National Aeronautics and Space Administration

Understanding Pilot Resilient Performance in Weather Risk Management:
Methods and Insights from a Simulation Study

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System Wide Safety

Background

- Analysis of flight crew operational performance suggests that pilots intervene to keep flights safe over 157,000 times for every time that pilot error contributes to an accident (Holbrook, 2021)
- Details of routinely successful performance may go unreported, be deemed unimportant, or may not be recalled at time of reporting
- Understanding what pilots routinely do to *produce* safety represents a significant additional source of aviation safety data

Methodology

- The current study* used a cued retrospective think-aloud protocol to collect data on pilots' accounts of what they were thinking while flying a simulated arrival during dynamically evolving convective weather

  How do pilots sustain safe operations under expected and unexpected changes?

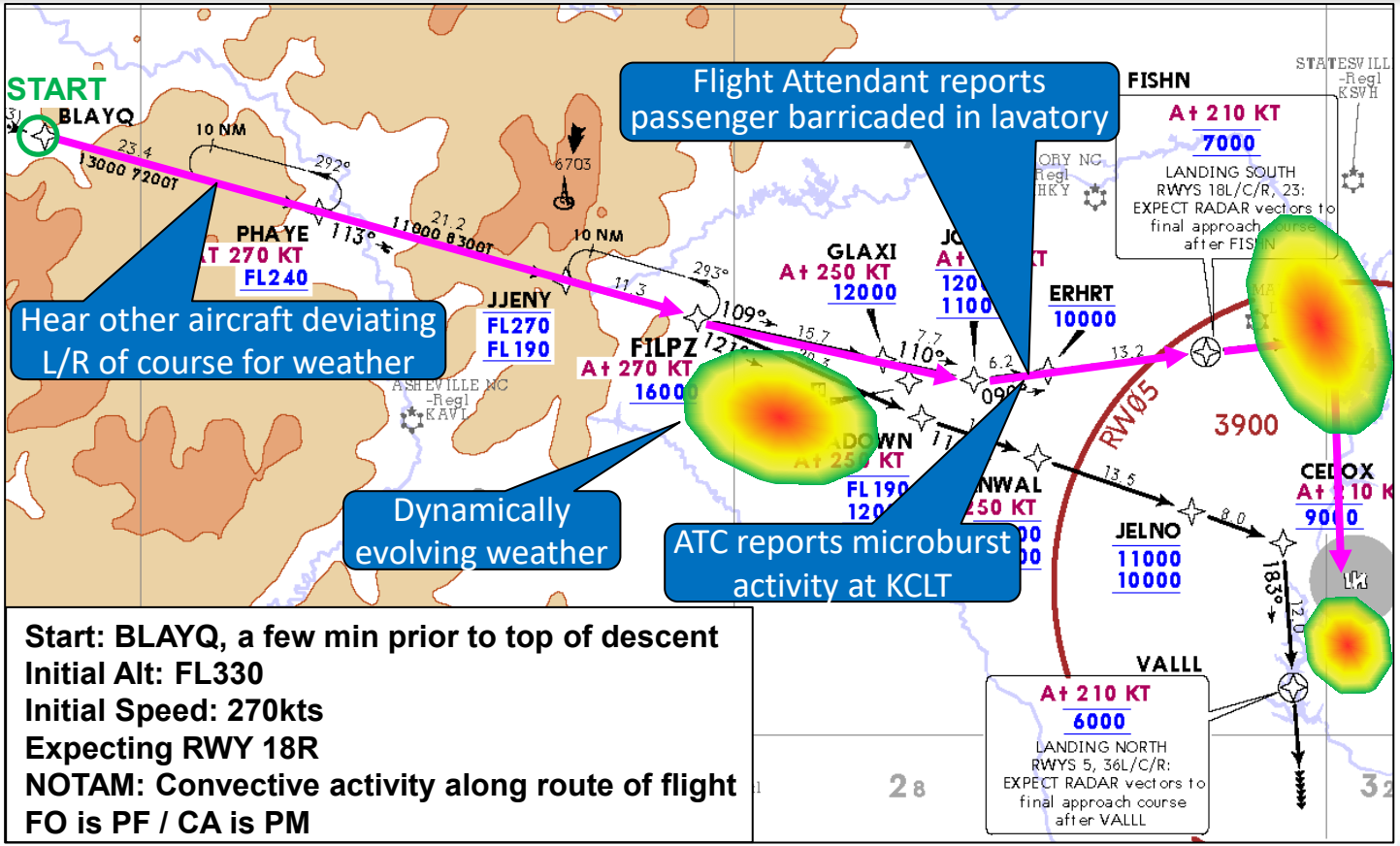
- Think-aloud protocols have been used extensively in fields from cognitive psychology to usability testing (see Boren & Ramey, 2000, for a review)

