Airspace Safety Threshold Study:
NAS-wide Encounter Rate Evaluation using Historical Radar Data and ACES

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Outline

• Analysis Overview and Definitions
• Simulation Setup
  – Traffic Scenarios
  – UAS Missions
  – ATC-like Mitigation Model
• Study Results
  – Analysis 1: Encounter Rates of Current Operations using Historical Data
  – Analysis 2: Encounter Rates of Proposed UAS Missions using NAS-wide Simulation
  – Analysis 3: Investigate effect of ATC mitigation on UAS-VFR encounters
• Conclusions
Unmitigated Encounter Rate Evaluation

Analysis 3
- ATC Conflict Mitigation Model

Analysis 1
- Air Defense Radar Data

Metrics
- Airborne Encounter Loss of Well Clear

ACES: Flight plan and NAS-agent modeling system

NAS-wide Simulation

Processing

Analysis 2 & 3
- UAS Models
- UAS Mission Profiles
- Air Defense Radar Data

Results
- Encounter Rates
- Altitude

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Airborne Encounter Definition

\[ \tau_{mod} = \frac{-R_{xy}^2 - DMOD^2}{\dot{R}_{xy}R_{xy}} \]

Self-Separation Threshold (SST)

Airborne Encounter

\[ 0 \leq \tau_{mod} \leq SST \]

\[ |\Delta h| \leq ZTHR \]

\begin{tabular}{|c|c|c|}
\hline
SST [s] & ZTHR [ft] & DMOD [ft] \\
\hline
100 & 2000 & 4000 \\
\hline
\end{tabular}

Time to Closest Point of Approach

\[ t_{CPA} \]

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Airspace Concept Evaluation System

National Traffic Management

Regional Traffic Management

Local Approach and Departure Traffic Management

Airport and Surface Traffic Management

NAS-Wide Simulation Environment
- Gate-to-gate ATM operations
- Full flight schedule
- Sector and Center Models
- Airspace Procedures

Agent-Based Modeling
- Air Traffic Controller Decision Model
- Traffic Flow Management Model
- Historical Radar Data Playback
- Detect and Avoid System

Trajectory Modeling
- Aerodynamic Models
- Customizable Uncertainty Characteristics
- Diverse UAS Models
- Pilot Behavior Models

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84th Squadron Air Defense Radar Data

- Data is processed as a single day in the NAS (24 hours starting at 0 UTC)
- The simulation runs were chosen across 4 seasons in 2012
- The data is NAS-wide
  - (Note: sections of the interior of the US have limited coverage in some areas).
- 21 Days Total
Processing Radar Data

• Algorithm 1: IFR and cooperative VFR
  – Collected raw data (Mode C transponder code, altitude)
  – Generate tracks using a minimum spanning tree based clustering algorithm
  – Tracks are uniquely identified and then smoothed using a Kalman Filter

• Algorithm 2: Non-cooperative VFR (developed by Honeywell, under contract with NASA)
  – Collected raw data (search only)
  – Track Association Method to generate tracks and smoothed using a Kalman filter
  – Altitudes are assigned using a Gamma distribution (generalized from ARSR-4 position report distributions)
UAS Missions Overview

Overall Characteristics from 18 Missions

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Aerosonde</th>
<th>Global Hawk</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAS Size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flight Duration</td>
<td>1 Hour</td>
<td>20 Hours</td>
</tr>
<tr>
<td>Flights Per Day</td>
<td>20</td>
<td>8,000</td>
</tr>
<tr>
<td>Cruise Altitude</td>
<td>2,000 ft</td>
<td>31,000 ft</td>
</tr>
</tbody>
</table>

Flight Pattern
- Grid Pattern
- Circular Loitering
- Point-to-point KXYZ

- Air Quality Monitoring
- Cargo Transport
- Flood Mapping
- Atmospheric Sampling
- Wildfire Detection and Reconnaissance
- On-Demand Air Taxi
ATC-Like Mitigation Model (AutoResolver)

• Lineage as a decision support tool for air traffic controllers.
  – Autoresolver has been used in fast-time and human-in-the-loop (HITL) evaluations.

