HALE UAS IN THE NAS

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Equivalent Level of Safety
Requirements for Meeting an
Avoiding Sense & Avoid

Developing
ACCES 5: 2004 - Present

- Standards Development
- Flight Test Demonstrations
- Simulation Tools
- Safety Analysis
- Requirements Development

Radar
EO/IR
Cooperative
Flight Test Demonstrations
Sensor Concept Development
Sensor Requirements

ERAST: 1993 - 2003

NASDA Dryden Flight Research Center

UAS Collision Avoidance Initiatives
- MITE
- Federal Aviation Administration
- Lockheed Martin (Ft. Worth)
- Northrop Grumman
- NASA Dryden & Langley

Team Members:

"Unmanned Aircraft Systems" RTCA Special Committee 203
- Provide inputs to the FAA and
- Flight demonstration
  through analysis, simulation, and
  Aircraft Systems (UAS) validated
  requirements for Unmanned
  Collision Avoidance (CA)
  (ELOS) for Sense and Avoid.
- Define Equivalent Level of Safety

Work Package Objectives:

Collision Avoidance Work Package
ACCESS 5
Perform CA Flight Test
- CA Task 5

Develop CA Simulation Tool
- CA Task 4

Perform CA Safety Analyses
- CA Task 3

Develop CA Requirements
- CA Task 2

Define ELOS for See & Avoid
- CA Task 1

5 Major Task Areas
ACCESS 5 Collision Avoidance Work Package
Task 1: ELOS Definition Document

- Objective: To present a recommended approach for defining an equivalent level of safety, as it pertains to sense and avoid.

- Deliverable Content:

- Safety Findings:
  - FAA Order 8110.4C, Equivalent Level of Safety
  - 14 CFR 21.21(b), Certification Procedures
  - 14 CFR 91.13(b), Right of Way Rules

- Performance for Sense and Avoid ELOS
  - Recommended Definition and Measures of Performance
    - Statistical Approach
    - Rule Based Approach
  - Defining ELOS
  - Potential Approaches & Methodologies for

- Org Sky
Definition: "Equivalent level of safety to managed aircraft, see-and-avoid" is the...
(All previous revisions have included FAA input and review)

Status: Intended to release Revision 0.0 in February 2006

- Verticalization Method (Analysis, Inspection, Simulation/Modelling, Demo, Test)
  - Performance Trade-offs
  - Design Guidelines
- Performance Requirements
- Functional Requirements
- Functional Flow Block Diagram
- List of Collision Avoidance Functions
- Functional Analysis
- Operational Requirements
- Interfaces
- Subsystem Architecture
- National CA Subsystem Description

Deliverable Content:

Performance Requirements for HALF UAS.

Objective: To develop the collision avoidance operational, functional, and

Task 2: Develop Collision Avoidance Regime
Collision Avoidance Functions

Task 2: Develop Collision Avoidance Regimes
Task 2: Develop Collision Avoidance Regime

Functional Flow Block Diagram

- Evaluate Collision Potential
  - Collision Potential exists
  - No collision Potential exists

- Prioritize Collision Threats
  - Prioritized Threats
    - CA F4
    - CA F5

- Determine an Avoidance Maneuver
  - Maneuver Command
    - CA F6

- Execute Maneuver
  - CA F7

- UA scale change
- U/A scale changes
- OR

- Detect Traffic
  - CA F1

- Track Traffic
  - CA F2
  - Detection results
  - Detection results detected
  - No traffic detected

- Maneuver
  - Recommendation
  - Recommended Maneuver
All detected traffic:

- F1:1. Minimum Detection Time - The CAS shall detect traffic within its surveillance volume.
- F1.2. Detection Range - The CAS shall detect cooperative traffic at a range of at least XX nautical miles. (See Table F1.2)
- F1.3. Azimuth Field of Regard - The CAS shall detect cooperative traffic within an azimuth FOR of at least +/−1.0° referenced from the right path of the UA.
- F1.4. Elevation Field of Regard - The CAS shall detect cooperative traffic within an elevation FOR of at least +/−1.5° referenced from the right path of the UA.
- F1.5: Detection Probability - The CAS shall detect cooperative traffic in the surveillance volume at a rate that supports the track probability guidelines (see F2.3).
- F1.6: Detection Rate - The average CAS detection rate shall be equal to or greater than XX hertz. (See Table F1.6)
- F1.7: Detection Accuracy - The CAS shall detect cooperative traffic within an accuracy of TBD% of TBDD.
- F1.8: False Detection/nuisance - False detections shall account for less than TBD% of all detected traffic.
Status: Currently finalizing final report and lessons learned

