National Aeronautics and Space Administration

# UAS Contingency Management:

## The Effect of Different Procedures on ATC in Civil Airspace Operations

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Human Systems Integration (HSI)
UAS Integration into the NAS

# Outline

- Background
- Method
- Results
- Discussion
- Limitations and Future Research

# Background

- **Unmanned Aerial Systems (UAS) in the National Airspace System (NAS)**:
  - Demand has skyrocketed for routine access to the NAS
    - Military, scientific, national security and emergency management applications have all called for easier admittance
  - Currently required to obtain Certificate of Authorization (COA), a time consuming, restrictive process
    - Also requires air traffic controllers (ATC) to block airspace, which can reduce airspace efficiency

# Background

- **Barriers to Integration**:
  - Lack of agreed upon minimum performance standards
    - A chief concern is contingency management
      - How will UAS deal with emergency events, such as the loss of the command and control link (i.e., lost link)?
      - How will procedures impact the rest of the system?
    - Standardized and predictable contingency management procedures are essential to integration

# Background

- **Current Behaviors**:
  - UAS response to contingency events are agreed upon within individual COAs with the FAA
    - UAS may:
      - Return to base
      - Continue to destination
      - Return to mission altitude

# Background

- **Purpose of Study**:
  - Examine the impact of existing UAS contingency management procedures on air traffic control (ATC)
    - How do current UAS behaviors impact a controller's ability to maintain a **safe** and **efficient** airspace?
    - How do the behaviors impact controller's self-reported workload?
  - Hypothesis:
    - More sudden and/or sizable maneuvers would negatively impact ATC performance and workload
      - Smaller maneuvers would have less impact on surrounding traffic
      - Less immediate maneuvers would provide time for pilot to inform ATC

# Method

## Contingency Behavior

- Four current contingency behaviors were modeled in this study
  - 3 behaviors for responding to lost link
  - 1 behavior for responding to severe loss in oil pressure
- Developed through:
  - Review of existing documentation
    - MQ-9 flight manual
    - Joint Unmanned Aircraft Systems CONOPS
  - Semi-structured interviews
    - 3 current UAS pilots from 2 different platforms

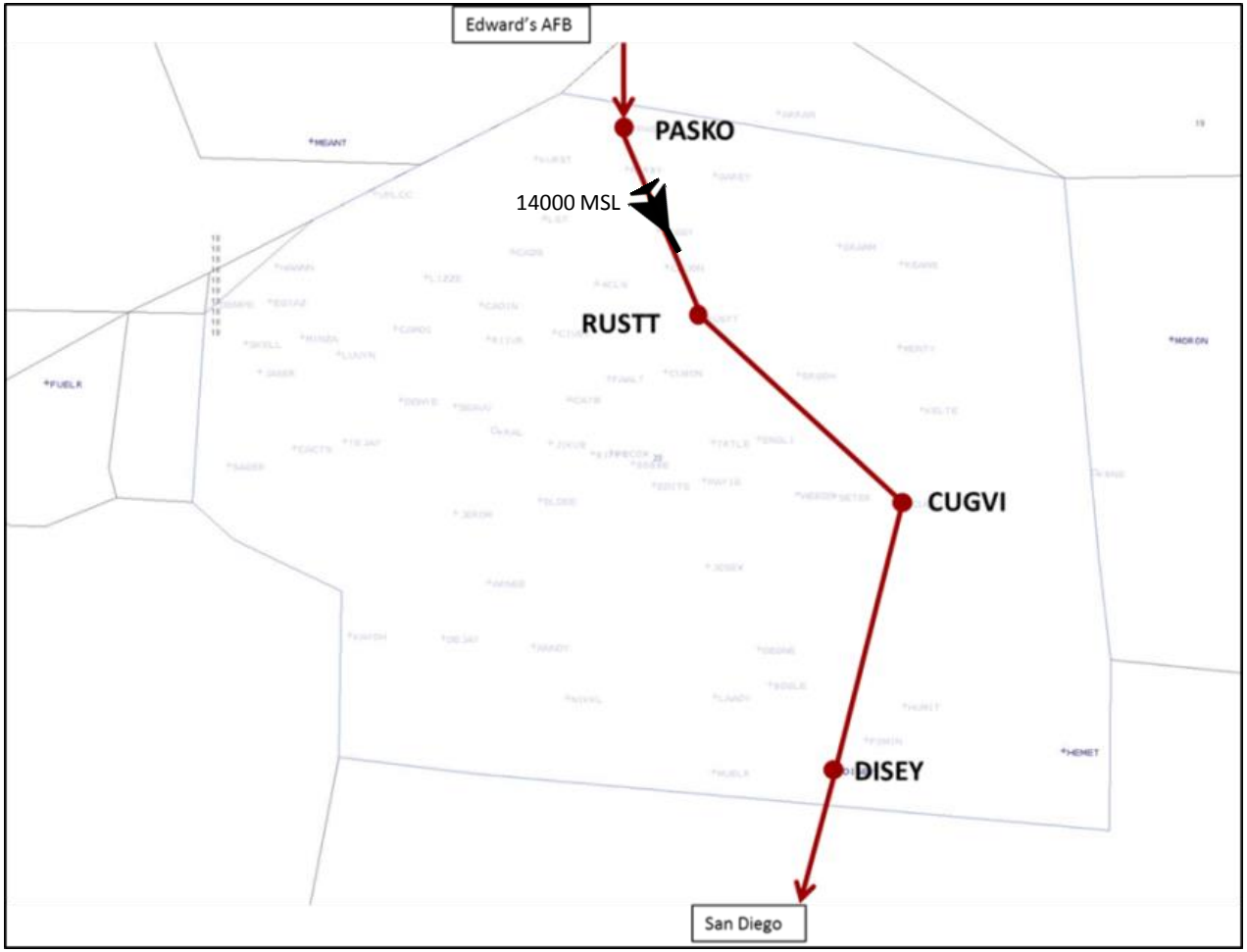
# Method

## ➢ Contingency Behavior

| ID | Event | Contingency Behavior | Time to Execute |
|---|---|---|---|
| C1 | N/A | N/A | N/A |
| C2 | Lost Link | Return to Base (incl. 180° turn) | 1 min |
| C3 | Lost Link | Return to Base (incl. 180° turn) | 8 min |
| C4 | Lost Link | Maintain Course (Return to Mission Altitude) | 1 min |
| C5 | Drop in Oil Pressure | Land at Emergency Site (incl. descent of maximum 10000ft) | Immediate |

