Overview

• Goals/Objectives
• Participants
• Test Configurations
  – Config 1: Scripted Encounters
  – Config 2: Full Mission
• Future Testing/Schedule
Flight Test 3 Overview

Top Level Research Goals:

– Validate results previously collected during project simulations with live data
  • Sensor performance, uncertainty
  • State data uncertainty
  • Wind compensation

– Evaluate TCAS II/SS interoperability

– Test fully integrated system in a relevant live test environment
  • HSI Proof of Concept GCS and pilot guidance displays
  • CNPC performance

– Inform final DAA and C2 MOPS

– Reduce risk for Flight Test Series 4
  • More complex multi-intruder scenarios

Full Mission Scenario Evaluations

• Live Ownship (Surrogate UA)
• Live and Virtual Intruders
• Representative Operational Mission
• UAS Pilot Participants using RGCS
Integration Roles & Responsibilities Summary

**NASA – AFRC (UAS-NAS / IT&E)**
- Provide RGCS Infrastructure
- Provide LVC-DE Infrastructure
- Provide Intruder Aircraft (T-34 &/or King Air)
- Provide Ownship Aircraft (Ikhana)
- Test Conductor Station (SAF)

**NASA – ARC (UAS-NAS / IT&E)**
- Provide HLA infrastructure
- Provide Pseudo pilot & Controller workstations (MACS)
- Develop traffic scenarios

**NASA – GRC (UAS-NAS / C2)**
- Provide UA Surrogate Aircraft (T-34)
- Provide ownership and intruder (S3)
- Provide CNPC infrastructure

**Honeywell**
- Provide instrumented TCAS II equipped intruder aircraft

**NASA - ARC (UAS-NAS / HSI)**
- Provide VSCS (form AFRL) and display definition

**NASA - ARC (UAS-NAS / SSI)**
- Provide JADEM (Autoresolver) SAA
- Provide Uncertainty model
- Devise Encounter matrix

**NASA - LaRC (UAS-NAS / SSI)**
- Provide DAIDALUS (Stratway+) SAA
- Devise Encounter matrix

**GA-ASI**
- Provide proof of concept SAA system (EDM DRR, SAAP, etc.)
- CPDS Display and IO Server
Research Objectives

- Validate CPA prediction accuracy in realistic flight conditions
- Evaluate TCAS/Self-separation interoperability
  - ownship CA/SS interaction
  - compatibility with Intruder’s TCAS
- Validate Self-separation trajectory model for ownship maneuvers
- Qualitatively evaluate pilot impression of Self-separation advisories
- Validate data fusion/best source selection model
- Validate sensor and tracking models used for preliminary MOPS
- Evaluate TCAS II installed performance on a UAS
- Inform final MOPS
Flight Test 3 Scripted Encounters

Test Requirements

• Test Requirements
  • Live Ownship (OS)
    - Low Speed OS – DRR, ADS-B, and TCAS Sensors, Sensor Fusion
      » Higher Priority Test Points
      » Ikhana
        • EDM DRR (±110° az and ±15° elev) non-coop sensor
        • ADS-B coop sensor
        • TCAS II v7.1 coop sensor
        • HON STM (sensor fusion/tracker)
    - High Speed OS – ADS-B coop sensor
      » Lower Priority Test Points
      » 250 KGS capable
      » CNPC equipped
      » S-3B-equipped with ADS-B only
        • Onboard pilot will maneuver based on onboard display cues of commands uplinked from RGCS pilot via CNPC link
  • Live Intruder(s)
    - ADS-B equipped
    - TCAS II Instrumentation for interoperability test
    - High speed (250 KGS capable)
    - Multiple – 2
Test Configuration #1a: Scripted Encounters (Ikhana)

Live Ownership

Ikhana Data Link
- C2
- Voice
- Health & Status
- Video
- Traffic (Radar, ADS-B, TCAS)

Displays of Proximal Traffic
SAA/DAA Algorithms

Stratway+/DAIDALUS
CPDS
Autoresolver

ADS-B Out

Live Intruder(s)
- ADS-B
- TCAS II
- High speed
Flight Test 3 Scripted Encounters

Test Requirements

• Test Requirements
  • Live Ownship (OS)
    – Low Speed OS – DRR, ADS-B, and TCAS Sensors, Sensor Fusion
      » Higher Priority Test Points
      » Ikhana
        • EDM DRR (±110° az and ±15° elev) non-coop sensor
        • ADS-B coop sensor
        • TCAS II v7.1 coop sensor
        • HON STM (sensor fusion/tracker)
    – High Speed OS – ADS-B coop sensor
      » Lower Priority Test Points
      » 250 KGS capable
      » CNPC equipped
      » S-3B-equipped with ADS-B only
        • Onboard pilot will maneuver based on onboard display cues of commands uplinked from RGCS pilot via CNPC link
  • Live Intruder(s)
    – ADS-B equipped
    – TCAS II Instrumentation for interoperability test
    – High speed (250 KGS capable)
    – Multiple – 2
Test Configuration #1b: Scripted Encounters (S-3B)

