National Aeronautics and Space Administration

Psychophysiological Research Methods to Assess Airline Flight Crew Resilient Performance in High-fidelity Flight Simulation Scenarios

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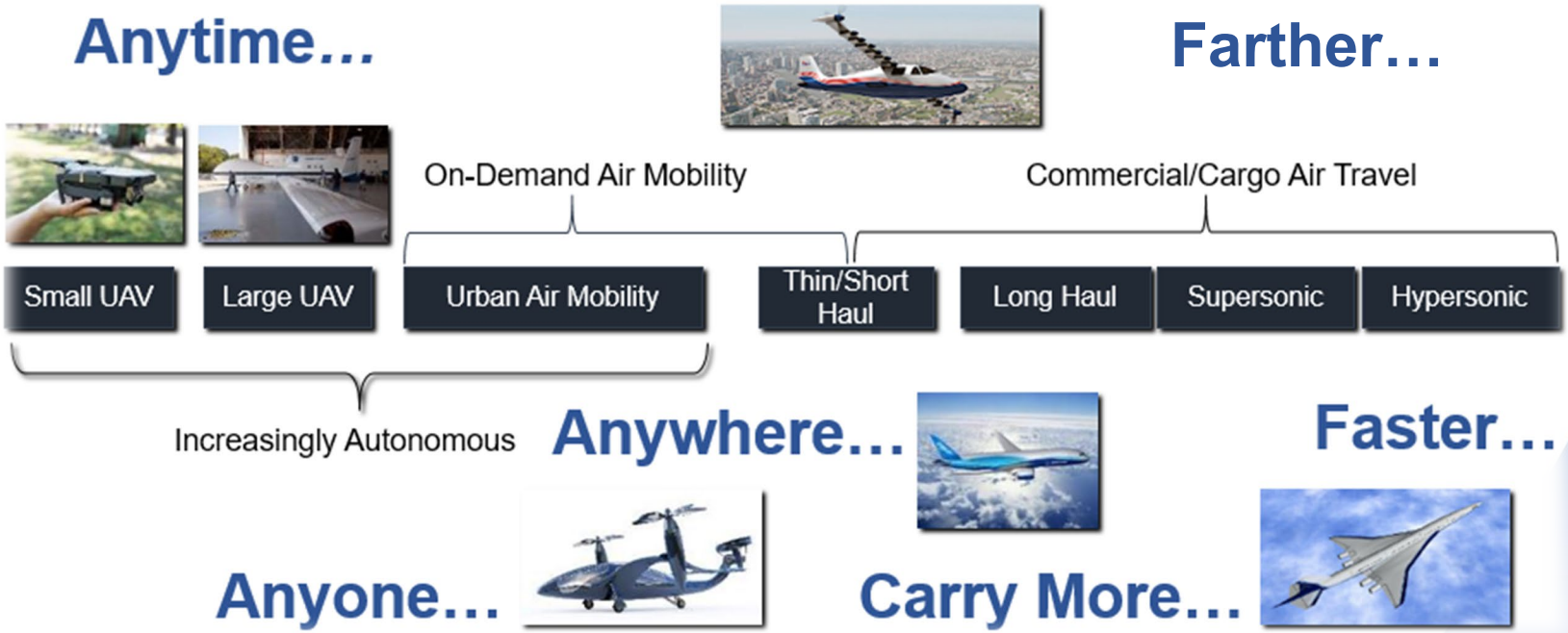
ISAP
International Symposium on Aviation Psychology
31 May – 3 June 2023
Rochester, NY