# Method

- **C1: No Contingency Event**



# Method

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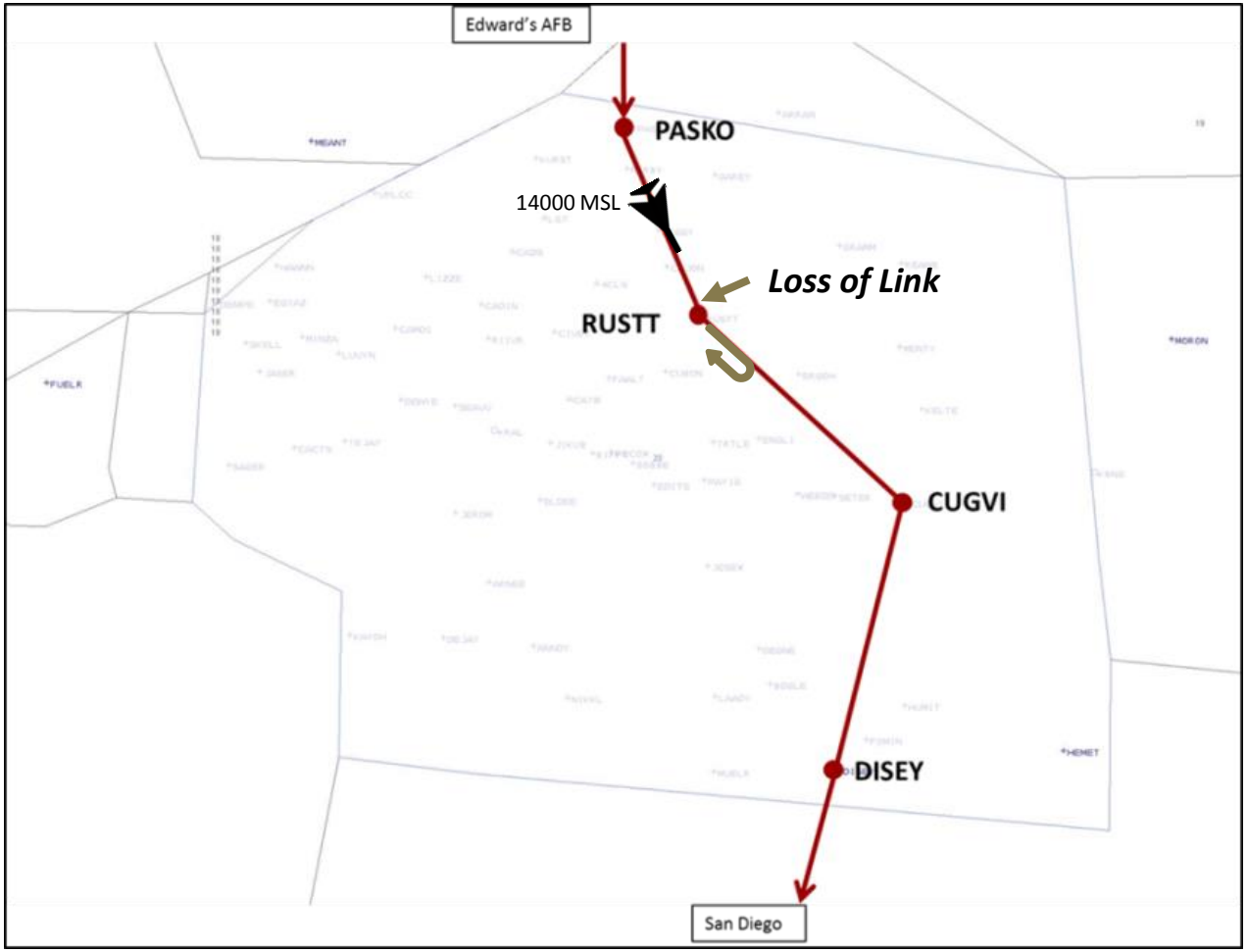
| C4 | Lost Link | Maintain Course (Return to Mission Altitude) | 1 min |
| C5 | Drop in Oil Pressure | Land at Emergency Site (incl. descent of maximum 10000ft) | Immediate |

