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
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
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

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Method

- C1: No Contingency Event
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- C2: Return to Base in 1 Minute
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- C3: Return to Base in 8 Minutes
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- C4: Maintain Course Return to Mission Alt

Loss of Link

12000 MSL

Begin Return to 14000 MSL
# Method

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Method

- C5: Emergency Landing at KRIV

- Oil Pressure Drop at 14000 MSL
- Begin Descent to 5000 MSL at RUSTT
- March Air Reserve Base (KRIV)
- Landing at KRIV
Method

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- 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
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 ($p > 0.05$)
  - LOS were low across all levels of Contingency Behavior

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Results: ATC Performance

➢ Workload

- No significant main effect of Contingency Behavior on number of handoff accept time ($p > 0.05$)
  • 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

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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 ($p’s>0.05$)
    - 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

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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 conflicts 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?