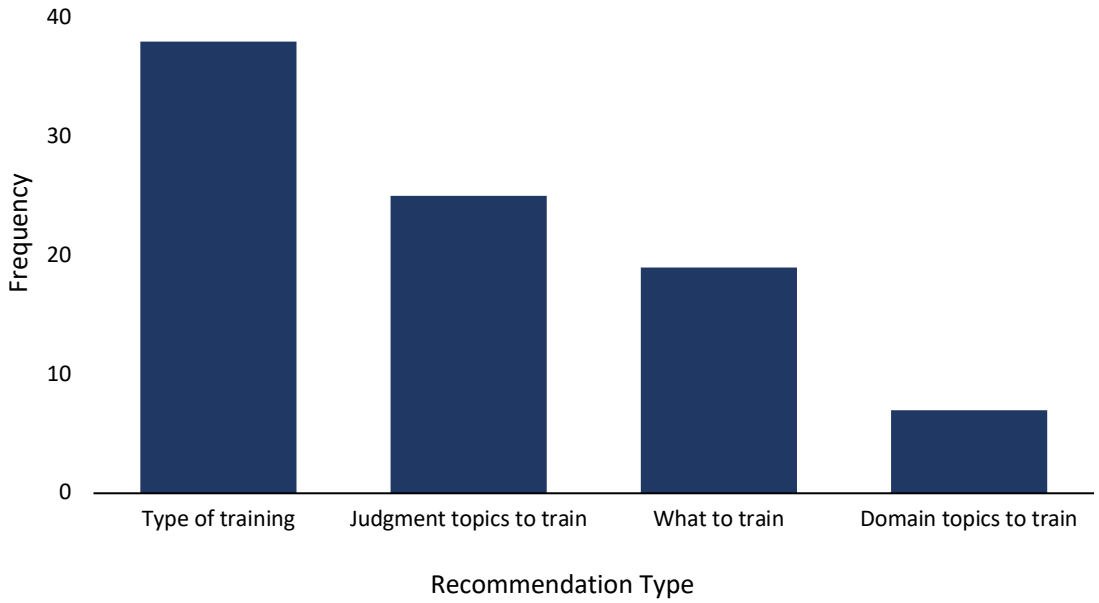


5.3.8 Question #8

Figure 20 reflects participant responses for Question #8, “What do you think can be done to improve pilot response and outcome to unexpected events in aviation?”

Participants identified specific methods of training that would be beneficial as well as what topics to train. Participants reported that more simulator, ground, and Line Oriented Flight Training (LOFT) training would help improve pilot response to surprising or unexpected events. Additionally, many participants stated that more training on prior events would help pilots handle unexpected events in the future.

Figure 19. Types of Recommendations to Improve Pilot Response and Outcome to Unexpected EventsZ

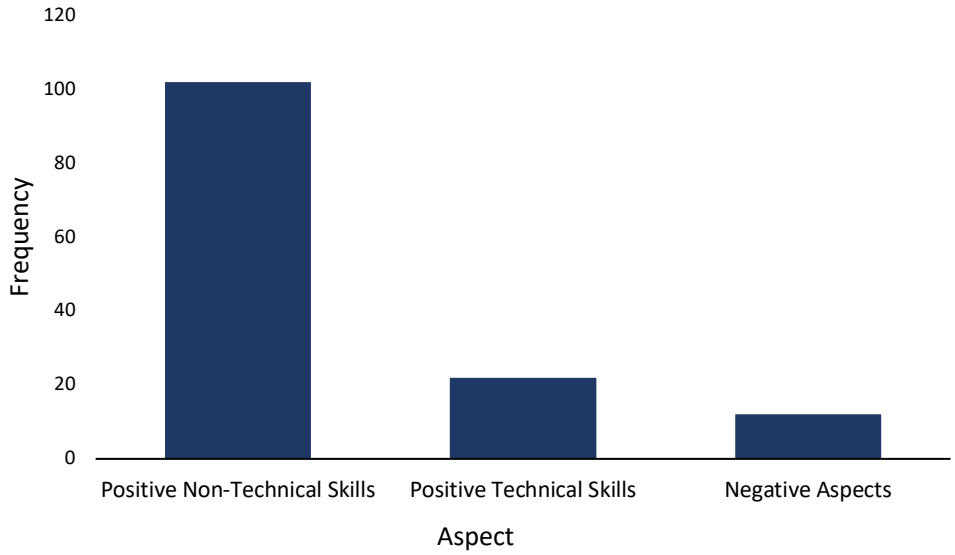


5.3.9 Question #9

Figure 21 reflects responses to Question #9: “With regard to your crew, what is most important when faced with an unexpected event? Have you had any training in this regard?”

This figure lists the frequencies of the aspects identified as important when faced with unexpected events. As this figure shows, both positive technical skills (e.g., those relating to domain expertise) (and non-technical skills (e.g., metacognition) were more important than negative aspects (e.g., complacency).