# Method

- **C2: Return to Base in 1 Minute**



# Method

## ➢ Contingency Behavior

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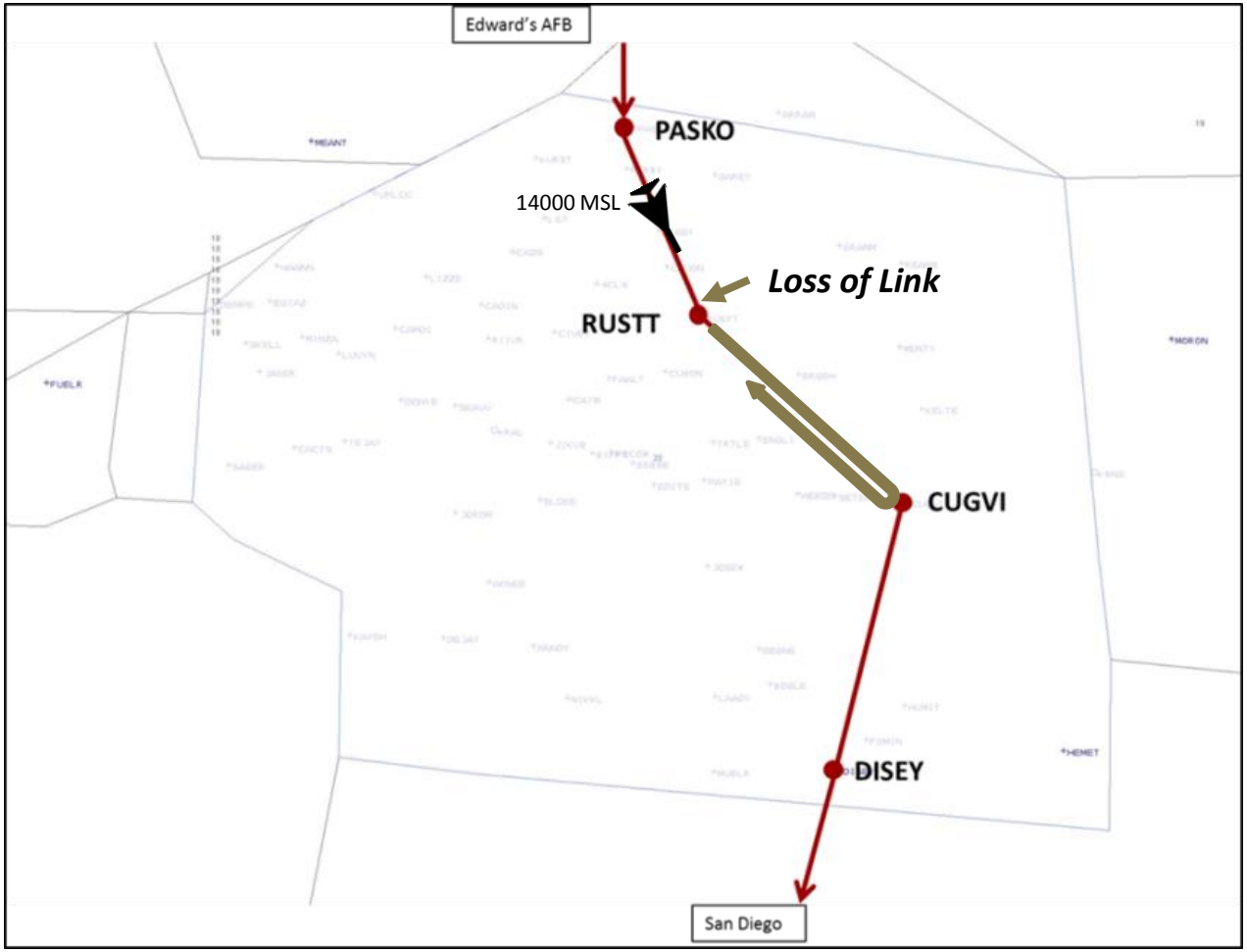
| C4 | Lost Link | Maintain Course (Return to Mission Altitude) | 1 min |
| C5 | Drop in Oil Pressure | Land at Emergency Site (incl. descent of maximum 10000ft) | Immediate |

# Method

- **C3: Return to Base in 8 Minutes**



# Method

## ➢ Contingency Behavior

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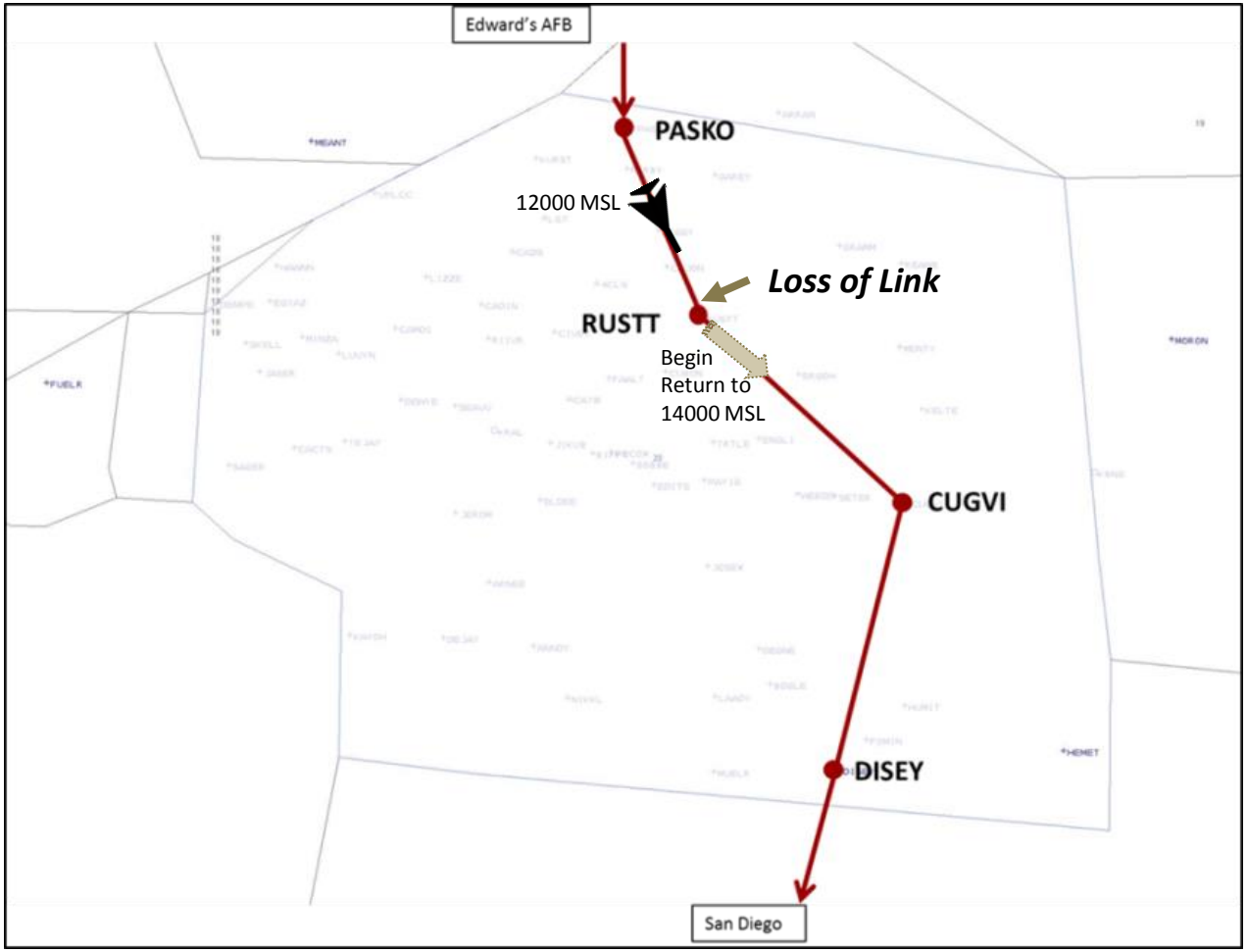
| C4 | Lost Link | Maintain Course (Return to Mission Altitude) | 1 min |
| C5 | Drop in Oil Pressure | Land at Emergency Site (incl. descent of maximum 10000ft) | Immediate |