Agenda

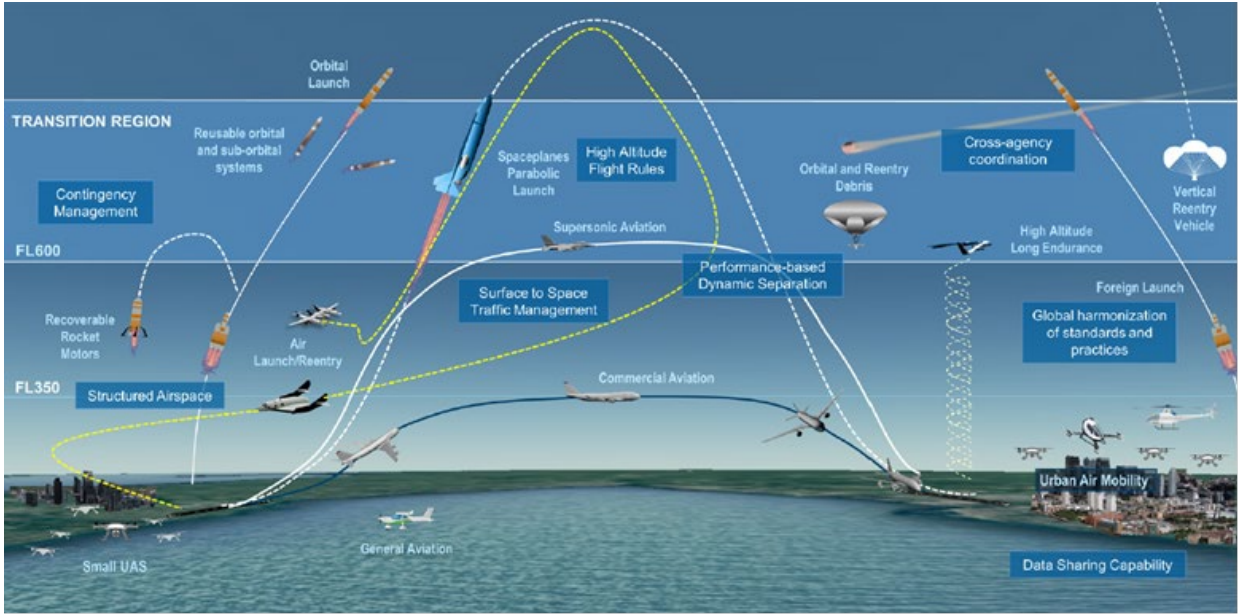
- Introduction
  - System-Wide Safety Project
- Methods
  - Apparatus
- Research Questions
- Results
- Conclusions

Introduction

- New, Emerging Aviation Sectors



In-time Aviation Safety Management System (IASMS)



Credit: FAA

NASA/TM—2020–5003981

In-time System-wide Safety Assurance (ISSA) Concept of Operations and Design Considerations for Urban Air Mobility (UAM)

Kyle Ellis and John Koelling
Langley Research Center, Hampton, VA

Misty Davies
Ames Research Center, Mountain View, CA

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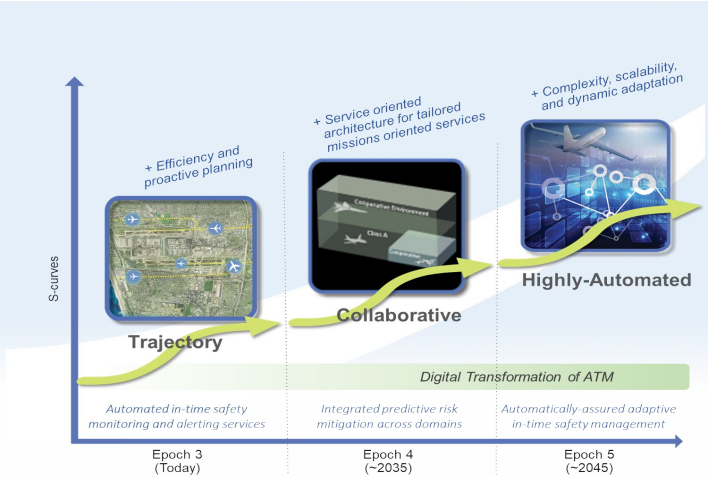
June 2020