Figure 20. Aspects Identified as Important when Faced with an Unexpected Event

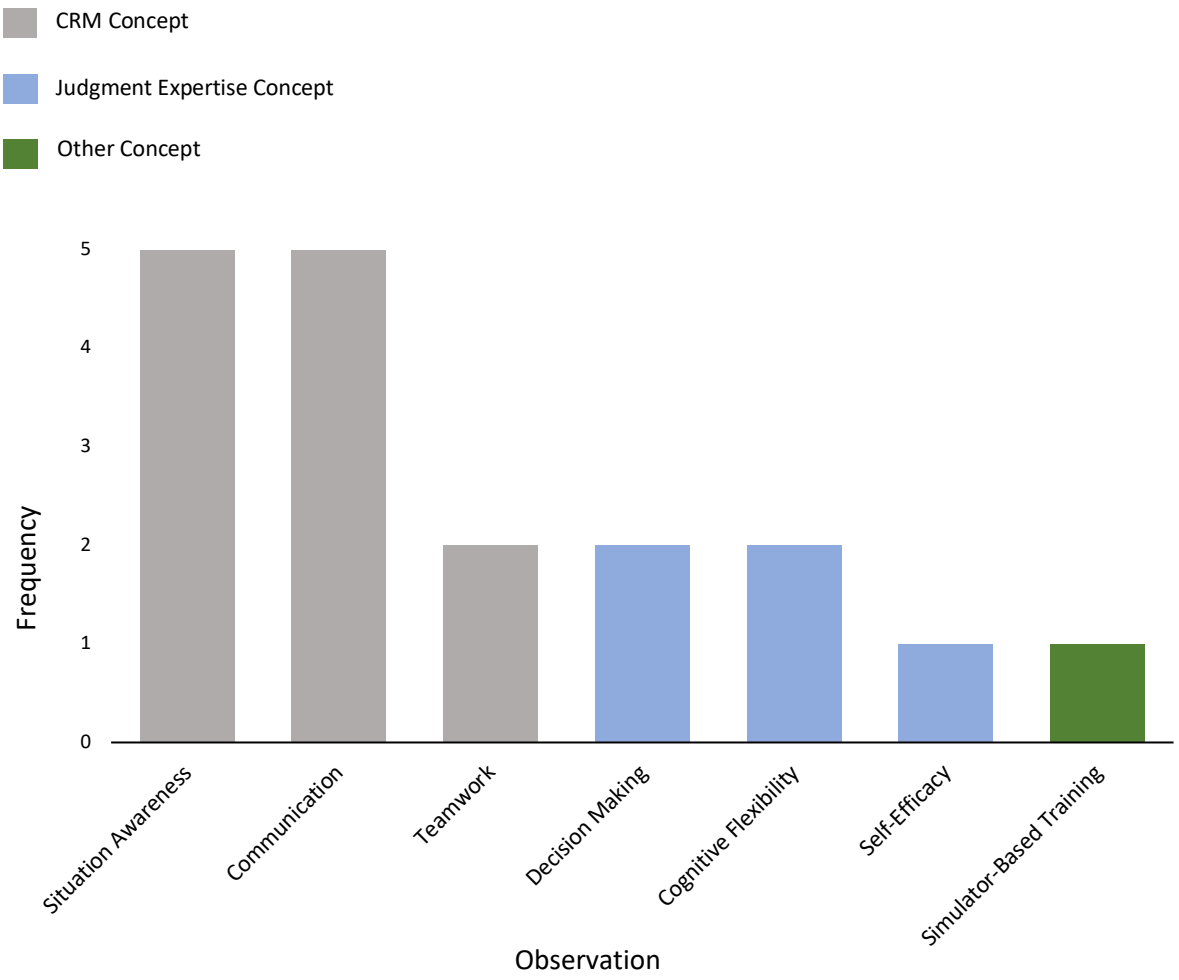


5.3.10 Question #10

Figure 22 reflects responses to Question #10: "Do you have any other observations/items to add?"

Participant responses for this question were categorized as either having to do with a CRM or judgment expertise concept (e.g., the participant reiterated the importance of teamwork), or the responses were categorized as "other" if they did not relate to CRM or judgment expertise. For instance, some pilots commented on how safety culture in aviation has changed over the years.

Figure 21. Ad Hoc Observations Regarding Unexpected Events by Concept Type



6. Conclusions and Recommendations for Future Research

6.1 Self-Reported Surprising or Unexpected Events

From Questions #1, #2, and #3, we learned what kind of events pilots SMEs reported as surprising or unexpected. The top three events participants reported as surprising or unexpected were aircraft systems events (e.g., engine, hydraulic, and gear failures), environmental events (e.g., icing, wake turbulence, and weight and balance events), and human events (e.g., events caused by crewmember and/or passenger behavior). Technology events (i.e., events involving the aircraft's computer, aviation, or avionics systems) were not-frequently reported as surprising or unexpected.

6.2 Reported Strategies for Handling Surprising or Unexpected Events

Questions #1, #2, and #4 informed us what strategies the participants used when faced with surprising or unexpected events. These strategies include “aviate, navigate, communicate,” following procedures and checklists, “winding the clock (i.e., slowing down and thinking through the process),” maintaining situation awareness, and utilizing the team (both within and beyond the flight deck).

6.3 Procedures: Used and Missing

From Questions #4 and #5, we learned that though participants reported following procedures when handling unexpected events, there are situations in which there is no known procedure. In these events, participants reported adapting known procedures and using their system knowledge and leveraging past experience when the checklist is incomplete or not correct.