# Method

- **C4: Maintain Course Return to Mission Alt**



# Method

## ➢ Contingency Behavior

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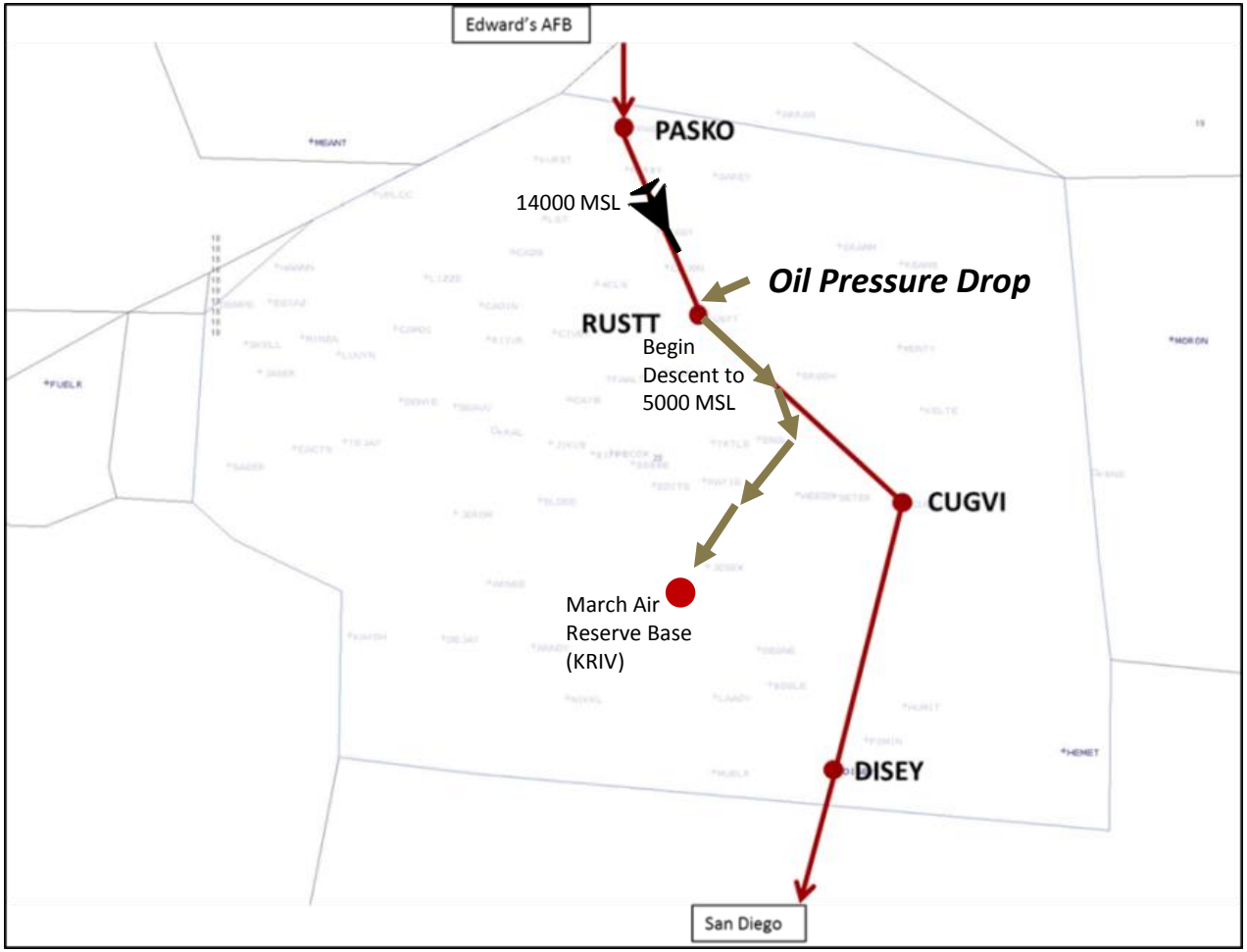
| C4 | Lost Link | Maintain Course (Return to Mission Altitude) | 1 min |
| C5 | Drop in Oil Pressure | Land at Emergency Site (incl. descent of maximum 10000ft) | Immediate |

# Method

- **C5: Emergency Landing at KRIV**



# Method

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| C4 | Lost Link | Maintain Course (Return to Mission Altitude) | 1 min |
| C5 | Drop in Oil Pressure | Land at Emergency Site (incl. descent of maximum 10000ft) | Immediate |

- Hypothesize that C3 and C4 will be least impactful on ATC performance
  - C2 and C5 most impactful

# Method

## Experimental Design

- One-Way Repeated Measures Factorial
  - Contingency Behavior (5 levels, within subjects)
    - Counterbalanced order of presentation within each block across participants
  - Block (2 levels; within subjects)
    - No systematic difference between levels
- Experimental Scenarios
  - 2 Blocks
    - 5 experimental runs per block
    - Experimental runs lasted 17 min
      - Each trial followed up by workload and general questionnaire