Live Ownership
- GRC S-3B

CNPC
- Data Link
  - C2
  - Voice
  - H&S
  - Traffic

ADS-B Out
- Live Intruders
  - ADS-B
  - TCAS II
  - High speed

Displays of Proximal Traffic
SAA/DAA Algorithms

Research GCS

Autoresolver
# FT-3 Aircraft Equipment Requirements

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Responsibility</th>
<th>EDM DRR</th>
<th>ADS-B</th>
<th>GPS</th>
<th>TCAS-II</th>
<th>Config 1A</th>
<th>Config 1B</th>
<th>Config 2</th>
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<tbody>
<tr>
<td>Ownship</td>
<td>NASA AFRRC’s Ikhana UAS</td>
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<td>Intruder</td>
<td>Ownship or Intruder UAS Surrogate NASA GRC, T-34 Mentor</td>
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<td>✔️</td>
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<tr>
<td>Intruder</td>
<td>Second / Backup Intruder NASA AFRC T-34</td>
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</table>
Flight Test 3 – Test Area
• Pairwise, low speed–low speed encounters that requires Ikhana ownship versus a low speed intruder aircraft (C90 or T-34C) [Configuration 1A];
• Pairwise, low speed–high speed encounters that requires Ikhana ownship versus S-3B [Configuration 1A];
• Pairwise, low speed–low/high speed encounters that requires Ikhana ownship versus multi-intruder aircraft (one low speed intruder (T-34C or C90) and one high speed intruder (S-3B) [Configuration 1A];
• Pairwise, high speed–low speed encounters that requires S-3B ownship versus a low speed intruder (T-34C or C90) [Configuration 1B].
### FT3 Sortie flow

<table>
<thead>
<tr>
<th>JADEM</th>
<th>CPDS</th>
<th>Stratway+</th>
<th>High Speed</th>
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<td>10 - L13A</td>
<td>15 - L15A</td>
<td>137 - L53C</td>
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<tr>
<td>19 - L52A</td>
<td>32 - L13C</td>
<td>37 - L15C</td>
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<td>20 - L32A</td>
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<td>57 - L15D</td>
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<td>29 - L12C</td>
<td>16 - L16A</td>
<td>11 - L13A</td>
<td>146 - L54D</td>
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<tr>
<td>30 - L52C</td>
<td>38 - L16C</td>
<td>33 - L13C</td>
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<td>31 - L32C</td>
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<tr>
<td>49 - L12D</td>
<td>14 - L15A</td>
<td>17 - L16A</td>
<td>151 - L56F</td>
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<tr>
<td>50 - L52D</td>
<td>36 - L15C</td>
<td>39 - L16C</td>
<td>151 - L56F</td>
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<td>56 - L15D</td>
<td>59 - L16D</td>
<td>159 - L57D</td>
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<td>15 - L15A</td>
<td>18 - L12A</td>
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<td>66 - L56C</td>
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<td>12 - L14A</td>
<td>11 - L13A</td>
<td>29 - L12C</td>
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<td>60 - L12E</td>
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<td>55 - L14D</td>
<td>56 - L15D</td>
<td>58 - L16D</td>
<td>121 - L32G</td>
</tr>
</tbody>
</table>

### Total Sorties – 11
- 105 JADEM
- 80 Stratway+
- 83 CPDS
- 14 - Config 1b JADEM

### Priority 1
- JADEM Only: Autoresolver 1
- Display Change: CPDS

### Priority 2
- JADEM Only: Autoresolver 2
- Display Change: Stratway+

### Priority 3
- XML File Change

### Priority 4

---

**Sortie length concerns**

- Margin

---

**Priority 1**

- Autoresolver 1
- Display Change: CPDS

**Priority 2**

- Autoresolver 2
- Display Change: Stratway+

**Priority 3**

- XML File Change

**Priority 4**

---

### 7 July 2015

- 105 JADEM
- 80 Stratway+
- 83 CPDS
- 14 - Config 1b JADEM
GA-ASI Radar Encounters (Ground Clutter)

<table>
<thead>
<tr>
<th>Flight 5 26-Jun</th>
<th>Flight 9 20-Jul</th>
</tr>
</thead>
<tbody>
<tr>
<td>108 - L12A (2)</td>
<td>110 - L12A (4)</td>
</tr>
<tr>
<td>107 - L12A (1)</td>
<td>109 - L12A (3)</td>
</tr>
<tr>
<td>112 - L11A (2)</td>
<td>114 - L11A (4)</td>
</tr>
<tr>
<td>111 - L11A (1)</td>
<td>113 - L11A (3)</td>
</tr>
</tbody>
</table>