6.4 How Well Pilots Handle Unexpected Events

From Question #6, we learned that our participants believed that pilots, in general, handle unexpected events well, though some better than others.

6.5 Training for the Unexpected

Question #7 revealed what training participants had on handling unexpected events. This training included Crew Resource Management (CRM), Line Oriented Flight Training (LOFT), Advanced Qualification Program (AQP), expanded envelope training, and leadership training.

6.6 Crew Procedures

Question #9 informed us on what crew response techniques participants believed to be useful when faced with surprising or unexpected events. Identified useful procedures included maintaining flight deck discipline, active and open communication, and reaching a consensus among the flightcrew.

6.7 Strategies for Improving Pilot Response

From Question #8, we learned that pilots believe that more simulator, ground, and LOFT training would help improve pilot response to surprising or unexpected events. Additionally, many participants stated that more training on prior events would help pilots handle unexpected events in the future.

6.8 Conclusions and Implications for Future Research

Since the process of the Pilot Knowledge Elicitation interviews was through self-report, it is prudent to further explore the findings through subsequent analyses that involve assessments of pilot performance in realistic unexpected event scenarios. At this time, we do not have sufficient, conclusive information to

suggest that the any of the results from Task 3 should be recommended as training interventions to be tested in a human-in-the-loop experiment. However, the interview and survey data added to the body of knowledge on unexpected events, their assessments, and potential methods of improvements. We recommend developing candidate scenarios that can be used to measure the constructs of interest described in Table 3. In addition to the candidate scenario, a corresponding performance measure is needed to measure how well the pilot is performing the necessary tasks for the chosen scenario. A cognitive task analysis should also be conducted to determine what tasks are necessary for the pilot to perform optimally during the chosen scenario as well as the knowledge, skills, and decisions needed for each task. Finally, any potential training characteristic should be explored and validated in a (HITL). The results could be ultimately to inform the FAA in their development of pilot training guidance.

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Appendix A: Task 3 Study Institutional Review Board Exemption

UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway Orlando, FL 32826-3246

EXEMPTION DETERMINATION

January 11, 2021

Dear Jessica Cruit:

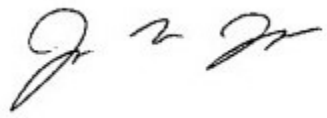
On 1/11/2021, the IRB determined the following submission to be human subjects research that is exempt from regulation:

Type of Review:	Initial Study, Category 2
Title:	Air Carrier Training Recommendations to Address Limitations of Pilot Procedures during Unexpected Events in NextGen Operations
Investigator:	Jessica Cruit
IRB ID:	STUDY00002394
Funding:	None
Grant ID:	None
Documents Reviewed:	HRP-254-FORM Explanation of Research (1).pdf, Category: Consent Form; HRP-255-FORM-Request for Exemption.docx, Category: IRB Protocol; Recruitment Email (3).docx, Category: Recruitment Materials; Researcher Debriefing Questions (1).docx, Category: Other; SME Knowledge Elicitation Study Interview Questions.docx, Category: Interview / Focus Questions; SME Survey 1.docx, Category: Survey / Questionnaire; SME Survey 2.docx, Category: Survey / Questionnaire; SME Survey 3.docx, Category: Survey / Questionnaire; SME Survey 4.docx, Category: Survey / Questionnaire; SME Survey 5.docx, Category: Survey / Questionnaire;

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made, and there are questions about whether these changes affect the exempt status of the human research, please submit a modification request to the IRB. Guidance on submitting Modifications and Administrative Check-in are detailed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