- Maneuver times, etc.
- Effectiveness, detection accuracies, detection times, reaction times,
  supported requirements development in the areas of surveillance
- Performed multiple assessments using results from the CA simulation tool
- Developed surveillance error models for GPS/ADS-B
- Developed visual acquisition model based on Lincoln Lab's SEE1 model

Accomplishments:

\[
\text{Risk Ratio} = \frac{p(\text{collision, managed AC})}{p(\text{collision, UAS})}
\]

- Established equivalent level of safety to managed aircraft using event/fault trees
- Avoidance for UAS

Objective: To develop a method for evaluating the safety of collision

Task 3: Perform Safety Analysis
Simplified Fault Tree

1. Maneuver aircraft using see & avoid + CAS
2. Maneuver aircraft using see & avoid
3. UAS with Sense & Avoid
4. UAS with Sense & Avoid + CAS

Generate Event/Fault Tree for Collision Probability Estimation

Task 3: Perform Safety Analysis
Task 4: Develop CA Simulation Tool

Status: Currently analyzing flight test data.

- Sensitivity analyses performed
  - CCA Component Models
  - Flight Test Risk Reduction
- Validated Against the System Integration Lab (SIL)
- Improve probability of obtaining useful data
  - Flight Test Risk Reduction
- Developed Tech Demo Scenarios

Accomplishments:
- Encounter scenarios
- CA Equipment and Software
- Ownship Vehicle Dynamics
- Allows characterization of via simulation as well as support the CA Flight Test activities.

Objective: To assess the validity of the proposed CA Functional Requirements
Can run in both Fast Sim-Time & Soft Real-Time

* PC Portable (> 32 MB)
* Multiple Pilot Outputs Available
* Uses Microsoft Excel Input Dataset
* Capable of Batch Runs for Parametric Variations Studies
  * Upgrades (e.g. CA Sensors, Maneuver Advisory)
  * Blocks can be copied and/or swapped out for software
  * Modular Components

Geometry
  * Scripts Trim & Initialize Aircraft to any Encounter
  * Aircraft
    * Generic Aircraft Models Represent Any Fixed Wing
  * Multiple-Vehicle Simulation (4 Aircraft Max)

MATLAB®/Simulink® Simulation Environment

Simulation Features

Task 4: Develop CA Simulation Tool
Status: Successfully completed over 50 collision scenarios during the last two weeks of September 2005.

- Post-processed flight data and prepared for data analysis effort
- Developed CA scenarios and test cards
- Procured CA sensors and integrated them onto Proteus platform
- Developed CA software and human interface tool
- Developed CA algorithms
- Developed System Integration Lab (SIL)
- Developed Interface Control Document

Accomplishments:

Simulation tool

Objective: To collect cooperative collision avoidance data to validate the CA

Task 5: Perform CA Flight Test
### Task 5: Perform CA Flight Test

#### Test Scenarios

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</table>

**Collision geometries:**

- Test scenarios included multiple collision geometries:

- Head-on, descending
- Head-on, co-altitude
- Abeam, co-altitude
- Co-heading, tail-chasing, climbing
- Co-heading, tail-chasing, level
- Co-heading, tail-chasing, descending
- Co-heading, co-altitude
- Co-heading, overtaking
- Co-heading, overtaking, climbing
- Co-heading, overtaking, level
- Co-heading, overtaking, descending
Minimum Aviation System Performance Standards (MASPS)

- Support RTCA SC-203 on developing the Sense & Avoid
- Conduct Non-cooperative Simulation Runs and Flight Demos
- Perform Trade Studies and Concept Assessments
- Derive unique Non-cooperative performance requirements
- Begin Non-cooperative Collision Avoidance Activities

- Utilize the safety analysis results
- Utilize the validated CA Simulation tool
- Derive practical values/ranges for the TBDs in the performance
- Complete validating the CA Simulation tool
- Analysis and Flight Test Activities
- Document the results and lessons learned from the safety

Next Steps