NASA System-Wide Safety Project

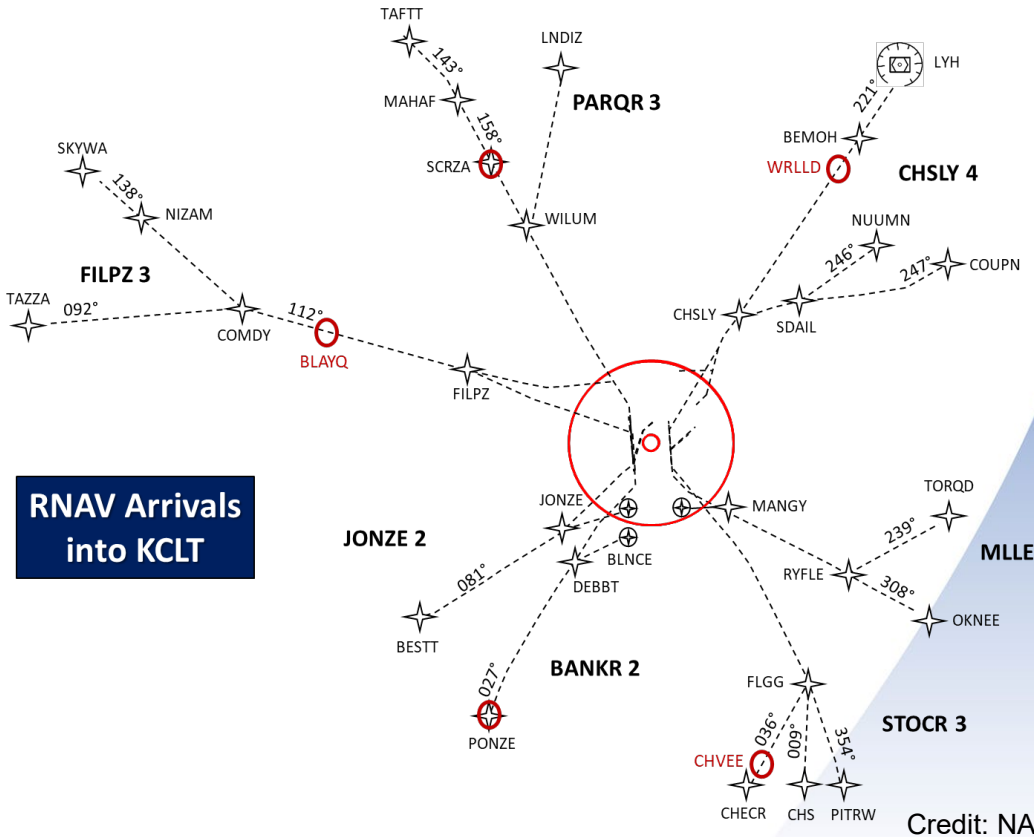
- To explore, discover, and understand the impact on safety of growing complexity introduced by modernization aimed at improving the efficiency of flight, the access to airspace, and/or the expansion of services provided by air vehicles.



- To develop and demonstrate innovative solutions that enable this modernization and the aviation transformation envisioned for global airspace system through proactive mitigation of risks in accordance with target levels of safety.

Human Contributions to Safety

- Stewart et al. (2018) determined that only 12.4% of flights fully complied with the vertical and lateral profiles on published arrivals
  - Based on aircraft flight track data for more than 10 million flights into 32 domestic airports



Credit: NASA

Alternative and Complementary Approach

- Holbrook et al. (2020) conducted interviews to understand routine disturbances during RNAV arrivals into Charlotte Douglas International Airport (KCLT)
  - Different data sources resulted in different estimates of the frequency of RNAV STAR non-adherences at KCLT
    - 30% TRACON controller estimate
    - 43% pilot estimate
    - 84% from flight track data specific to KCLT arrivals collected for Stewart et al. (2018)

Methods

- SWS Operations and Technologies for Enabling Resilient In-Time Assurance (SOTERIA) flight simulation study
  - Conducted at NASA Langley Research Center in Hampton, VA USA
    - May-June 2022
  - Twenty-four (24) healthy airline transport pilots (9 women, M = 49.2 years) from a major US airline volunteered for the study
  - The experiment was conducted under approval from NASA's Institutional Review Board
    - Subjects provided informed verbal and written consent to participate
  - See Stephens et al. (2021) for details of the full data collection plan and flight simulation scenarios
    - Stephens, C., Prinzel, L., Kiggins, D., Ballard, K., & Holbrook, J. (2021). Evaluating the use of high-fidelity simulator research methods to study airline flight crew resilience. 21st International Symposium on Aviation Psychology, 140-145.