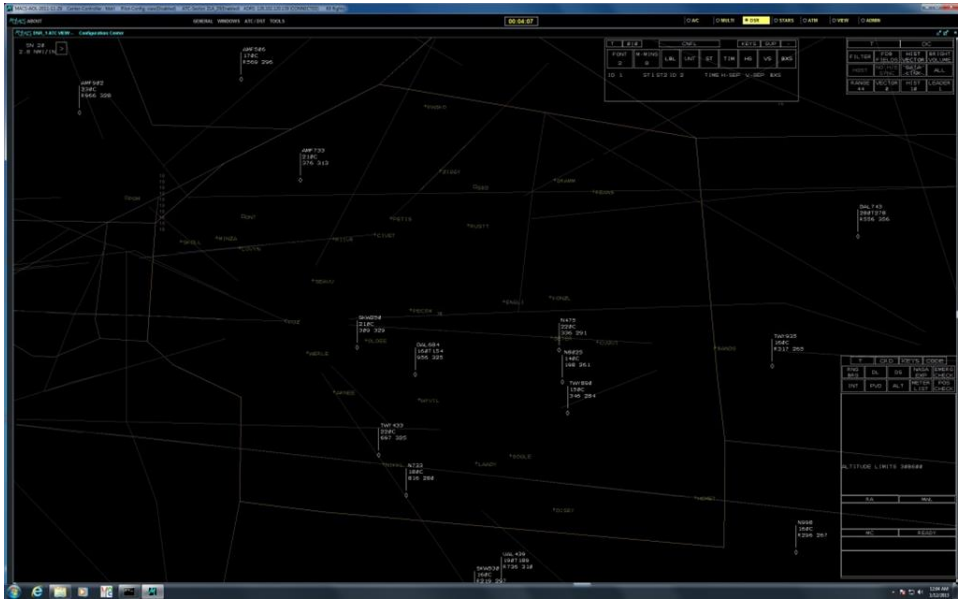
# Method

## Participants

- 14 Retired Controllers (Male):
  - Civilian ATC Experience:
    - TRACON – 14/14 (26 years on avg.)
      - 13/14 had experience working East Feeder
    - Tower – 10/14
    - Center – 2/14
  - Military ATC Experience:
    - TRACON – 5/14
    - Tower – 4/14

# Method

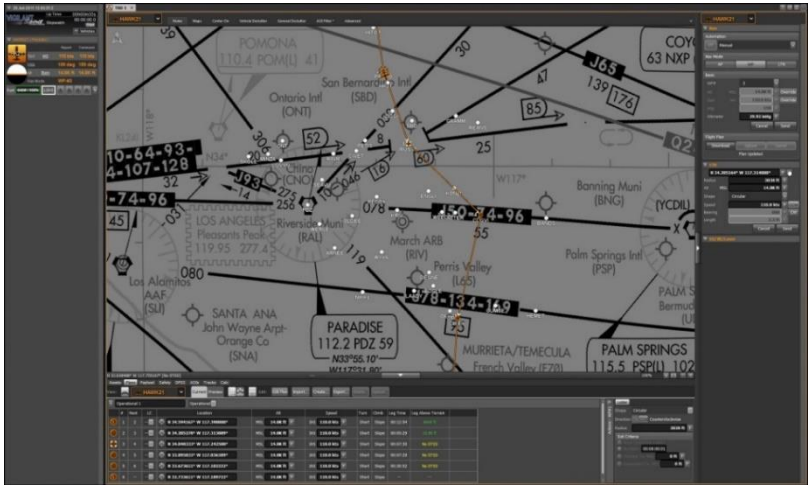
- **Apparatus**
  - Multi Aircraft Control System (MACS) provided controller display
    - Display System Replacement (DSR) presentation of Southern California TRACON [East Feeder/ZLA20]
      - Hybrid sector – airspace positively controlled from surface to FL230
      - Participants used keyboard and mouse for inputs



# Method

## ➢ Apparatus

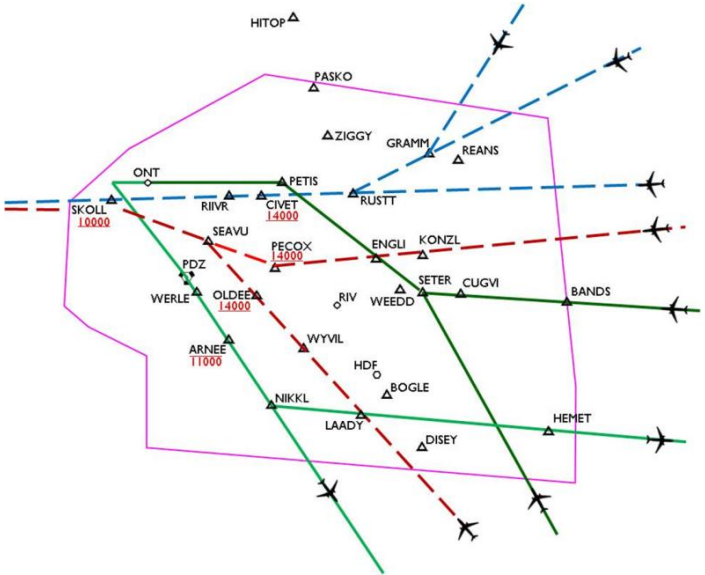
- Vigilant Spirit Control Station (VSCS) provided simulated UAS ground control station
  - Allowed for simulated injection events (e.g., loss link and severe oil loss)
  - UAS pilot provided with script when coordinating with ATC following contingencies
  - MQ1 Predator (Modified)
    - Speed: 110 knots
    - Mission Alt: 14000 MSL




-Vigilant Spirit Control System, AFRL-

# Method

- **Apparatus**
  - Traffic Scenarios
    - Designed off of a busy, current day at SoCal TRACON
      - Included arrivals into LAX and ONT, as well as overflights (in addition to single UAS)
    - Manned aircraft were level when entering sector
      - Arrivals had to be manually descended by ATC



