AUTOMATIC COLLISION AVOIDANCE TECHNOLOGY (ACAT)

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Automatic Collision Avoidance

- **Automatic Ground Collision Avoidance (AGCAS)**
  - Uses Digital Terrain Elevation Data (DTED) for mapping functions
  - Uses Navigation data to place aircraft on map
  - Scans DTED in front of and around aircraft
  - Uses future aircraft trajectory (5g) to provide automatic flyup maneuver when required

- **Automatic Air Collision Avoidance (AACAS)**
  - Uses data link to determine position and closing rate
  - Contains several canned maneuvers to avoid collision
  - Automatic maneuvers occur at last instant and both aircraft maneuver when using data link
  - System can use sensor in place of data link
Auto GCAS

• Auto-GCAS recovers an aircraft before it penetrates a minimum clearance distance from the terrain
  - Projects predicted trajectory over a digital terrain map
  - Warns pilot of impending collision
  - Automatically performs recovery at the last instant if the pilot takes no action
- Features
  - Recovery model easily tailored to different aircraft
  - Embedded integrity monitoring prevents erroneous activation
Development History

• Auto GCAS Development
  – Initial Research & Development – 1984
    • Limited Envelope
    • Flat Earth
  – Follow-on Research & Development – 1990
    • Expanded Envelope
    • Digital Terrain Database
    • Full Envelope
  – LFT&E GLOC Demonstration – 1999
  – ACC Evaluation – 2000

– Over 2200 Auto-Recoveries in Flight
  • Pilot Activated, SWIM, GLOC, DTS, Flat Earth
– Over 700 DTS Based Auto-Recoveries
– Thousands of Simulation Runs
– Over 30 Evaluation Pilots
– Prevented the Loss of the AFTI/F-16 in 1995
Auto ACAS prevents penetration of a clearance distance from other aircraft
- Evaluates escape trajectories against other aircraft
  - Does not impede tight formation
  - Uses flight rules such as “UAVs always evade first”
- Initiates the escape maneuver at last instant
- Features
  - Can utilize many sensors depending on requirements
  - Embedded integrity monitoring prevents erroneous activation
• Auto ACAS Development
  – Auto GCAS Follow-On – 1999
  – Concept Study – 2000
    • Concept Study
  – Algorithm Development – 2001
    • Focus on Vehicle Control not Sensors
      – Data Link as Primary Sensor
    • Develop & Flight Demonstrate Technology
      – 3 Piloted Fighter Aircraft
      – Surrogate UAV
      – Cooperative & Non-Cooperative Sensors (UAV applications.)
      – Demonstration of Automatic Collision Avoidance
      – Buildup for Unmanned Testing
    • Identify Sensor & System Requirements
  – Nuisance Criteria Testing – TBD
  – Final Development Testing – TBD
  – Hosted in 2 Different Architectures
  – 416 Evasions Initiated in Flight
  – Thousands of Simulation Runs
  – 8 Evaluation Pilots
• Substantial reductions in F/A CFIT and MIDAIR mishap rates require automatic intervention
• ACAT are feasible & have been proven effective
• If implemented on F-16, F/A-18, F-22, and F-35, ACAT could save over the estimated service lives
  – LIVES 78 pilots
  – ASSETS $6.7B
  – CAPABILITY 136 aircraft

136 aircraft ~ 8 squadrons
• Auto GCAS
  – Robust & Ready for Production Integration
  – Would Prevent Most CFIT Mishaps in the Fighter Community
    • Inclusion of GPS Navigation Technologies
    • Inclusion of Latest Digital Terrain Data
  – Should be Converted to a More Modular Architecture

• Auto ACAS
  – Promising Technology
    • Platform Specific Requirements & Development Needed
  – Could Prevent Many MAC Mishaps in the Fighter Community
    • Affordable Sensors Appear to be the Primary Limit to Performance
    • Most mishaps occur during training and data link operation can be provided
  – Should be Integrated with Auto GCAS

• Automatic Collision Avoidance Requirements
  – Provide means to ease transition to other air vehicles including UAVs
Automatic Collision Avoidance Technology

Flight Test Development & Evaluation

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Auto GCAS

Flight Test

Development & Evaluation
Avoid Impeding Operations

Concept

- Nuisance Activations
  - Definition
    - An Unwarranted Recovery as Judged by a Situationaly aware Pilot