• Attempts to resolve conflicts on the 1-8 minute time horizon
  – Suggests maneuvers based on minimum delay and heuristics derived from feedback from HITL evaluations.
  – Maneuvers include: path stretch, direct-to, step altitude, temporary altitude, and speed change

![Diagram](image.png)
Analysis 1: Encounter Rate from Historical Radar Data

Objective:
Compute Airborne Encounter Rate for:
- IFR vs. IFR
- IFR vs. Cooperative VFR
- IFR vs. Non-cooperative VFR

Air Defense Radar Data

Metrics
- Loss of Well Clear
- Airborne Encounter

Processing

Results
- Encounter Rates
- Altitude
Analysis 1

Results
Encounter Rates based on Historical Data

Airborne Encounters per IFR Flight Hour

- **IFR**: 2.044
- **Cooperative VFR**: 0.372
- **Non-Cooperative VFR**: 0.174
- **Overall**: 2.591

**Legend**:
- **IFR**: Green
- **Cooperative VFR**: Blue
- **Non-Cooperative VFR**: Orange
Analysis 2: Encounter Rate from NAS-wide Simulation

Objective:
Compute Airborne Encounter Rate for:
- UAS vs. Cooperative VFR
- UAS vs. Non-cooperative VFR

Metrics
- Loss of Well Clear

Analysis 2
- UAS Models
- UAS Mission Profiles
- Air Defense Radar Data

NAS-wide Simulation

Processing

Results
- Encounter Rates
- Altitude

Objective: Compute Airborne Encounter Rate for:
- UAS vs. Cooperative VFR
- UAS vs. Non-cooperative VFR

Metrics
- Loss of Well Clear

Analysis 2
- UAS Models
- UAS Mission Profiles
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NAS-wide Simulation

Processing

Results
- Encounter Rates
- Altitude

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Analysis 2

Results
Encounter Rates based on Simulation

- **Cooperative VFR**: 0.200
- **Non-Cooperative VFR**: 0.025
- **VFR**: 0.225

Encounter rate per UAS flight hour
Analysis 3: Encounter Rates with ATC Intervention

Objective:
Check assumption that ATC reroutes of UAS and IFR aircraft for separation are infrequent and have negligible effect on UAS-VFR encounter rates.

Analysis 3
ATC Conflict Mitigation Model

Metrics
Airborne Encounter
Loss of Well Clear

Analysis 3
UAS Models
UAS Mission Profiles
Air Defense Radar Data

NAS-wide Simulation
Processing

Results
Encounter Rates
Altitude

Objective:
Check assumption that ATC reroutes of UAS and IFR aircraft for separation are infrequent and have negligible effect on UAS-VFR encounter rates.
Analysis 3 Approach

• Proxy for ATC conflict mitigation (i.e., aircraft-to-aircraft separation): Autoresolver

• 4 Days were analyzed (January 11, April 21, July 17, and October 6, 2012)

• Autoresolver conflict detection
  – Identifies conflicts (5 nmi/1000 ft):
    • UAS vs manned IFR
    • Two manned IFR
  – No uncertainty

• Autoresolver conflict resolution
  – Develops conflict resolution maneuvers for the two conflict types above to maintain 5 nmi/1000 ft separation
  – Maintains smaller separation standard of 1.5 nmi/500 ft for:
    • UAS vs VFR
    • Manned IFR vs VFR
Analysis 3

Results
Encounter Rate Comparison with and without ATC-like Mitigation

<table>
<thead>
<tr>
<th>Month</th>
<th>Percentage Difference in UAS-VFR Encounter Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 11</td>
<td>0.537</td>
</tr>
<tr>
<td>Apr 21</td>
<td>1.311</td>
</tr>
<tr>
<td>Jul 17</td>
<td>1.326</td>
</tr>
<tr>
<td>Oct 6</td>
<td>1.074</td>
</tr>
<tr>
<td>Overall</td>
<td>1.072</td>
</tr>
</tbody>
</table>

The diagram shows the comparison of encounter rates with and without ATC-like mitigation across different months.
Conclusions

• Three analyses were conducted using recorded VFR traffic.
  – 21 days for Analysis 1 and 2
  – 4 days for Analysis 3
• 18 UAS missions were used in Analysis 2 and 3.
• Results indicate:
  – Overall encounters occur approximately once every 22 minutes.
  – Encounters between IFR and VFR occur approximately once every 1.8 hours
  – Encounters could occur between UAS and VFR approximately once every 4.4 hours
  – ATC conflict mitigation between UAS and IFR conflicts would be infrequent enough to change the encounter rate between UAS and VFR.
Questions

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