- Self-report can provide data about goals & motivations that are not readily observable

Image Credit: NASA

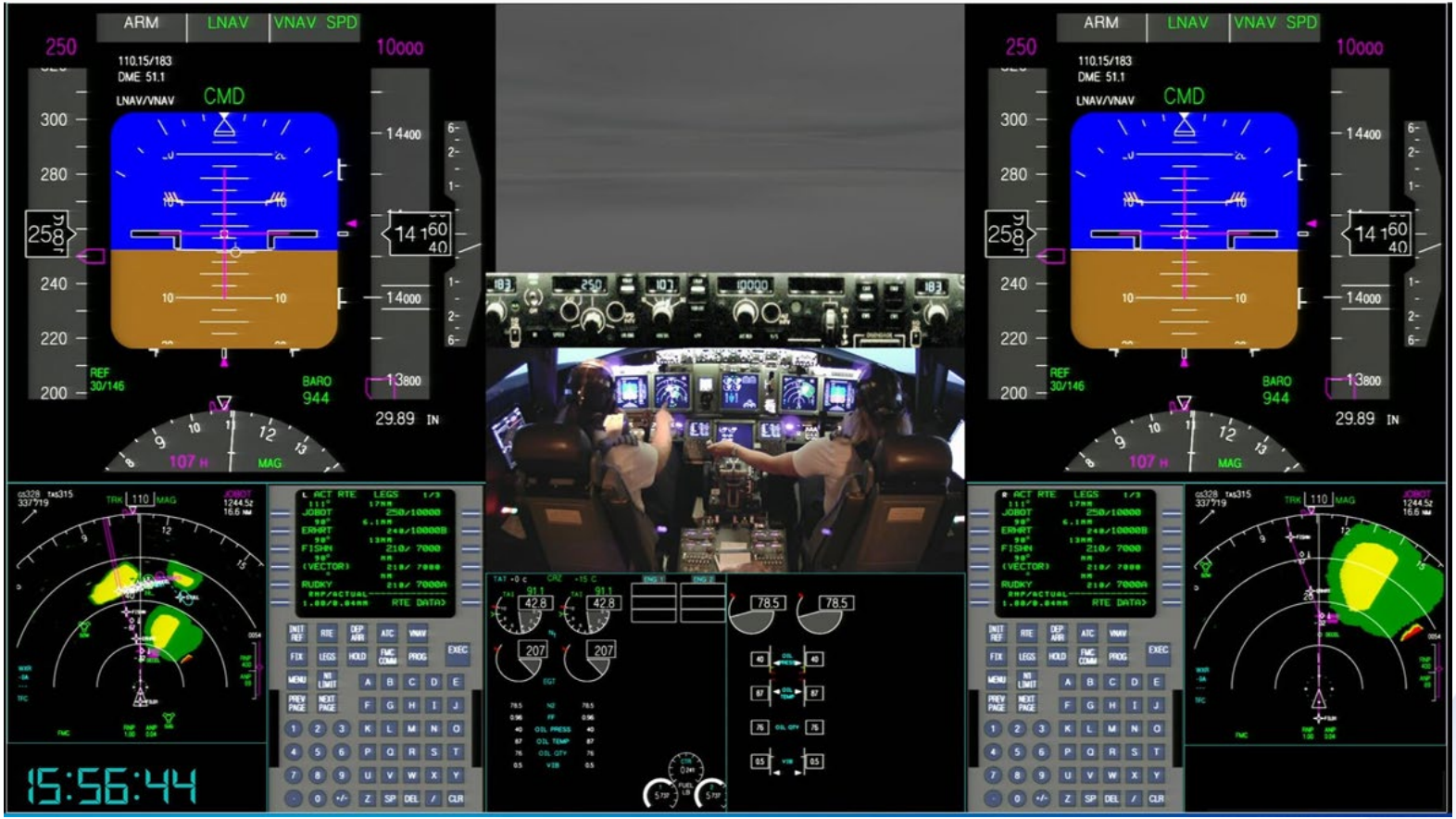
* Part of a larger investigation of 12 crews of Boeing 737-rated pilots from a US air carrier who performed multiple arrivals into Charlotte Douglas International Airport (KCLT). Other scenarios presented different but typical challenges, such as traffic congestion, energy management, wake encounter, unexpected airport flip, unanticipated tailwind, automation failures, etc.