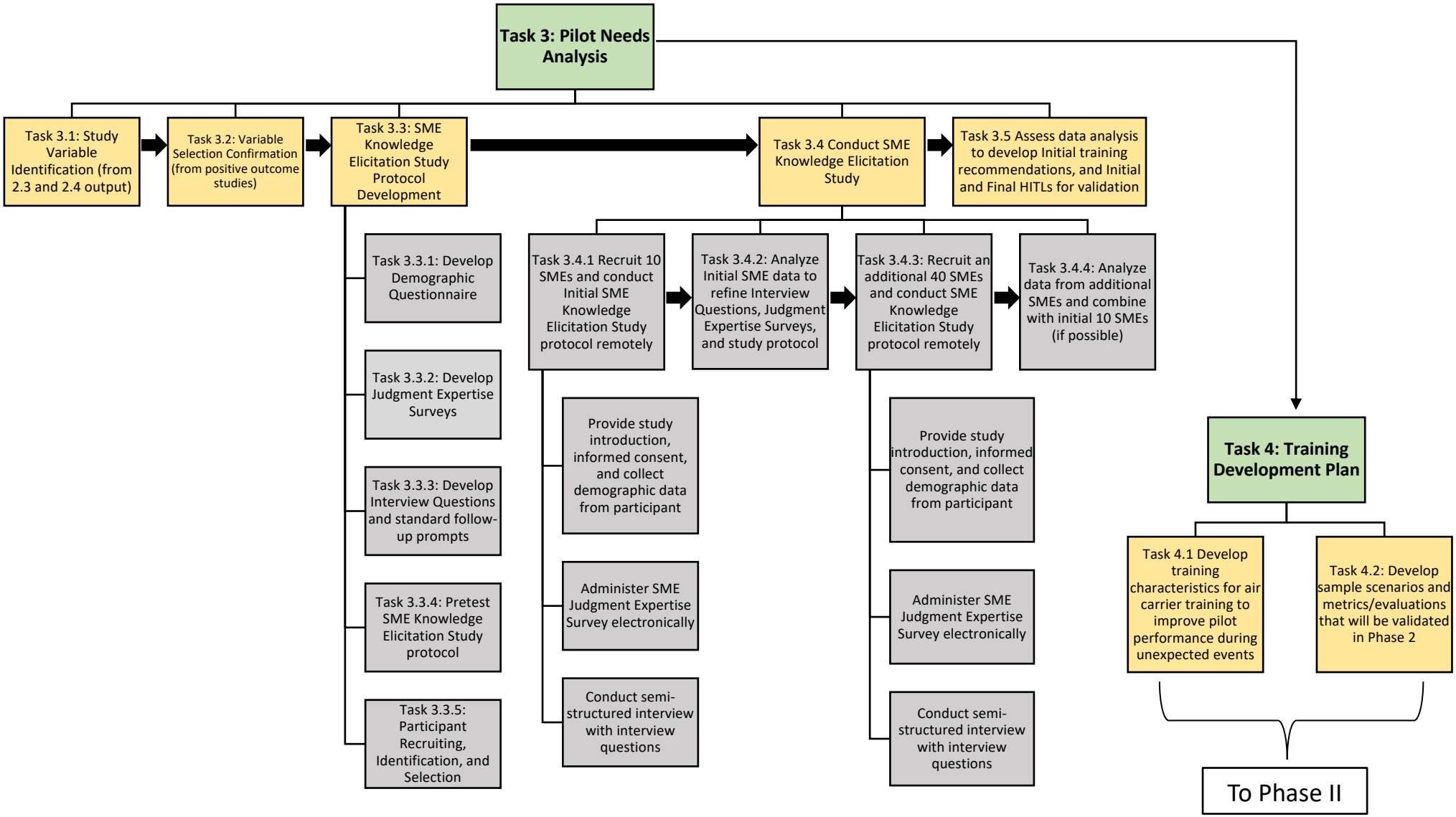
If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,



Racine Jacques, Ph.D.
Designated Reviewer

Appendix B: Pilot Needs Analysis Flow Chart



Appendix C: Task 3.3.1 – Demographic Questionnaire Development

Background Information (Collected on Qualtrics)

Age in Years_____

Highest Educational Level Obtained_____

Current Pilot Position/Title_____

Airman Certificates, Ratings, and Qualifications

Private Pilot (ratings) _____

Commercial Pilot (ratings)_____

Airline Transport Pilot (ratings)_____

Certified Flight Instructor (ratings)_____

Company Instructor (aircraft types)_____

Pilot Examiner (authorizations)_____

Check Airman (authorizations)_____

Years flying_____Total flight hours_____Flight Hours Last 12 Months_____

Types of aircraft flown_____

Current airplane type(s) flying now? _____

Were you or are you in the military?_____Which Branch?_____Flight Status?_____

Are you familiar with the Interviewer?_____

Appendix D: Task 3.3.2 – Judgment Expertise Surveys

The following surveys are included in the experimental protocol for the Pilot Needs Analysis (Phase I-Task 3). They will be administered electronically via Qualtrics as part of the Subject Matter Expert (SME) interviews. The same measures are expected to also be used in the Phase II, Human-in-the-Loop study.

The purpose of the surveys is to obtain measures of four factors (human traits/states/behaviors) found in the literature (Hancock et al., in preparation) that contribute to being able to best respond to unexpected events. The data from these surveys will be included in the analysis of the SME Knowledge Elicitation Study as well in Phase II analyses.

Participants will be instructed to complete the following instruments that will be posted as a single survey. The surveys (measurement instruments) and primary references are:

Survey #1 – Self-Efficacy and Metacognition

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and Psychological Measurement, 53*(3), 801–813. https://doi.org/10.1177/0013164493053003024

Schmidt, A.M., Ford, K.J.: Learning within a learner control training environment: the interactive effects of goal orientation and metacognitive instruction on learning outcomes. *Personnel Psychology 56*, 405–429 (2003).

Wells, A., & Cartwright-Hatton, S. (2004). A short form of the metacognition questionnaire: properties of the MCQ-30. *Behaviour Research and Therapy, 42(*4), 385–396. https://doi.org/10.1016/S0005-7967(03)00147-5

Survey #2 – Generalized Self-Efficacy

Scholz, U., Doña, B. G., Sud, S., & Schwarzer, R. (2002). Is general self-efficacy a universal construct? Psychometric findings from 25 countries. *European Journal of Psychological Assessment, 18*(3), 242–251. https://doi.org/10.1027/1015-5759.18.3.242

Schwarzer, R., & Jerusalem, M. (1995). Generalized Self-Efficacy scale. In J. Weinman, S. Wright, & M. Johnston (Eds). *Measures in health psychology: A user's portfolio. Causal and control beliefs* (pp. 35–37). NFER-NELSON. http://userpage.fu-berlin.de/~health/engscal.htm