Apparatus

- Advanced Brain Monitoring (ABM) B-Alert X-10 system
  - 9 channels of electroencephalography, EEG (sampling frequency: 256 Hz)
  - 1 channel of 2-lead electrocardiography, ECG (sampling frequency: 256 Hz)
    - https://www.advancedbrainmonitoring.com/products/b-alert-x10
- Empatica E4 wristband
  - Photoplethysmogram, PPG -> Blood Volume Pulse, BVP (sampling frequency: 64 Hz)
    - to derive heart rate variability to infer Autonomic Nervous System activity
  - EDA Sensor (to measure Galvanic Skin Response, GSR (sampling frequency: 4 Hz)
    - to infer Sympathetic Nervous System activity
  - Peripheral Skin Temperature (sampling frequency: 4 Hz)
  - 3-axis Accelerometery (sampling frequency: 32 Hz) for actigraphy measures
    - https://www.empatica.com/research/e4/
- SmartEye Pro system
  - Head and Eye Tracking with 5-cameras
    - https://smarteye.se/smart-eye-pro/)

Apparatus

- eyesDX Multi-modal Analysis of Psychophysiological and Performance Signals (MAPPs; IA, USA)
  - psychophysiological devices were time synced and triggered for recording
- The data were exported from MAPPs for processing with custom python (Python3) scripts
- Eye tracking data analysis is ongoing
- Eye tracking-derived metrics of interest
  - Head Heading Velocity
  - Pupil Diameter
  - Gaze Velocity
  - Gaze Variance

Apparatus

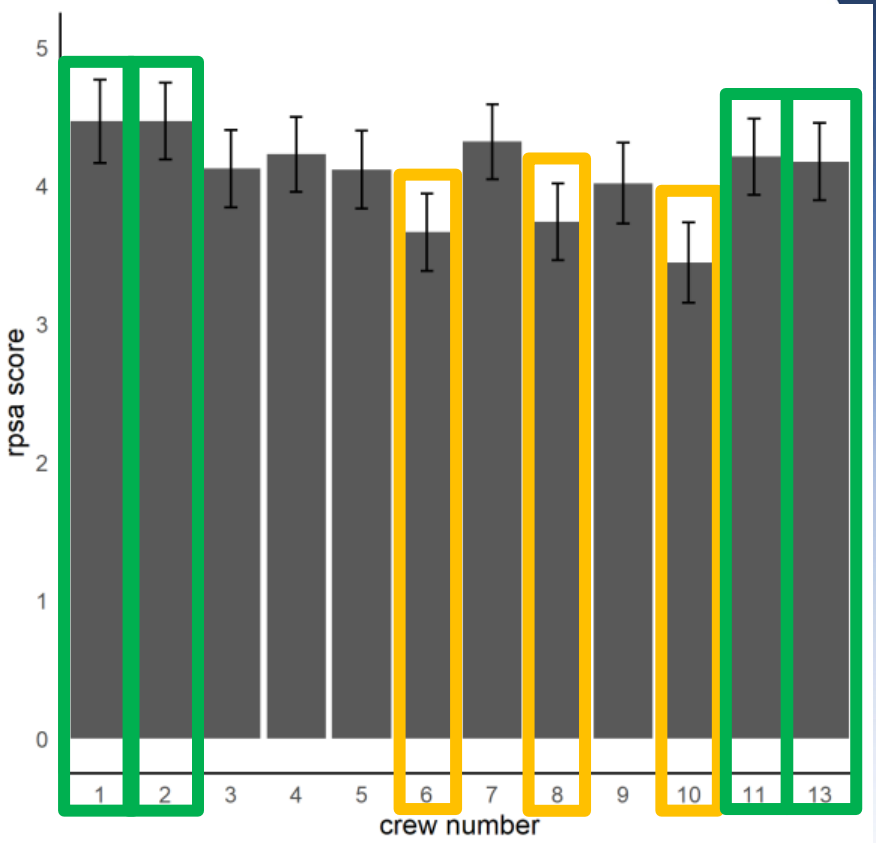
- Traditional human factors measures including self-reported workload and situation awareness
  - NASA Task Load Index (NASA-TLX)
  - Situation Awareness Rating Technique (SART)
- Custom resilience questionnaire, “Resilient Performance Self-Assessment” (RPSA)
  - 16 questions modeled on American Airlines Learning Improvement Team (LIT) Proficiencies (American Airlines, 2020)

Research Questions

1) Do resilience scores differ by crew?
2) Do the same crews that exhibit different resilience scores, exhibit differing psychophysiological behaviors, specifically in eye tracking measures?