- Nuisance Factors
  - In command

A Recovery Must be Both Aggressive and Timely

Aggressive but not timely

Timely but not aggressive

Recovery Initiation
Avoid Impeding Operations
An Aggressive Recovery

- Nuisance Activations
  - Definition
    - An Unwarranted Recovery as Judged by a situationally aware pilot
  - Nuisance Factors
    - A Recovery Must be Both Aggressive and Timely
Avoid Impeding Operations
A Timely Recovery

The Recovery Initiation Must be Timely

- Measure of Performance
  - Time Available
The Recovery Initiation Must be Timely

- Measure of Performance
  - Time Available

Too Late

Time Available

Delayed Recovery Profile
The Recovery Initiation Must be Timely

- **Performance**
  - **Objective** \( \leq 1.0 \text{ sec. Time Available} \)
  - **Threshold** \( \leq 1.5 \text{ sec. Time Available} \)

\[
T_o = \frac{h_{\text{min}}}{(V_{\text{init}} + T_o + a_{\text{init}}) + V_{\text{init}} \cdot \sin(y_{\text{min}})}
\]

Where:
- \( h_{\text{min}} \)
- \( V_{\text{init}} \): Initial Velocity
- \( T_o \): Time Available
- \( a_{\text{init}} \): Initial Acceleration
- \( y_{\text{min}} \): Minimum Approach Angle

**Nuisance Criteria**

**Too Soon**
- Recovery Initiation

**Too Late**
- Time Available

**Too Soon**
- Time Available

**Too Late**
- Recovery Initiation
### Auto GCAS Results

**30 Missions**  **38.3 Flight Hours**

- **Excellent Ground Collision Prevention**
  - Successful in all **316** Cases Tested
  - **81** Successful Cases Run from Crash Data Recorder

- **Pressed Bomb Attack**
- **Pressed Strafing Run**
- **SDO into Mountain**
- **GLOC Supersonic**
- **NVG Disorientation**
- **Gear Up Landing**

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<th>Mishap Type</th>
<th>Number of Times Flown</th>
<th>Dive Angle (deg)</th>
<th>Bank Angle (deg)</th>
<th>True Airspeed (kts)</th>
<th>Load Factor (g)</th>
<th>Average Altitude Pad (ft)</th>
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Auto GCAS Results

- **Nuisance Free**
  - Initiates Recovery After Pilot Would
  - Nominally 0.25 Seconds Prior to Required Time
  - Pilot Nuisance Threshold is 1.2 Seconds
  - Nuisance Free Flight at 30 Feet Possible
- **SRTM Shuttle Digital Terrain Data**
Auto ACAS Results

- Successful Proof of Concept
- Collision Avoidance
  - Head-On
  - Maneuvering Flight
  - Multi-Ship
  - Non-Cooperative (viewed from intruder)
  - Overtaking
- Nuisance Evaluation Incomplete
  - Initiates Recovery After Pilot Would
    - Wingman Work Not Completed
- Follow-On Work Needed
  - Apply Vehicle Specific Requirements
  - Integrate with Vehicle Specific Sensors
  - Complete Nuisance Evaluation
  - Integrate with Auto GCAS

325 - 580 Knots Calibrated Airspeed

Timeliness (sec)

Flight Test (Initial Corrupted Software)
Simulation (Initial Corrupted Software)
Simulation (Final Corrected Software)
Top-Level Requirements for Ground Collision Avoidance

1. Do not Cause a Mishap
   - System Wide Integrity Management
     - Do not fly lead into wingman
     - Do not exceed operating limits

2. Avoid Impeding Operations
   - Avoid Unwarranted (nuisance) Activations

3. Avoid Collisions
   - CFIT

4. Minimize Integration Effort (FRRP Requirement)
   - For F-16, F-35 & others
   - Interface definitions
Minimize Integration Effort

• Concept
  – Create a plug & play software capability
  – Ensure interoperability between all platforms

• Requirements
  – Create a modular functionally partitioned software architecture with clear interface requirements
  – Performance: Leave behind a regression level capability for future platform integration
  – Mid-Level Requirement Examples
    a) Establish a common core modular software architecture
    b) Establish the interfaces between the modules
    c) Document the process for tailoring the modules to specific platform requirements
Questions