# Method

## Procedure

- Task:
  - Maintain safe separation
    - 3nm and 1000ft (approach airspace separation requirements)
  - Ensure LAX arrivals meet appropriate altitude restrictions.
    - LAX arrivals required to exit sector @SKOLL at 10000 MSL
  - Descent ONT arrivals to 5000 MSL for visual approach
    - No coordination with ONT tower
  - Manage overflights (including UAS)
- Training
  - Trained on MACS software and overall sector operations
    - Included brief on UAS characteristics and potential contingencies
  - 3 practice scenarios (2 with only manned AC, 1 with UAS)
    - No practice on UAS contingency behaviors

# Method

## Metrics

- *ATC Performance*
  - Safety
    - Number of Losses of Separation (violation of 3nm and 1000ft)
  - Workload
    - Handoff Accept Time
      - Time elapsed between adjacent sector's initial handoff and experimental controller's acceptance)
  - Efficiency
    - Avg. time in sector per AC
    - Avg. distance flown per AC
- *Subjective Ratings*
  - NASA-Task Load Index
    - Mental Demand, Physical Demand, Temporal Demand, Performance Degradation, Effort and Frustration
  - Post-Trial Questionnaire
    - Assessed impact of contingencies on controller's self reported separation strategies
  - Post-Simulation Questionnaire
    - Queried controllers on overall simulation fidelity and compared across levels of Contingency Behavior

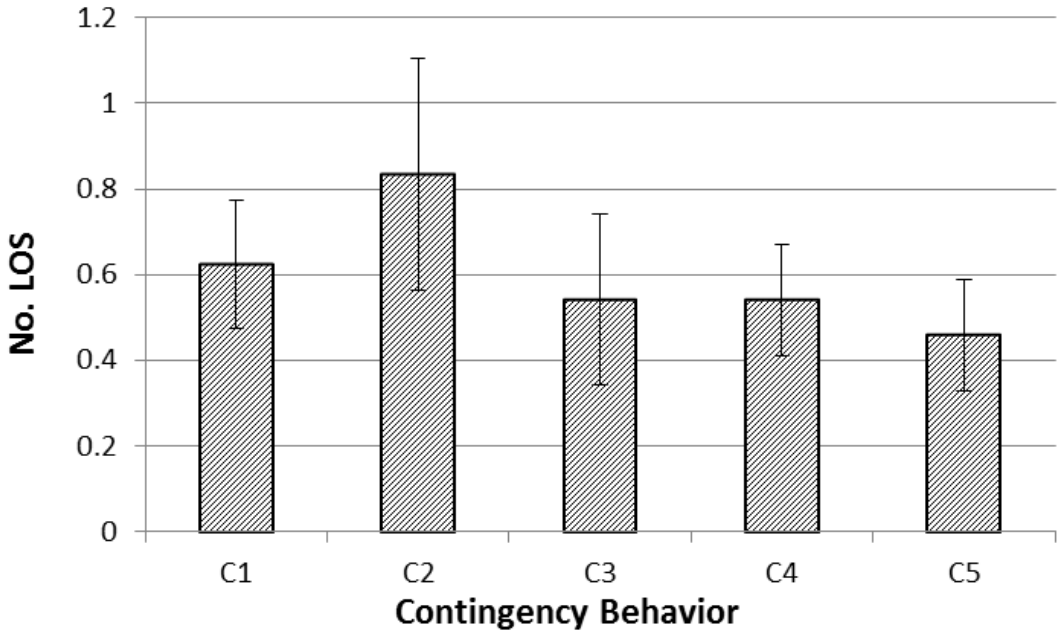
## Analysis

- Data analyzed using a 5 (Contingency Behavior: C1-C5) x 2 (Block: 1-2) Repeated Measures ANOVA

# Results: ATC Performance

- **Safety**
  - No significant main effect of Contingency Behavior on Number of LOS ($p$>.05)
    - LOS were low across all levels of Contingency Behavior

| Label | Description |
|---|---|
| C1 | No contingency (baseline) |
| C2 | Return to base (1 minute) |
| C3 | Return to base (8 minutes) |
| C4 | Maintain course (return to alt) |
| C5 | Emergency landing |



# Results: ATC Performance

- **Workload**
  - No significant main effect of Contingency Behavior on number of handoff accept time ($p$>.05)
    - Handoff accept times were low and stable across conditions

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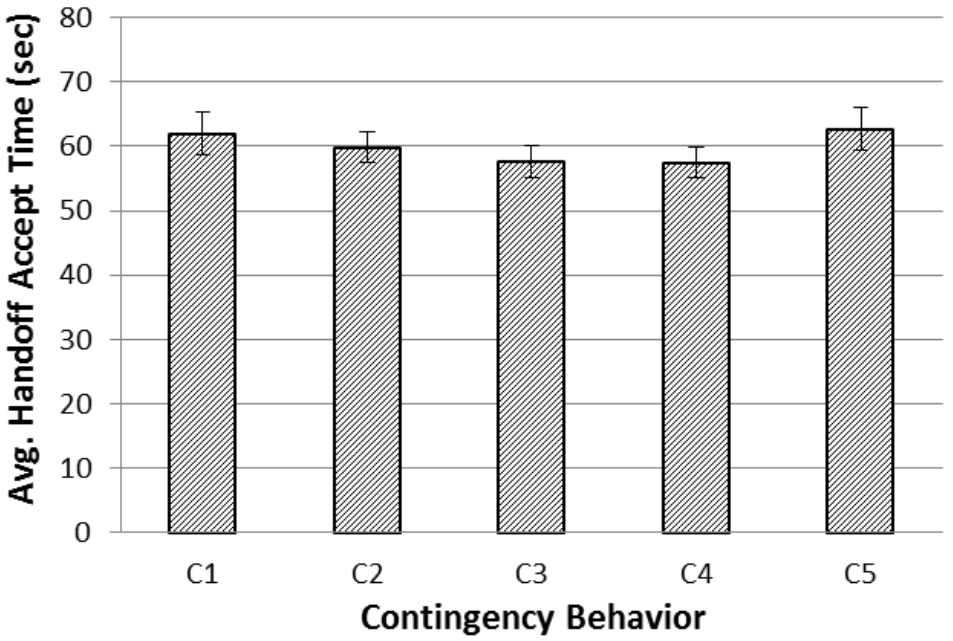