FILPZ3 KCLT Arrival Scenario



Start: BLAYQ, a few min prior to top of descent
Initial Alt: FL330
Initial Speed: 270kts
Expecting RWY 18R
NOTAM: Convective activity along route of flight
FO is PF / CA is PM

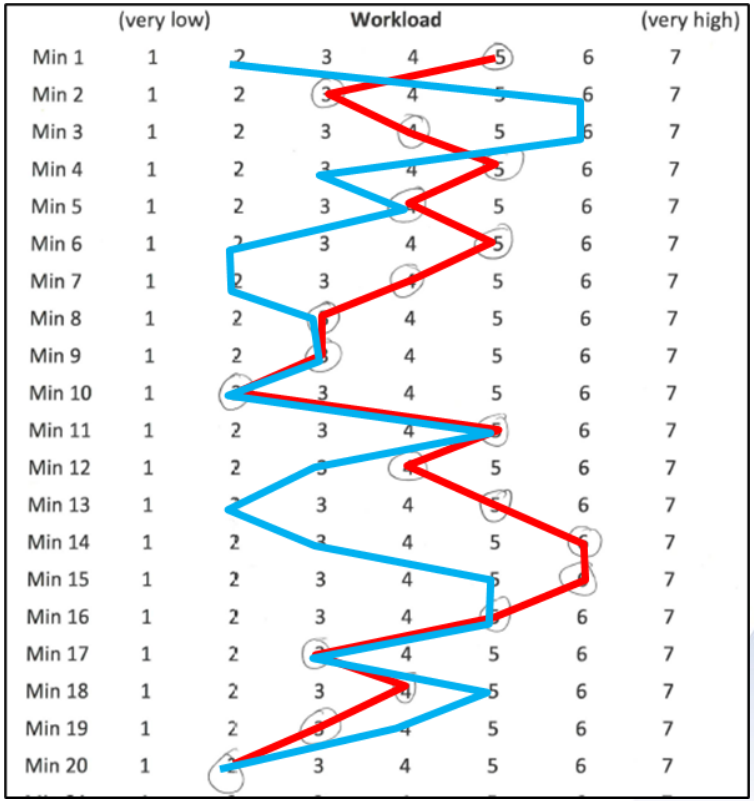
Over-the-Shoulder Video



Cued Retrospective Think-Aloud Procedure

- One day after sim flight, video played on a 55-inch high-definition television
- Crew seated together 6-8 ft from display
- Video paused after each minute
- Crew asked to describe what they were doing and, more importantly, thinking, during that 1-min interval
- FO always spoke first
- Crew assigned a personal workload rating for that interval

CA/PM (**red**) | FO/PF (**blue**)



Coding Process

- Transcript parsed into distinct statements by topic
  - “Intelligent verbatim” transcription
  - Speaker (FO / CA)
  - Minute (numbered sequentially)
- Coding included
  - Semantic pairing between FO and CA statements
  - Was described thinking observable?
  - Most applicable American Airlines Learning & Improvement Team code
  - Most applicable macrocognitive function and process (Klein et al., 2003)
- Independently coded by two analysts & discussed to consensus
  - As necessary, consulted with a commercial airline pilot SME

Adapted from Klein et al., 2003

Coding Results (illustration from single crew)

- 100 statements coded
- 55% by FO | 45% by CA
- 50% of statements were “paired” (same topic discussed by FO and CA)
- 33% coded as “not readily observable”
- 20% described positive actions not directly covered in formal training

Macrocognitive Functions	LIT Potentials: Learn	Plan	Adapt	Coord.
Planning	1	17	0	0
Adaptation	0	0	16	0
Coordination	1	0	0	27
Decision Making	5	0	4	1
Sensemaking	2	10	0	3
Problem Detection	3	8	2	0

Selected Insights

- **Pilots communicated using informal body language cues & gestures**

  Used to quickly convey their thoughts at times when verbal communication was not a good or convenient option. Gestures were used to convey simple messages, such as “I trust you to handle this” or to quickly establish real-time agreement without a verbal back-and-forth.

  - *CA: Because I was on ATIS [Automated Terminal Information Service], I gestured to let the FO know that I was aware and trusting him to respond to ATC clearances. Because I was distracted by the ATIS, you can’t be certain you’re getting the full information from ATC, so I was letting the FO know that I was trusting him on that.*
  - *FO: During ATC’s call providing an update on weather conditions at the airport, CA gives a thumbs-down, making it clear we’re not going to mess with that, and it’s time to start changing gears.*

Selected Insights

- **Pilots described instances in which they were trying to ascertain the “right time” or a “good time” to perform a task**
  - *CA: I was kind of letting the controller do with us what he wanted, but there is a point during the approach where we have to be proactive and say what we need to do. I wanted to make sure we had the basics out of the way, to minimize distractions down the line as we get closer to the ground.”*
  - *FO: Now that we had briefed the approach, it was a good time to circle back and say “this is what I’m thinking”. Maybe a good time to ask if we can go direct to one of these points.*