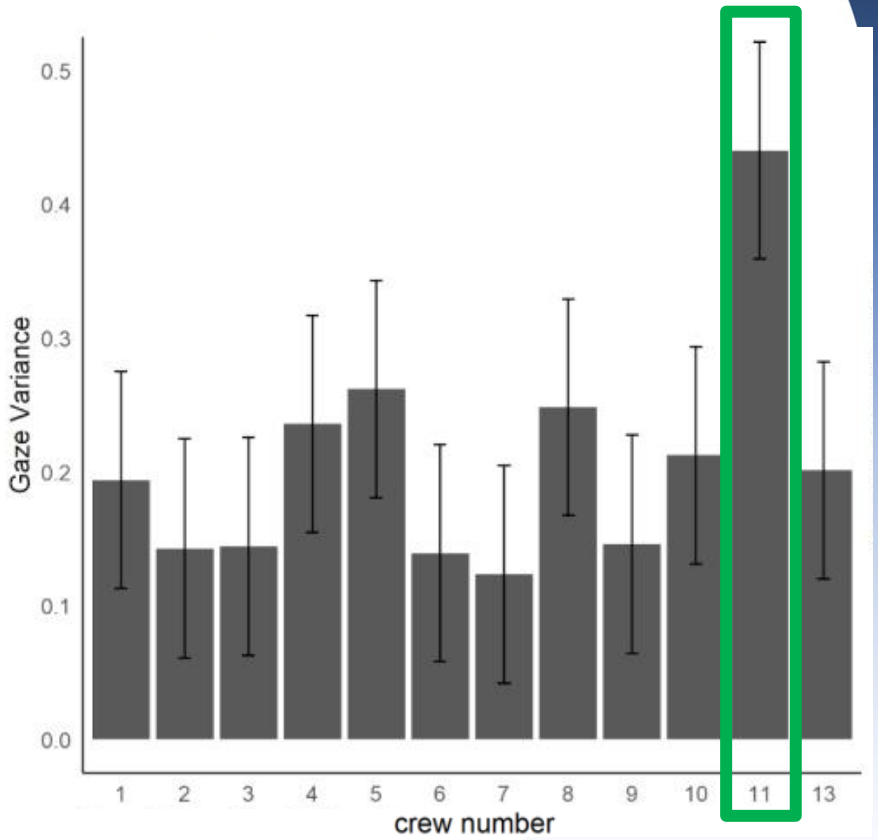
Results

- Figure 1 shows the results by crew for the reported resilience scores (combined across questions)
- Crews 6, 8, and 10 showed the lowest RPSA scores, and were significantly different from Crews 1, 2, 11, and 13 (95% confidence intervals did not overlap)



