Investigating Surveillance Performance for UAS Detect-and-Avoid Systems

Seung Man Lee and Chunki Park
University Affiliated Research Center/UCSC

Eric Mueller
NASA Ames Research Center
Background and Motivation

• A Detect-And-Avoid (DAA) capability is required for UAS to meet the requirement in CFR 91.113 to “see and avoid” other aircraft and maintain “well clear”.

• RTCA Special Committee 228 is developing Minimum Operational Performance Standards (MOPS) for DAA systems.

• A surveillance system is a critical component of DAA system to detect and track intruder aircraft. Thus, the MOPS will include surveillance system requirements.

• Encounter characteristics of “well-clear” violations between UAS and manned aircraft have not been investigated.
Objectives

• Investigate unmitigated encounter characteristics of well-clear violations between UAS and cooperative VFR aircraft in Class E airspace

• Investigate the relationship between encounters to surveillance system characteristics in terms of detection range and fields of regard (FOR)
  – the effect of surveillance volumes on the ratio of undetected well-clear violations (WCV)
  – the time to WCV of intruders with different surveillance volumes
Concept of Well Clear Violation

- Airborne separation standard
- Time and distance-based definition of “Well-Clear Violation”
  - When two aircraft are within distance thresholds
  - When the projected closest point of approach (CPA) of two aircraft is within a distance-based volume in particular time thresholds
- Similar to Traffic Collision Avoidance System (TCAS) II alerting logic and criteria

“Well Clear” Distance Thresholds

- 6000 ft
- 475 ft

“Well Clear” Time Thresholds

- Time to CPA: 30 sec
- Time to Co-altitude: 20 sec
Generic Surveillance Model

Surveillance Range

Heading

Horizontal Field of Regard (Azimuth Angle)

Vertical Field of Regard (Elevation Angle)
NAS-Wide Air Traffic Simulation

- Airspace Concept Evaluation System (ACES)
  - Simulate NAS-wide air traffic operations and encounters between UAS and VFR traffic

- Traffic scenario for a single day
  - Historical cooperative VFR traffic
    - Air Defense radar data on July 25, 2012
    - Total 26,770 flights, 24,838 flight hours
  - Proposed UAS flights
    - Various types of UAS missions generated by Intelligent Automation Inc.
    - Total 18,262 flights, 18,900 flight hours
Simulation Results and Analysis
Relative Position of Threats at the WCV

At 120 seconds before the WCV:

At 80 seconds before the WCV:

At 40 seconds before the WCV:

At the time of the WCV:

Relative Position of Threats

Head-On
Relative Horizontal Distance of Threats

Percentage of Intruders within a given range (%)

Relative horizontal distance (nmi)

At Well Clear Violation
At 40 sec to WCV
At 80 sec to WCV
At 120 sec to WCV
Relative Heading Angle of Threats

Percentage of Intruders within a given horizontal FOR (%)

- At Well Clear Violation
- At 40 sec to WCV
- At 80 sec to WCV
- At 120 sec to WCV

Relative heading angle (± azimuth angle in deg)
Relative Vertical Angle of Threats

Percentage of Intruders within a given vertical FOR (%)

Relative vertical angle (± elevation angle in deg)

- At Well Clear Violation
- At 40 sec to WCV
- At 80 sec to WCV
- At 120 sec to WCV

AUVSI 2014
Effects of Surveillance Parameters

• Selected sets of surveillance parameters
  – Surveillance Range: 6, 10, 20 nmi
  – Horizontal Field of Regard: (±) 60, 90, 120, 180 deg
  – Vertical Field of Regard: (±) 20, 40 deg
  – Total 24 sets of surveillance parameters (3*4*2)

• Analysis for undetected WCV
  – Metric: Ratio of the number of undetected WCV to the total number of WCV for a given set of surveillance parameters

• Analysis for Detected WCV
  – Metric: Time to WCV of threats at first detection with a given set of surveillance parameters
* Percentage of undetected WCVs is closely related to horizontal field of regard!
Analysis of the Time to WCV

Percentage of threats who could be detected at a given time to WCV (%)

<table>
<thead>
<tr>
<th>Range (nmi)</th>
<th>Horizontal field of regard (deg)</th>
<th>Vertical field of regard is ±20°</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>12</td>
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<tr>
<td>20</td>
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</table>

Time to Well-Clear Violation (sec)

(10nm, ±90, ±20)

20 nmi detection range

10 nmi detection range

6 nmi detection range
Concluding Remarks

- Analyzed and built a database for well-clear violations between UAS and VFR traffic
  - Allow system designers to conduct trade space analysis

- The ratio of undetected WCV was substantially affected by horizontal field of regard
  - 90% of WCV could be detected with a surveillance volume (6nmi, ±120°, ±20°)

- The time to WCV was most sensitive to surveillance detection range
  - 90% of threats could be detected at least 60 sec before the violation with a surveillance volume (10nmi, ±90°, ±20°)
Future Works

• Perform sensitivity analysis with multiple days of traffic
  – Effects of different traffic density of VFR and UAS traffic
  – Effects of different UAS missions and flight characteristics

• Conduct mitigated surveillance study with a DAA system
  – Effects of threat prediction and avoidance algorithms

• Use high-fidelity sensor models to detect intruder aircraft under uncertainty

• Investigate the effects of various definitions of well-clear separation standard
Questions?

- Paper to be published in AIAA Aviation, Technology, Integration, Operation (ATIO) 2014 conference

Chunki Park, Seung Man Lee, and Eric Mueller


Contact Information

Seung Man Lee
seungman.lee@nasa.gov
BACKUP SLIDES
Characteristics of UAS and VFR Flights

Average Speed of UAS: 172 knots
Average Speed of VFR: 124 knots
Definition of Well Clear Violation

\[ R_{xy} \leq DMOD \text{ or } (P_{cpa} \leq HMD \text{ and } 0 \leq Tau_{Mod} \leq TTHR) \]

and

\[ R_z \leq ZTHR \text{ or } (0 \leq T_{COA} \leq TCOA) \]

Where

- \( R_{xy} \): Horizontal Range
- \( P_{CPA} \): Predicted horizontal range at time of closest point of approach
- \( Tau_{Mod} \): Modified Tau
- \( R_z \): Relative Altitude
- \( T_{COA} \): Time to Co - Altitude

\[ DMOD = 6000 \text{ ft} \quad HMD = 6000 \text{ ft} \quad ZTHR = 475 \text{ ft} \]
\[ TTHR = 30 \text{ sec} \quad TCOA = 20 \text{ sec} \]