Survey #3 – Trust in Automation

Wojton, H. M., Porter, D., Stephanie T. Lane, S. T., Bieber, C., & Madhavan, P. (2020). Initial validation of the trust of automated systems test (TOAST), *The Journal of Social Psychology, 160*(6), 735–750. https://doi.org/10.1080/00224545.2020.1749020

Hoff, K. A., & Bashir, M. (2015). Trust in Automation: Integrating Empirical Evidence on Factors That Influence Trust. *Human Factors*, *57*(3), 407–434. https://doi.org/10.1177/0018720814547570

Survey #4 – Cognitive Flexibility

Dennis, J. P., & Vander Wal, J. S. (2010). The Cognitive Flexibility Inventory: Instrument development and estimates of reliability and validity. *Cognitive Therapy and Research, 34*(3), 241–253. https://doi.org/10.1007/s10608-009-9276-4

Survey #5 – Aviation Self-Efficacy

Cruit. J. (2016). Predicting general aviation pilots' weather-related performance through a scenario-based written assessment. [Doctoral dissertation, Embry-Riddle Aeronautical University]. https://commons.erau.edu/edt/198

SME Survey #1 (Self-Efficacy and Metacognition)

PARTICIPANT ID #_____

DIRECTIONS: Please answer the following questions by circling the appropriate rating.

1. I believe I will receive excellent ratings for my performance on this interview.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

2. I'm certain I can handle the most difficult situations that arise in flying.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

3. I memorize key words to remind me of the important concepts when studying.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

4. I practice material mentally while "chair flying."

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

5. Considering the difficulty of the flying task and my skills, I think I do well.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

6. I believe that I perform within the top 10% of all participants on the flying task.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

7. I read over my notes and the course materials often when I am in training.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

8. I expect to do well in my flying.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree

1	2	3	4	5

9. I am confident I can do an excellent job on my flying tasks.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

10. I make lists of important terms and memorize the lists.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

SME Survey #2 (Generalized Self-Efficacy)

PARTICIPANT ID #_____

DIRECTIONS: Indicate for each statement below how true it is for you.

1. I can always manage to solve difficult problems if I try hard enough.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

2. If someone opposes me, I can find the means and ways to get what I want.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

3. I am certain that I can accomplish my goals.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

4. I am confident that I could deal efficiently with unexpected events.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

5. Thanks to my resourcefulness, I can handle unforeseen situations.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

6. I can solve most problems if I invest the necessary effort.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

7. I can remain calm when facing difficulties because I can rely on my coping abilities.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

8. When I am confronted with a problem, I can find several solutions.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

9. If I am in trouble, I can think of a good solution.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

10. I can handle whatever comes my way.

Not at all True	Hardly True	Moderately True	Exactly True
1	2	3	4

SME Survey #3 (Trust in Automation)

PARTICIPANT ID #_____

DIRECTIONS: Please answer the following questions regarding aircraft flight management systems by circling the appropriate rating.

1. I understand what the system should do.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

2. I understand the limitations of the system.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

3. I understand the capabilities of the system.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

4. I understand how the system executes tasks.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

5. The system helps me achieve my goals.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

6. The system performs consistently.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

7. The system performs the way it should.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

8. I am rarely surprised by how the system responds.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

9. I feel comfortable relying on the information provided by the system.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

SME Survey #4 (Cognitive Flexibility)

Participant ID #_____

DIRECTIONS: Please use the scale below to indicate the extent to which you agree or disagree with the following statements when dealing with an unexpected event in aviation.

1. I am good at "sizing up" situations.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

2. I have a hard time making decisions when faced with difficult situations.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

3. I consider multiple options before making a decision.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

4. When I encounter difficult situations, I feel like I am losing control.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

5. I like to look at difficult situations from many different angles.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

6. I seek additional information not immediately available before attributing causes to behavior.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

7. When encountering difficult situations, I become so stressed that I cannot think of a way to resolve the situation.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

8. I try to think about things from another person's point of view.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

9. I find it troublesome that there are so many different ways to deal with difficult situations.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

10. I am good at putting myself in others' shoes.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

11. When I encounter difficult situations, I just don't know what to do.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

12. It is important to look at difficult situations from many angles.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

13. When in difficult situations, I consider multiple options before deciding how to behave.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

14. I often look at a situation from different viewpoints.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

15. I am capable of overcoming the difficulties in life that I face.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

16. I consider all the available facts and information when attributing causes to behavior.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

17. I feel I have no power to change things in difficult situations.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

18. When I encounter difficult situations, I stop and try to think of several ways to resolve it.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

19. I can think of more than one way to resolve a difficult situation I am confronted with.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

20. I consider multiple options before responding to difficult situations.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

SME Survey #5 (Aviation Self-Efficacy)

Participant ID #_____

A number of situations are described below that pertain to situations during flying in which you encounter something surprising or unexpected. Please rate in the blanks below how confident you are that your decisions for the given situations will result in a positive outcome.

