<table>
<thead>
<tr>
<th>1. REPORT DATE</th>
<th>2. REPORT TYPE</th>
<th>3. DATES COVERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 SEP 2003</td>
<td>N/A</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. TITLE AND SUBTITLE</th>
<th>5a. CONTRACT NUMBER</th>
<th>5b. GRANT NUMBER</th>
<th>5c. PROGRAM ELEMENT NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic Air Collision Avoidance Air Collision Avoidance System Auto-ACAS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. AUTHOR(S)</th>
<th>5d. PROJECT NUMBER</th>
<th>5e. TASK NUMBER</th>
<th>5f. WORK UNIT NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</th>
<th>8. PERFORMING ORGANIZATION REPORT NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryden Flight Research Center - NASA USA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</th>
<th>10. SPONSOR/MONITOR’S ACRONYM(S)</th>
<th>11. SPONSOR/MONITOR’S REPORT NUMBER(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>12. DISTRIBUTION/AVAILABILITY STATEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved for public release, distribution unlimited</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13. SUPPLEMENTARY NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>See also ADM001676, UAV 2002 Conference &amp; Exhibition., The original document contains color images.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>14. ABSTRACT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>15. SUBJECT TERMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>16. SECURITY CLASSIFICATION OF:</th>
<th>17. LIMITATION OF ABSTRACT</th>
<th>18. NUMBER OF PAGES</th>
<th>19a. NAME OF RESPONSIBLE PERSON</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. REPORT</td>
<td>unclassified</td>
<td>UU</td>
<td></td>
</tr>
<tr>
<td>b. ABSTRACT</td>
<td>unclassified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. THIS PAGE</td>
<td>unclassified</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. LIMITATION OF ABSTRACT</td>
<td>UU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. NUMBER OF PAGES</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19a. NAME OF RESPONSIBLE PERSON</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
Overview
Auto-ACAS Provides the “Avoidance” for See and Avoid

• A Common Architecture for UAVs & Piloted Aircraft

• Industry Advancement
  – Address UAV Equivalency for See & Avoid in U.S. Airspace
  – Imbedded Flight Rules for Avoidance Onus
  – Enable UAV Swarming (Multiple UAVs in Close Proximity)
  – Prevent Midair Mishaps in Piloted Aircraft (JAS-39 Gripen)

• Architecture
  – Algorithm
    • Collision Prediction
    • Best Escape Determination
  – Sensor Integration
    • Cooperative – Datalink/Transponder
    • Non-Cooperative – Optical/IR
    • Fusion
Goals & Objectives

• Goals
  – Allow Safe Operation of Multiple UAVs and Manned Aircraft in Close Proximity
  – Military Application with Commercial Sector Potential
  – Define a Design Process/System Architecture
    • Broad Application
    • Ease Adaptation to Any Platform
  – Independent from TCAS
    • Initiates with feet/seconds of separation not miles/minutes
    • Higher level of redundancy than TCAS

• Objectives
  – Develop and Demonstrate a “Nuisance Free” System
  – Demonstrate Collision Avoidance
Auto-ACAS Design

• **Algorithm for Avoidance Decision**
  – Predicts Recovery Flight Path
  – Evaluates Other Neighboring Aircraft Flight Paths
  – Determines Minimum Approach of “Best Escape” Maneuver

• **Auto-Pilot Executing Avoidance Maneuver**
  – Aggressive Maneuver Relative to Aircraft Limits
    • Roll to Best Escape Bank Angle
    • Pull to 5g/AOA-limits
  – Disengage As Soon As Flight Paths De-Conflict

• **Technology Heritage**
  – Automatic Ground Collision Avoidance (Auto-GCAS)
  – Sensor Fusion/System Wide Integrity Management
  – Aircraft Response Model
  – Auto-Pilot Architecture
  – Lower Technical Risk
Auto-ACAS
Algorithm Architecture

- Aircraft Response Model
- Track Files & Conflict Determination
- Collision Estimation
- Predicted Trajectory
- 3-D Intersection Profile
- Time-to-Escape
- Flight Control Autopilot

- Navigation Solution
- Neighboring Aircraft Location/Intent
- Cooperative & Non-Cooperative Sensors

Aircraft State

Dryden Flight Research Center

AutoACAS
Auto-ACAS Operation

Overtaking Opponent

Scissors Maneuver
Heritage
Auto-GCAS History

Nuisance Potential

- Flight Test
  - Began in 1984
  - Over 2200 Auto-Recoveries in Flight
  - Over 700 DTS Based Auto-Recoveries
  - 30+ Evaluation Pilots
  - Most Likely Prevented Loss of the AFTI Aircraft
Project Description
Program Plan

• **Phase 1** (May 00 to Mar 01)
  – Concept Study

• **Phase 2** (3Qtr FY01 to 4Qtr FY03)
  – Focus on Vehicle Control not Sensors
    • Data Link is Primary Sensor
  – Develop & Flight Demonstrate Technology
    • 2 Piloted Fighter Aircraft
    • Flight Demonstration of Minimum Clearance Penetration Prevention
    • Buildup for Unmanned Testing
    • Demonstrate UAV Avoidance of Manned Aircraft
  – Identify Sensor & System Requirements

• **Follow-On Phase : Full Integration**
  – UAV/ROA Flight Test
  – See-and-Avoid Sensor Integration
  – Auto Ground Collision Avoidance Integration