# Results: ATC Performance

- **Efficiency**
  - No significant main effect of Contingency Behavior on Distance Through Sector ($p$>.05)
    - Controllers remarkably consistent between conditions

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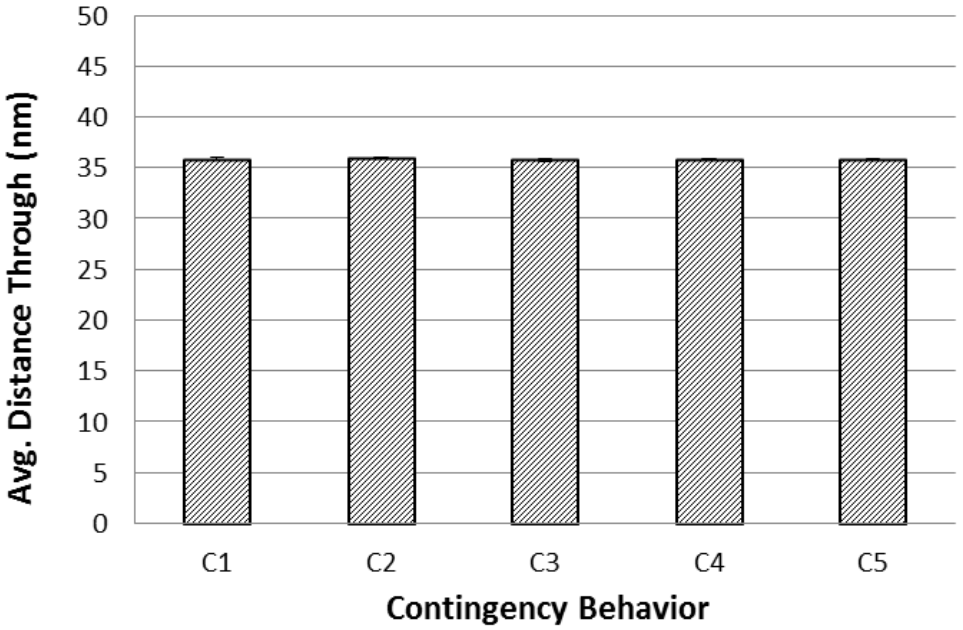

# Results: ATC Performance

- **Efficiency**
  - No significant main effect of Contingency Behavior on Time Through Sector ($p$>.05)
    - Controllers consistent across conditions

| Label | Description |
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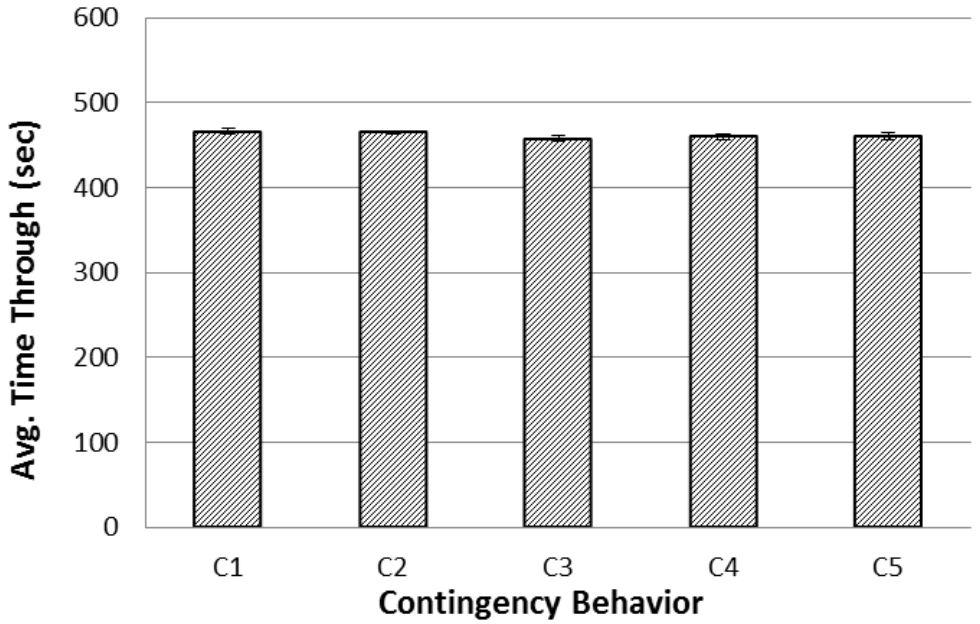
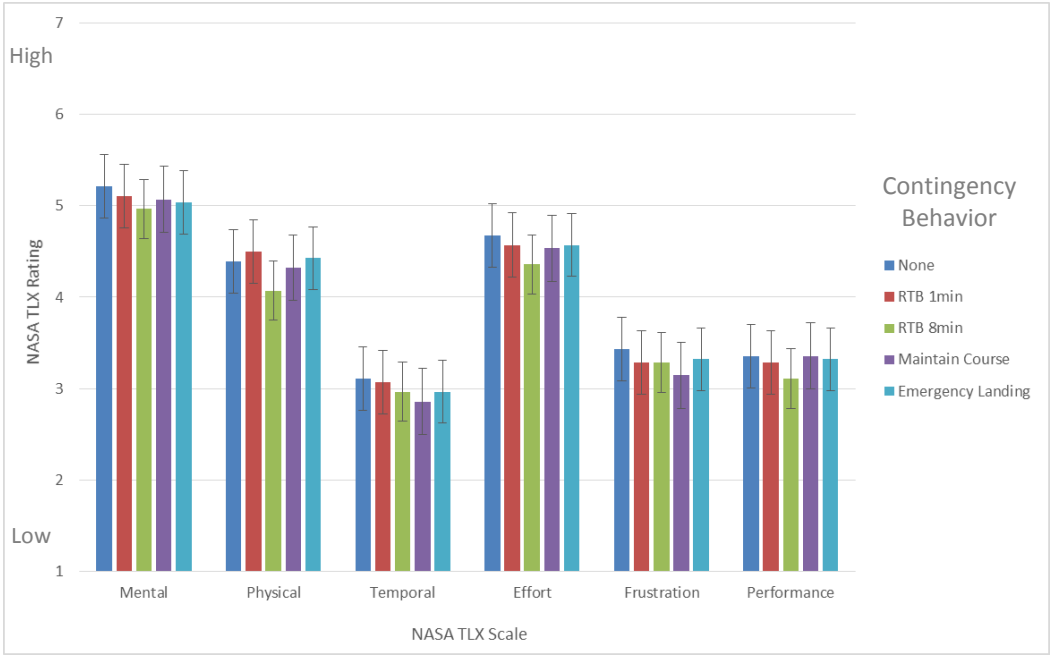