Rate your degree of confidence of a positive outcome to the situation by entering a number from 0 to 100 using the scale given below:

0	10	20	30	40	50	60	70	80	90	100
Cannot do at all					**Moderately can do**					**Highly certain can do**

Situation	Confidence of Positive Outcome (0-100)
Contradictory Resolution Advisories from TCAS	_____
An event for which you were not trained	_____
Severe and sudden weather phenomena	_____
Incapacitated crewmember	_____
Loss of Situation Awareness	_____
An event that has no prescribed procedure	_____
Loss-of-communication with ATC	_____
Engine failure or power loss on takeoff	_____
Jet upset	_____
Loss of reliable airspeed	_____
Last minute Instruement Approach Procedure change	_____
Last minute runway change	_____

Appendix E: Task 3.3.3 - SME Knowledge Elicitation Study Interview Question Development

Interview Questions Rationale and Interview Prompts

This Appendix presents the rationale for the SME Interview questions based on the research questions in the Statement of Work, Task 3 and subject matter expert knowledge elicitation research (Ericsson & Simon, 1993; Morgan, 2014) Some of the interview questions will address more than one research question.

In some cases, we chose to leave out potential questions or aspects of questions that may inhibit or bias the response. We are sensitive to the effects of how the questions are worded (Kahneman, 2011) and therefore purposefully constructed somewhat vague and open-ended questions for this interview. Although NextGen technologies are the underlying concepts of interest, we are interested in capturing data regarding all unexpected situations. Thus, the lack of specificity in most of the questions.

We expect the outcome of these interviews to inform us as to the types of unexpected events that have personally been experienced by the SME participant, their response, and outcome to those events. We will also elicit their expert opinion regarding unexpected events in general and their observations of how they were handled. Possible follow-on questions are also listed here for use in cases where the knowledge elicitation requires prompting from the researcher. These prompts will also be used to better uncover, in a covert manner, any effects of NextGen technologies associated with the events described. The reason or expected outcome for the prompt is also listed.

1. **"Describe the two most surprising or unexpected events that *you have experienced* in aviation and what were the outcomes to these events? (When did these occur?)**

Rationale: This question intends to elicit examples, personally encountered by the SME. We place a boundary on the questions, asking for two events, so that details about each event can be gathered. Experience has shown that often lengthy discussions can ensue in this type of interview, (Kochan & Robinson, 2018; Kochan et al., 1997) Though this question does not specifically ask what the response to the event was, we expect that information will be generated when the outcome is explained.

Prompts:

- "Can you tell me more about how the situation came about?" This will result in more detailed description.
- "What were you thinking when…?" This will explore the metacognition of the SME while handling the situation.
- "Now, what was another unexpected event?" This will move the discussion along if it gets off track.

2. **"Have you ever had an unexpected event occur because of technology or a particular Instrument Flight Procedure? If so, explain."**

Rationale: This question investigates whether the SME has had an event that may specifically be attributed to NextGen technologies or an instrument procedure or if the event they described previously was somehow related.

Prompts:

- "Were either of your previously described events affected by NextGen technologies?" To encourage information pertaining to flight procedures or other technologies that may have been associated with the previously explained events. It is worded in a neutral format (not good or bad).
- "Do you have any suggestions about how these effects of technologies could be mitigated?" This prompt aims to elicit additional suggestions on how to respond (from a retrospective view).

3. *"In general*, what do you consider the most surprising events that happen in flying?"

Rationale: This question elicits expert opinion regarding observations made by the SME participant. Unlike the personal events, we expect to obtain a sampling of events from this question.

Prompts:

- "Do you have an idea of how often (example provided) happens in flying?" This obtains a rough idea of the SME's view of the rate of occurrence for the event. Although we have not discussed trying to obtain quantitative numbers from this SME Interview study, alternative protocols could be developed for additional studies (see Heming et al., 2017).
- "Can you think of any other unexpected or surprising events that happen often in flying?"

4. "What are the procedures, guidance, best practices, and/or habits that you use in dealing with unexpected events?"

Rationale: This deals with whether there are any particular resources that the SME has available and/or uses in dealing with an unexpected event.

Prompts:

- "What do you mean by…?"
- "What materials are available that help in dealing with the unexpected?"
- "Was there any training involved with or without these materials?"

5. "Are there procedures or guidance that you have found missing or unavailable for a given event? If so, explain."

Rationale: This question will follow-on from the previous question to investigate the SMEs awareness of needed guidance.

Prompts:

- "Where do you think you could find guidance or instructions that address dealing with unexpected events?" This prompt delves into the SMEs knowledge of materials that may exist but have not been made available in the context of their training.
- "What type of information do you think would be helpful to pilots in dealing with these situations?" This should elicit ideas of what materials would be useful.

- "What would be the best format to have that information in?" These suggestions will be helpful in determining what materials and resources the SME thinks are most useful.

6. **"In general, how well do pilots handle unexpected events?"**

Rationale: This very open-ended question should elicit a qualitative discussion on how pilots in general handle the unexpected.

Prompts:
- "What do pilots do well in handling the unexpected?"
- "What do pilots not do so well in handling the unexpected?"
- "Why do you think pilots have difficulty with surprising or unexpected events?"

7. **"Have you had any specific training on reacting to unexpected events, for example in Crew Resource Management (CRM) or Upset Prevention and Recovery Training (UPRT)? If so, describe the training."**

Rationale: This question directedly addresses (a) the state of the art in related training, and (b) the gaps in this type of training.

Prompts:
- "What exactly did you learn in the training?" This is getting at more specifics of the training.