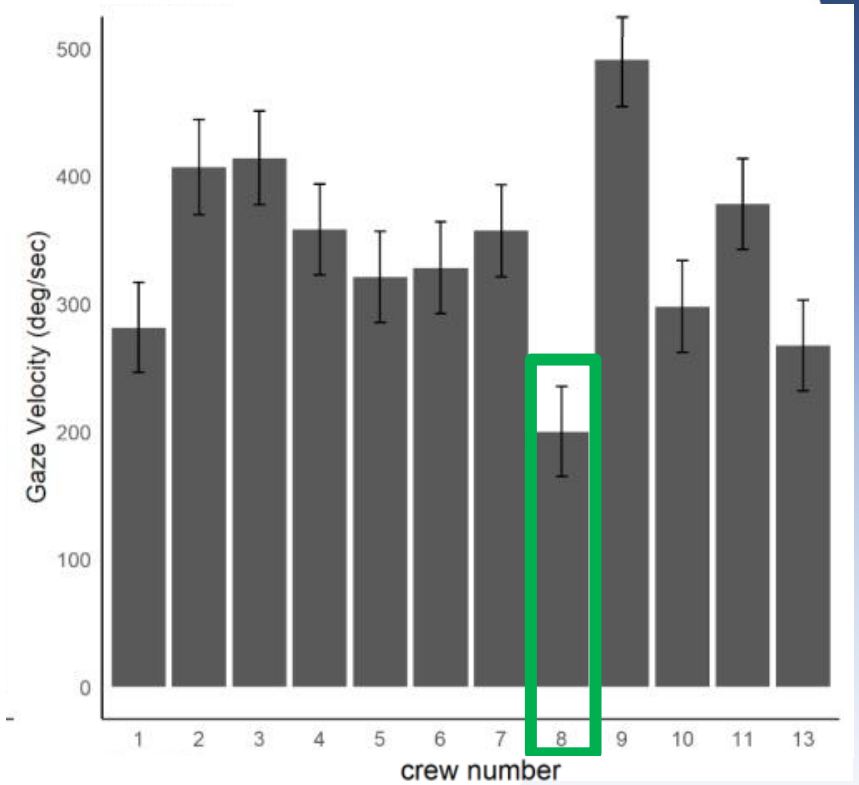
Results

- Crew 11 had a statistically significant difference in Gaze Variance
  - Significantly higher Gaze Variance compared to all other crews
  - Suggests that Crew 11 looked at more of the cockpit than the other crews throughout the scenarios



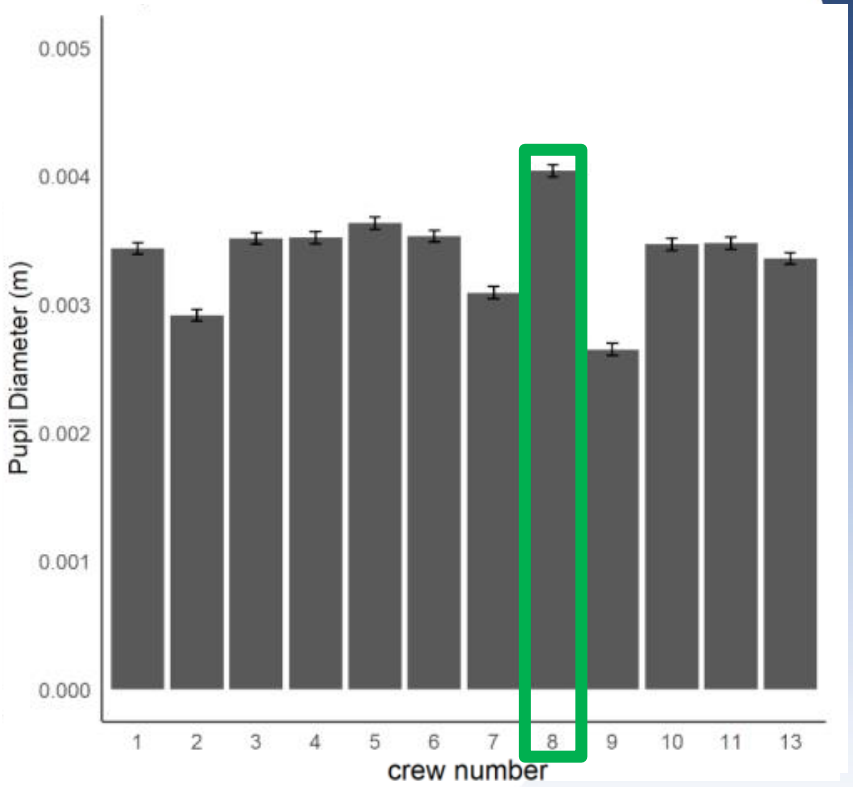
Results

- Crew 8 was one of the crews that showed relatively lower resilient scores
- Crew 8 exhibited the lowest Gaze Velocity of all crews
  - Low gaze velocity indicates less shifting of attention over time
- Gaze Velocity is a candidate for predicting resilient behavior



Results

- Crew 8 exhibited the largest Pupil Diameter out of all crews
  - Pupil dilation correlated to the demands on sustained attention
- Pupil Diameter is a candidate for predicting resilient behavior



Discussion

- Preliminary analyses of self-reported RPSA and eye tracking data
  - Significant differences between some crews in self-reported resilience scores and the psychophysiological measures
- Considerations
  - Crews did not exhibit the same differences across all the psychophysiological measures, for example Crew 11
  - Psychophysiological results from data across the entirety of the scenarios
  - RPSA was created for use in this study, but it is not a psychometrically validated measure
- Future work will address the issues discussed in the Considerations section, but also expand on the current work.
  - Additional psychophysiological sensors (EEG, EKG) to be analyzed
  - More detailed resilience scores for each crew to be extracted
    - Observations of video and audio recording to be completed by The LOSA Collaborative and American Airlines LIT that will provide resilience metrics for each scenario and crew

Thank you