Selected Insights

➢ Pilots generalized formally learned techniques to other situations

Independent verification by each crew member

- *CA: One thing I'm always concerned about when briefing the approach. I never want to set his mins [minimums]. I'll set other things – course and frequency – but I want to make sure 2 pilots are looking at the approach plate. I'll say "244, you got it?" and he'll say "yep, those are the mins I've got". Versus possibly making a mistake without a secondary chance to correct if I'm wrong.*

Strategic offloading of tasks

- *CA: This is a technique I use a lot. When we're doing something different or things are kind of off, I want the guy flying the airplane to focus on flying the airplane. By taking the briefing, it allows him the extra space to focus on where the airplane's going.*

Order of operations

- *CA: I decided I would get back to the cabin [flight attendant] later. Right now, we needed to fly the airplane and decide what we're going to do initially to get away from this weather. That's all I wanted to focus on – just fly the airplane and get away from the weather.*

Selected Insights

- **Pilots adapted how they communicated to support shared situational awareness**
  - *FO: I decided to really verbalize what I was thinking because I knew the CA was just coming back from talking to the cabin, so wanted to make sure he knew where we were at, and that I wasn't going to fly through the weather.*
- **Pilots gauged the competency of their copilots, and this determination impacted their decision making**
  - *CA: I thought it was great that the FO let me know what he was thinking, because there are FOs that would just go "well, that's our clearance, so I'm just going to drive ahead". It really showed his competency. Because he showed he was highly competent, I was like "oh good, now I can go deal with this cabin issue".*

Selected Insights

- **CAs thought about their role as "mentor" to the FO**
  - *CA: As a CA, you're always trying to adjust your leadership style and intervention strategy – what you're doing either for or with the FO to make it work.*
  - *CA: I like it when the FO asks me "what do you think about doing this?". If I like it, I'll go ahead and request it. If I don't, I'll say "I don't know about that" and we'll talk about it. In this case, I totally agreed and made the call to ATC.*
  - *CA: I commented "we've got a tailwind" to prompt him [the FO] to be a little more aggressive on the speed control, which he did by using more speedbrakes.*

Selected Insights

- **Paired statements by the FO and the CA do not always reflect paired thinking**

  In some instances, although the FO and CA were clearly talking about the same decision, they sometimes approached that decision differently. For example, when briefing a landing, the CA brought up that it would likely be wet on the runway, and suggested a different autobrake setting, to which the FO concurred. The following statements highlight a difference between the FO's rule-based thought process and the CA's context-based thinking.

  - *FO: I asked the CA about the wind, because typically when we talk about brake setting we are also talking about flap setting. Depending on wind speed and direction, I was considering between flaps 30 and flaps 40.*
  - *CA: I wasn't as worried about the winds, but more concerned about dynamic weather – if everything is going to change. That's what was going through my brain.*

Selected Insights

Automating a procedure does not necessarily reduce crew workload

For some tasks that have been automated, crewmembers still mentally perform the tasks themselves as an independent verification of the automation and to support building or maintaining their own mental model of the situation. Backing up the automation requires many if not all of the same mental resources used to perform the task without automation, and, given that analysis of LOSA data has indicated that pilots must intervene to manage aircraft malfunctions on 20% of normal flights (PARC/CAST, 2013), this represents an important crew responsibility.

- *FO: I performed my own personal check of the upcoming points on the arrival while checking the chart and what we had in the FMS to make sure those point were going to be met.*

Selected Insights

- **Pilots used tactile cues to maintain situational awareness**
  - *FO: I rest my arm on the thrust levers, so I can feel if they change. Are they pushing up? Is that something I need to happen? Oh, I probably don't need the speedbrakes anymore if the thrust levers are coming back up.*
- **Pilots leveraged duplicated displays to maintain situational awareness**

CA reported that he routinely sets his ND to a different zoom than his FO's display

- **Crews used the cued retrospective think-aloud activity to learn from each other**

Key take-aways

- Weather represents a significant yet routine source of risk, uncertainty, and dynamic change
- The processes and means by which frontline personnel regularly manage weather-induced disturbances are poorly understood
- Understanding the routine resilient performance of flight crews has the potential to massively expand the pool of available safety-relevant data
- Cued retrospective think aloud methodologies show promise for revealing insights into difficult-to-obtain operator performance (e.g., airmanship/technique)
- This methodology is straightforward to employ, and could be used in conjunction with simulator training or adapted for use (in a group or individually) with flight replay animations
- A more complete understanding of what pilots do and think about could inform the design and use of technologies and procedures intended to support pilot performance, as well as support individual learning

Thank you!

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To learn more about this study, click here