Trustworthy Autonomy
Development & Flight Demonstration
Multi-Monitor Run Time Assurance Research Update

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Research Timeline

1980

Automated Maneuvering Attack System (AMAS)

AFTI/F-16

Advanced Fighter Technology Integration

AFTI & ACAT/F-16

Automated Collision Avoidance Technology

2000

Dedicated Safety Work for Fighters

Automated Collision Avoidance

2010

Ground Collision Avoidance

2017

Platform Diversity

SUAV/iGCAS/SR22

Improved Collision Avoidance System

Air

Integrated

Quad-Rotor

Transition

Small UAS

GA
Ground Collision Avoidance System (GCAS)

Common Functional Architecture

Predict Escape Trajectories
- Evasion Types
- Maneuvering Capability
- Evasion Trajectory Estimations
- Associated Uncertainties

Predict Future Threat State
- Scan/Track Pertinent Threat
- Simplify Threat Profile
- Associated Uncertainties

Determine Need to Evade & Threat Lethality
- Minimum Approach
- Integrity Check
- Time to Evade
- Command Evasion

Evade
- Integrity Check
- Execute
- Evasion

Pilot Controls
- Mode Selection
- Interface

Sense Own-State & Atmospherics
- Sufficient to support trajectory estimation

Sense Collision Threat
- Terrain
- Aircraft
- Weather
- Missiles

Common Interface

Autopilot Coupler

Alert
- Record
- Recall

Notify

Sufficient to support trajectory estimation

Minimum Approach

Time to Evade

Command Evasion

Mode Selection

Interface

Alert

Record

Recall
Avoid Collisions
Do Not Impede the Pilot
Flight 18 event 6, 45 kts, 100' buffer

sUAV
Automatic Air Collision Avoidance System (Auto ACAS)
Automatic Integrated Collision Avoidance System (Auto ICAS) - Air & Ground Multi-Ship
The Challenge of Autonomy

- Verification & Certification of a Complex System
- A Possible Solution – Run-Time Assurance (RTA)
Ground Collision Avoidance System (GCAS)

- Predict Escape Trajectories
- Predict Future Threat State
- Determine Need to Evade & Threat Lethality
- Evade
- Notify

- Evasion Types
- Maneuvering Capability
- Evasion Trajectory Estimations
- Associated Uncertainties

- Minimum Approach
- Integrity Check
- Time to Evade
- Command Evasion

- Sense Own-State & Atmospherics
  - Sufficient to support trajectory estimation
- Sense Collision Threat
  - Terrain
  - Aircraft
  - Weather
  - Missiles

- Common Interface
- Autopilot Coupler
- Pilot Controls
  - Mode Selection
  - Interface
- Notify
  - Alert
  - Record
  - Recall

- Trajectory Predictions

- Scan/Track Pertinent Threat
- Simplify Threat Profile
- Associated Uncertainties

- Command Evasion
- Execute
Informing the Standards Community

Research findings vetted with ASTM International through Working Group 53403 (WK53403)

- WK53403 Goal: Develop a standard practice that safely bounds the flight behavior of autonomous UAS
- Involvement originated from AFRC collaboration with FAA regarding Auto GCAS and integrity management work on early autonomy concepts
- Published Industry Standard Practice in Oct 2017
MM-RTA Framework

This Work is Unique to AFRC
Objective

- Develop research findings to inform standards development for certifiable autonomy
- Evaluate the dynamic interaction of an MM-RTA with no integration between monitors

Expandable Variable-Autonomy Architecture (EVAA)

- Stretching the paradigm of autonomy
- Deterministic Rulesets Bounding Autonomous Behavior
  - Functionally Partitioned Monitors
  - Risk-Based Decision Making
- A process enabling certification
  - Software Architecture/Framework
  - Test Approach
- Scalable autonomy
  - Pilot-in-the-Loop to “Fully Autonomous”

Low Altitude Small UAS Test Ranges (LASUTR)

- A tool for certification
- High-risk integrated research
**MM-RTA: Key EVAA Accomplishments**

- **Aircraft/Testbed Modifications**
  - Research Processor Integrated Jan 17
  - Sound & Lighting System Installed May 17

- **Research System**
  - Functional Requirements Completed Nov 16
  - Design Completed Feb 17
  - Coding Completed Mar 17
  - Patent for GCAS Monitor Issued May 17

- **V&V**
  - Hardware in the Loop Sim Completed Mar 17
  - Integrated V&V Completed May 17

- **Flight Test**
  - Aircraft Characterization Test Completed Mar 17
  - EVAA Flight Test Began May 17

- **Reporting**
  - Update to FAA & ASTM May 17
Flight Test Accomplishments

EVAA Command Delegation with Conflicting Multi-Monitor Resolution

- Waypoint Following Control
- GeoFence Control
- Ground Collision Avoidance Control
- 600' Tall Obstacle
- No-Fly Zone
EVAA Phase 2
## EVAA Phase 2 Development
**OSD’s JCTD Resilient Autonomy Project**

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**OSD Resilient Autonomy**

**GCS Features**
- Mission Plan Verification
- Situational Awareness Displays

**EVAA**
- Certifiable Autonomy
- Safe Pilotless BLOS Ops
- Risk-Based Decision Logic
- Easily Tailored to any Vehicle & Mission

**HQ-90**
- Cellular or Other Link

**Non-Safety Critical Link**
- Visual-Nav System – transient operation in GPS denied or degraded environment

**Automatic Well-Clear & Air Collision-Avoidance**
- Automatic Airspace Boundaries
- Safe-Ditch Contingency Management

**Automatic Ground & Obstacle Collision-Avoidance**

**Terrain**
• 103 Lbs. Max Gross Takeoff Weight
• 14’ 8” Wingspan
• 20 to 30 Pound Payload
• 12 to 24 hours Endurance

HQ-90 Testbed
DAA Approach

Separation Assurance
Behavioral

Air Collision Avoidance
Loss of life

TCAS 2

Ground Collision Avoidance
Loss of property
Questions