# Results: Subjective Ratings

- **NASA-TLX**
  - No significant main effect of Contingency Behavior on any of controller's self-reported workload scales (*p*'s>.05)
    - Mental, Physical and Effort demands slightly above average
    - Temporal, Frustration and Performance demands slightly below

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# Results: Subjective Ratings

## ➢ Post-Trial Questionnaire

- No significant effect on any of the 8 questions (*p*'s>.05)
  - Rating: 0 (Strongly Disagree) – 5 (Strongly Agree)
- Questions included:
  - Impact on ability to safely/efficiently manage sector
  - Impact on situation awareness
  - Predictability of behavior
  - Buffer size for UAS

| Label | Description |
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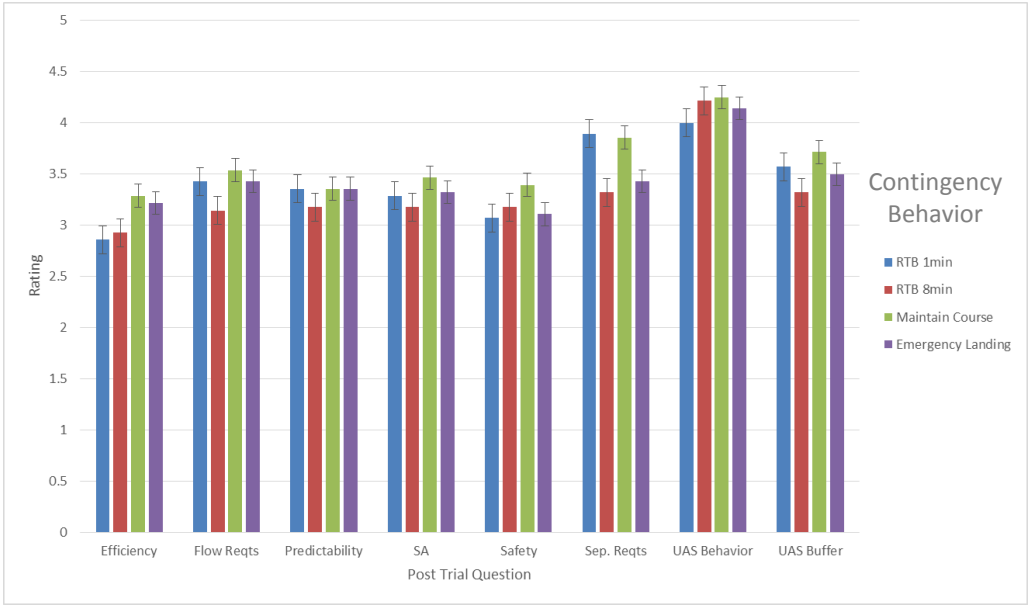

# Results: Subjective Ratings

- **Post-Simulation Questionnaire**
  - Controller's were asked their preferred contingency behavior (from *Most Impactful* to *Least Impactful*) in terms of:
    - Safety
    - Efficiency
    - Workload
  - For all 3 questions controllers responded:
    - C4 (Return to Mission Alt/Maintain Pre-Programmed Course)
    - C3 (Return to Base in 8min)
    - C2 (Return to Base in 1min)
    - C1 (Emergency Landing)

# Conclusion

- **Study suggests:**
  - Contrary to hypothesis, current contingencies found to have no positive or negative effects on controller performance or subjective reports
  - No differences between contingencies or relative to baseline condition (with no contingency event)
    - Losses of separation, handoff accept times, time and distance through sector saw no significant effects
    - Workload, post trial and post simulation questionnaires also failed to see effects
  - However, when asked, controllers found the Return to Altitude/Maintain Course & the 8 minute Return to Base contingencies to be the least impactful
    - Emergency landing contingency was rated as most impactful

# Conclusion

- **Explanation of findings**
  - Controllers commented that dealing with a single UAS (even when operating under a variety of contingency procedures) was not problematic
    - Nearly all controllers noted that they frequently dealt with "special" AC while working ZLA20 (East Feeder)
      - DEA and FBI routinely flew helicopters or fixed-wing AC at low altitudes with unpredictable routing
    - Participants had worked East Feeder, likely very motivated/talented controllers
  - Suggests controllers' skill sets were robust enough to accommodate a single, unpredictable, slow-moving AC
  - FAA likely designs contingency procedures that are *intentionally* minimally impactful

# Conclusion

- **Limitations:**
  - No “true” baseline scenario – i.e., trial without UAS present
    - May have obscured comparisons
  - Looked only at approach airspace that was relatively conflict free
    - Used a hybrid sector (part approach, part center) with traffic that was flying level
    - Class A (no VFR included in scenario)

# Conclusion

- **Recommendations for Future Research:**
  - Present the contingencies within more difficult contexts
    - Higher density traffic
    - Different airspace (e.g., Class E or D)
    - Script complex conflictions with the UA
  - Simulate different types of contingencies
    - Context-sensitive contingencies
      - UAS behavior is dictated by the current airspace or operation
    - Design purposefully disruptive contingencies to demonstrate sensitivity of our metrics
      - May make it easier to accept null hypothesis
  - NORTHCOMM is currently testing impact of contingency operations in flight test conditions

# Conclusion

- **Questions?**