8. **"What do you think can be done to improve pilot response and outcome to unexpected events in aviation?"**

Rationale: This is aimed to elicit expert information on suggested methods to improve pilot reactions to unexpected events. Although not specifically framed as suggestions for training, it is expected that the responses will focus on such.

Prompts:
- "Specifically, what can be done to enhance pilots' reactions to the unexpected?"
- "You have suggested training. What format should that training take and what should the content entail."

9. **"With regard to your crew, what is most important when faced with an unexpected event? Have you had any training in this regard?"**

Rationale: This question opens the conversation to multicrew situations and/or the involvement of others involved in the system (e.g., air traffic control, dispatch, cabin crew, maintenance, or other actors associated directly or remotely with the event).

Prompts:
- "What are some good contributions from your crew when faced with the unexpected?"

- "What else would you have liked (or would like) for your crew to do in such an event?" These prompts solicit more direct information from the SME.

10. "Do you have any other observations/items to add?"

References for Interview Preparation

Dekker, S. W. A. (2003). Illusions of explanation: A critical essay on error classification. *The International Journal of Aviation Psychology, 13*(2), 95–106.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data (2nd Edition).* Cambridge, MA: MIT Press.

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Kahneman, D. (2011). *Thinking, fast and slow.* Farrar, Straus and Giroux: New York.

Kochan, J. A., & Robinson, M. J. (2018). *Expert elicitation for System Safety Management Transformation (SSMT) pilot study report*. Report submitted to Robert Frenzel, Senior Attorney, ANG, Regulations Division.

Kochan, J. A., Jensen, R. S., Chubb, G. P., & Hunter, D. R. (1997). *A New Approach to Aeronautical Decision-Making: The Expertise Method*. (DOT/FAA/AM-97-6). Washington, DC: Federal Aviation Administration, Office of Aviation Medicine.

Morgan, M. G. 2014. *Use (and Abuse) of expert elicitation in support of decision making for public policy*. Proceeding of the National Academy of Sciences of the United States of America 111(20): 7176–7184.

Appendix F: Task 3.3.4 – SME Study Protocol

Researcher:_____
Date:_____Time (local):_____
Location:_____
Participant Number:_____

SME Study Protocol Checklist

1. Schedule participant
   1.1. Follow-up with confirmation email
2. Prepare participant file (use a copy of this document)
   2.1. Name the document "SME Study (participant #) (date) (researcher initials)." For example, "SME Study 1001 21 January 2021 jak"
   2.2. Use this document to take notes during interview
      2.2.1. Choose font color for notes
3. Zoom set-up
   3.1. Log-in 10 minutes before appointment time
   3.2. Check that participant video and audio is enabled
4. Admit participant to Zoom
   4.1. Greet participant (read "Participant Greeting")
      4.1.1. Answer any questions
   4.2. Assign Participant Number for use in Qualtrics
   4.3. Post Qualtrics link in chat http://ucf.qualtrics.com/jfe/form/SV_5hdvLKakdlUmjKl
5. Ask the participant to log-in to Qualtrics to complete demographics and surveys. Advise that you will be on mute, but available if they have any questions while they are working on the forms.
6. When the surveys are complete, proceed to "Unexpected Events Interview Questions."
   6.1. Start recording
   6.2. Administer interview questions using prompts when necessary.
   6.3. Take notes, preferably on computer so that you are not looking down.
   6.4. Keep track of time and keep total time of session to one-hour.
7. Once interview is complete, brief participant to feel free to forward additional thoughts by replying to the email they will receive with their gift card number.
8. Send thank you email with gift card number to participant immediately.
   8.1. Follow-up on any questions or further comments.
9. Complete notes on participant file document and send a copy to Jessica Cruit.
10. After data is entered in SPSS, review entries.
11. For secondary interview coding, complete a "secondary" participant file
   11.1. Name the document "SME Study Secondary (participant #) (date of second review) (researcher initials)." For example, "SME Study Secondary 1001 26 January 2021 sp"
12. For any questions, check with Jessica Cruit at 386-679-2632 or Janeen Kochan at 863-207-0484.

Participant Greeting

Interviewer:

"Thank you for your time today. This study is being conducted by researchers from the University of Central Florida. Please be assured that all of your individual information will be held in strict confidence and will only be accessible to the principal investigators and their immediate research assistants. All data will be encoded; neither your name nor any other identifying information will be collected. Your participation will contribute to improving aviation safety.

We will be talking about how pilots respond to unexpected events. This session has three parts; first you will answer a few questions about your background and complete a short survey online that I cannot see and will be aggregated electronically in the data. We will then talk about unexpected and surprising events. To aid in how you can best share your expertise, we ask that you consider the following definition of unexpected event during our discussion.

An unexpected event is any event that takes someone by surprise, which can violate a pilot's expectations and can affect the mental processes used to respond to the event. This includes situations that are difficult to identify, do not have known procedures to respond, or appear to not fit into a specific checklist.

We are studying pilots' perceptions of unexpected events in aviation. Our goal is to learn what types of events pilots find surprising or unexpected, how they are handled, and how they might affect flight outcome. Do you have any questions?"

