UAS Detect, Sense, and Avoid: Tech Survey and Regulatory Gap Analysis

• Research Objective
  – Perform survey of existing DSA technologies
  – Articulate regulatory requirements on pilots to see and avoid other aircraft

Milestones/Schedule
  – Kickoff: SEP 07
  – Tech survey: DEC 07
  – Gap analysis: MAY 08
  – Report draft: AUG 08

Accomplishments/Planned Activities
  – Tech survey complete
  – Gap analysis complete
  – Report in revision

<table>
<thead>
<tr>
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Detect, Sense, and Avoid: Regulatory Gap Analysis

Christopher Reynolds
Tim Wilson

20 November 2008
Overview

• Literature review and technology survey
• Regulatory review
• Regulatory gap analysis
Literature Review and Technology Survey

- Literature reviewed
- Collision avoidance by traffic separation
- Technologies for cooperative aircraft
- Technologies for uncooperative aircraft
- Computational issues
Literature Reviewed

• Included...

  – Hottman, Hansen, & Berry, “Literature Review on Detect, Sense, and Avoid Technology for Unmanned Aircraft Systems”


Traffic Separation Layers

- Procedural
- Air Traffic Management
- Cooperative Traffic Avoidance
- Non-cooperative Traffic Avoidance

Conflict Avoidance

Collision Avoidance

Sense and Avoid

NASA Access 5, Collision Avoidance: Functional Requirements For Step 1, 2006
Cooperative Traffic Avoidance

- Traffic Alert and Collision Avoidance System (TCAS)
- Automatic Dependent Surveillance – Broadcast (ADS-B)
• Primary cooperative collision avoidance system in the national airspace
• TCAS transmits and receives information via transponder
• Obtains information regarding relative location of other aircraft
• TCAS II provides resolution advisories if conflict exists
  – RA alerts pilot to conduct specified maneuver
ADS-B

- Uses satellite-based Global Positioning System to determine aircraft location
- Aircraft type, altitude, speed, flight number, and maneuvering status is broadcasted
- Aircraft and ground-based stations within 100-miles can obtain information
- Cockpit Display of Traffic Information increases situational awareness
Non-Cooperative Technologies

• Active technologies
  – RADAR
  – LASER
  – SONAR

• Passive technologies
  – Electro-optical
  – Infrared
  – Acoustic
Computational Issues

• Data fusion of multiple input sources at different data rates
  – TCAS and ADS-B
  – EO, IR, RADAR/LASER, acoustic
• Processing to determine hypothetical targets
  – Optical flow, etc.
• Distinct decision criteria for detect and sense, confirmation and monitoring of avoidance operations
• Determination of avoidance operations
Regulatory Review

- Materials reviewed
- Categories
- Collaborative layering expanded
- High-applicability sections
- FAR/AIM analysis and details
Materials Reviewed

• Part 91
• Aeronautical Information Manual
• Other FAA materials
  – Orders
  – Advisory Circulars
  – Pilot Handbook and Manuals
• Non FAA materials
Categories

- **Marshall categories**
  - Applies
  - Does not apply
  - Applies with interpretation
  - Applies with revision

- **Layering categories**
  - Human perception, cognition, execution
  - Machine detection
  - Subsidiary systems
  - Preventative procedures
## Collaborative Layering

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High-Applicability Sections (I)

- **Title 14 CFR, Sections**
  - 91.111 (Operation near other aircraft)
  - 91.113 (Right of way over land, See and avoid)
  - 91.115 (Right of way over water)

- **AIM**
  - 4-4-14 (Visual separation)
  - 4-4-15 (Clearing procedures)
  - 5-5-8 (See and avoid)
  - 8-1-6 (Vision in flight, illumination, scanning)
  - 8-1-8 (Judgment in collision avoidance)
High-Applicability Sections (II)

• ACs
  – 90-48c (Pilot’s role in collision avoidance)
  – 91-73c (Single pilot taxi operations)

• FAA Orders
  – 7610.4k (Military operations, includes requirement for equivalent level of safety in see and avoid)
  – 8130.34 (UAS airworthiness, includes requirement for visual observation)

• Interim Operational Approval Guidance 08-01
  – Includes requirement for visual observation
High-Applicability Sections (III)

• Other FAA documents:
  – FAA-H-8083-3A: Airplane Flying Handbook (See and avoid, runway incursion avoidance)
  – FAA-H-8083-25: Pilot’s Handbook of Aeronautical Knowledge (Ground ops, see and avoid)
  – FAA Pamphlet 8740-51: How to Avoid a Mid-Air Collision

• Non FAA documents:
  – RTCA DO-304: Guidance material…
  – Office of the Secretary of Defense
    • Roadmap
    • Airspace integration plan
**FAR/AIM Analysis**

| M-Moderate Application | HC: Human Cognition | SD: Subsidiary System |
| L-Low Application | HE: Human Execution | PP: Preventive Procedures |
| CA: Clearly Applies | MA: May Apply Through Interpretation | R: May Apply with Revision |

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<td>Restricted and prohibited areas</td>
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<td>Temporary flight restrictions in national disaster areas in the State of Hawaii</td>
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4.4.15. Use of Visual Clearing Procedures

a. Before Takeoff. Prior to taxiing onto a runway or landing area in preparation for takeoff, pilots should scan the approach areas for possible landing traffic and execute the appropriate clearing maneuvers to provide them a clear view of the approach areas.

b. Climbs and Descents. During climbs and descents in flight conditions which permit visual detection of other traffic, pilots should execute gentle banks, left and right at a frequency which permits continuous visual scanning of the airspace about them.

c. Straight and Level. Sustained periods of straight and level flight in conditions which permit visual detection of other traffic should be broken at intervals with appropriate clearing procedures to provide effective visual scanning.

d. Traffic Patterns. Entries into traffic patterns while descending create specific collision hazards and should be avoided.

e. Traffic at VOR Sites. All operators should emphasize the need for sustained vigilance in the vicinity of VORs and runway intersections due to the occurrence of traffic.

f. Training Operations. Operators of pilot training programs are urged to adopt the following practices:

1. Pilots undergoing flight instruction at all levels should be requested to verbalize clearing procedures (call out "clear" left, right, above, or below) to instill and sustain the habit of vigilance during maneuvering.

2. High-wing airplane. Momentarily raise the wing in the direction of the intended turn and look.

3. Low-wing airplane. Momentarily lower the wing in the direction of the intended turn and look.

4. Appropriate clearing procedures should precede the execution of all turns including flybys, lazy eights, stall, slow flight, climbs, straight and level, Carson, and other complex maneuvers.

APPLICABLE TO COLLISION AVOIDANCE: YES
APPLICABLE TO DSA: YES
COVERS: Recommends visual clearing maneuvers to maintain pilot SA and detect threats
NOTES: Certain flight situations, such as descents into traffic patterns, require extra precautions and pilot vigilance. Visual clearing procedures are executed prior to the execution of certain maneuvers. In some cases, these maneuvers may be different based on aircraft design characteristics. DSA platforms must take into account these same situations, and may actually lessen the need for visual clearing procedures depending on their design requirements. It is
Regulatory Gaps

- DS&A moves aspects of Part 91, related materials, from pilot certification to aircraft system certification.
- Manufacturers must demonstrate compliance or equivalent competencies for noted applicable sections of:
  - Part 91
  - AIM
  - ACs 90-48, 91-73
- Currently no FAA-endorsed performance measures.
Summary

• Literature review and technology survey
• Regulatory review
• Regulatory gap analysis
Questions?