SME Knowledge Elicitation Study Informed Consent (Presented on Qualtrics)

We are studying pilots' perceptions of unexpected events in aviation. Our goal is to learn what types of events pilots find surprising or unexpected, how they are handled, and how they might affect flight outcome. We will ask you to provide some basic background information relating to your flight experience (e.g., years flying, total flight time, etc.) as well as some demographic information. This interview should not take more than 60 minutes.

This study is being conducted with FAA funding by researchers from the University of Central Florida. Please be assured that all of your individual information will be held in strict confidence and will only be accessible to the principal investigators and their immediate research assistants. All data will be encoded; neither your name nor any other identifying information will be collected. **No individual data will be reported to any aviation agency (including the FAA).** Your participation will contribute to improving aviation safety. If you have any questions, please contact Dr. Jessica Cruit at jcruit@ist.ucf.edu.

Are you at least 18 years of age and do you understand that completing this interview constitutes your informed consent?

Yes_____ No_____

Unexpected Events Interview Questions

(Start recording)

1. **"Describe the two most surprising or unexpected events that *you have experienced* in aviation and what were the outcomes to these events? (When did these occur?)"**

Prompts:

- "Can you tell me more about how the situation came about?" This will result in more detailed description.
- "What were you thinking when…?" This will explore the metacognition of the SME while handling the situation.
- "Now, what was another unexpected event?" This will move the discussion along if it gets off track.

2. **"Have you ever had an unexpected event occur because of technology or a particular Instrument Flight Procedure? If so, explain."**

Prompts:

- "Were either of your previously described events affected by NextGen technologies?" To encourage information pertaining to flight procedures or other technologies that may have been associated with the previously explained events. It is worded in a neutral format (not good or bad).
- "Do you have any suggestions about how these effects of technologies could be mitigated?" This prompt aims to elicit additional suggestions on how to respond (from a retrospective view).

3. **"*In general*, what do you consider the most surprising events that happen in flying?"**

Prompts:

- "Do you have an idea of how often (example provided) happens in flying?" This obtains a rough idea of the SME's view of the rate of occurrence for the event. Although we have not discussed trying to obtain quantitative numbers from this SME Interview study, alternative protocols could be developed for additional studies (see Heming et al., 2017).
- "Can you think of any other unexpected or surprising events that happen often in flying?"

4. **"What are the procedures, guidance, best practices, and/or habits that you use in dealing with unexpected events?"**

Prompts:

- "What do you mean by…?"
- "What materials are available that help in dealing with the unexpected?"
- "Was there any training involved with or without these materials?"

5. **"Are there procedures or guidance that you have found missing or unavailable for a given event? If so, explain."**

Prompts:

- "Where do you think you could find guidance or instructions that address dealing with unexpected events?" This prompt delves into the SMEs knowledge of materials that may exist but have not been made available in the context of their training.
- "What type of information do you think would be helpful to pilots in dealing with these situations?" This should elicit ideas of what materials would be useful.
- "What would be the best format to have that information in?" These suggestions will be helpful in determining what materials and resources the SME thinks are most useful.

6. **"In general, how well do pilots handle unexpected events?"**

Prompts:

- "What do pilots do well in handling the unexpected?"
- "What do pilots not do so well in handling the unexpected?"
- "Why do you think pilots have difficulty with surprising or unexpected events?"

7. **"Have you had any specific training on reacting to unexpected events in general (not for specific procedures), for example in Crew Resource Management (CRM) or Upset Prevention and Recovery Training (UPRT)? If so, describe the training."**

Prompts:

- "What exactly did you learn in the training?" This is getting at more specifics of the training.

8. **"What do you think can be done to improve pilot response and outcome to unexpected events in aviation?"**

Prompts:

- "Specifically, what can be done to enhance pilots' reactions to the unexpected?"
- "You have suggested training. What format should that training take and what should the content entail."

9. **"With regard to your crew, what is most important when faced with an unexpected event? Have you had any training in this regard?"**

Prompts:

- "What are some good contributions from your crew when faced with the unexpected?"
- "What else would you have liked (or would like) for your crew to do in such an event?" These prompts solicit more direct information from the SME.

10. **"Do you have any other observations/items to add?"**

Appendix G: Task 3.3.5 - Participant Recruiting, Identification, and Selection

Participant Recruitment Email

Dear Colleague,

We are writing to request your participation as a Subject Matter Expert (SME) in a short discussion regarding pilots' reactions to unexpected and ill-defined events. This is part of an FAA study on Air Carrier Training Recommendations to Address Limitations of Pilot Procedures during Unexpected Events in NextGen.

These discussions will be held virtually via Zoom and scheduled at a time convenient for you. We will be scheduling these sessions Monday-Friday 8:00 am to 6:00 pm, from 11 January through 30 October 2021.

We will be asking you questions about your professional experience and observations of pilot performance. The session will last approximately one-hour and will be recorded. Your individual responses will be deidentified and only aggregated data will be published.

Participants will receive $150 in the form of an electronic gift card to Sporty's Pilot Shop upon completion of the study. Participants will receive full compensation if they withdraw early. Participants will be emailed their gift card.

Please respond to this invitation regarding your availability to participate by 4 October 2021 and include your current aircraft type, position (captain or first officer), and if you are an instructor pilot or check airman. If you have questions regarding your participation, please contact Jessica Cruit jcruit@ist.ucf.edu.

Sincerely,

Jessica Cruit

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