- **Initial Point (IP)**
- **Maneuver Point (MP)**
- **Closest Point of Approach (CPA)**
- **Lateral Offset = 0.5 nmi**
- **SS Alerting Boundary=0.75 nmi**
  - **Minimum Altitude Offset ≥ 1000 ft**

*Flight 5: 26-Jun
Flight 9: 20-Jul
L12 Series: Level/H-Level
L11 Series: H-Level/Level*
**Card#**

| L56A | Ownship |

**VISUAL ID REQUIRED WITHIN 1NM**

1. TC announces COMEX time.
2. Announce "<Callsign>, IP Inbound, altitude & special procedure review" crossing IP.
3. Aircraft on condition at least 2 minutes prior to CPA.
4. TC calls "terminate" when run complete.
5. TC announces next Card Number.

**LOST LINK MISSION:**

LL-CP7 (WP7)

**DECONFLICTION ALT:**

13000

**ABORT PROCEDURE**

13000

**COMEX TIME:**

<table>
<thead>
<tr>
<th>PT</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>ALT/ V/V</th>
<th>DIST/MC</th>
<th>G/S</th>
<th>TIME HACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP</td>
<td>N34° 57.09'</td>
<td>W117° 18.47'</td>
<td>15500</td>
<td>7.5</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N34° 57' 05.4&quot;</td>
<td>W117° 18' 28.2&quot;</td>
<td>-1000</td>
<td>258</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPA</td>
<td>N34° 57.09'</td>
<td>W117° 27.62'</td>
<td>12500</td>
<td>0</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N34° 57' 05.4&quot;</td>
<td>W117° 27' 37.2&quot;</td>
<td>0</td>
<td>258</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DECONFLICTION ALT:**

12000

**ABORT PROCEDURE**

11500

**COMEX TIME:**

<table>
<thead>
<tr>
<th>PT</th>
<th>LATITUDE</th>
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<th>TIME HACK</th>
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</thead>
<tbody>
<tr>
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<td>W117° 38.60'</td>
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<td>9.0</td>
<td>180</td>
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<td></td>
<td>N34° 56' 35.8&quot;</td>
<td>W117° 38' 36.0&quot;</td>
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<td>78</td>
<td></td>
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<tr>
<td>CPA</td>
<td>N34° 56.60'</td>
<td>W117° 27.62'</td>
<td>12000</td>
<td>0</td>
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<td>W117° 27' 37.2&quot;</td>
<td>0</td>
<td>78</td>
<td></td>
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</tr>
</tbody>
</table>
• **T-1 (Noon-ish):** Day before detailed brief
  – To protect crew rest for back-to-back flights
• **T-0 (0415):** All crew pre-flight delta brief
• **(0430):** Individual aircraft crew brief, as required
• Each aircraft take-off to arrive within R2515 at required time
  – 0600 for Ikhana
• Ikhana and single manned aircraft perform altitude calibration
  – If multiple intruders, manned and manned aircraft perform altitude calibration
• Prior to each scenario
  – Verify scenario number
  – Verify LL Mission and Initial Way Point and Altitude Loaded (Ikhana)
  – Verify FT-3 software mode (Ikhana)
  – Verify expected FT-3/Ikhana behavior
  – Review scenario abort procedures
  – Verify Nav error
  – Verify appropriate display is being displayed to pilots (Ikhana)
SAF UAS-NAS TC/TD Workstation

- Provides ‘full picture’ to Test Conductor & Test Director
- Enhancements include:
  - Large screen displays (32”)
  - SS display repeater
  - Common architecture
Video Distribution System

For FT3, VSCS, CPDS, and Ikhana Nose Camera Video Feeds will be sent to the SAF UAS-NAS TC/TD Workstation.
FT3: Configuration 1A (Scripted-Low Speed Ownship) – Ikhana
FT3: Configuration 1B (Pairwise-High Speed Ownship) – S-3B

Live Ownship

Live Intruder(s)

[Diagram of FT3 configuration with various elements such as LVC Core, LVC Participants, Live Ownership, Live Intruders, CNPC Data Link, ADS-B Data, ASR Data, AFTC/Bldg.1440, AFRC/AFRC Alliance Link Bldg. 4800, MSET Multi-Source Correlate, SAA Proc, JADEM, Voice Comm System (DICES III), CPDS, ADRS, Stratway+, ZEUS Display, LVC Gateway, Pilot Station, Voice Comm, Eye Tracker, VSM, Voice I/O, LVC I/O, STANAG I/O, LVC Data Logger, AFRC LVC LAB, AFRC RGCS LAB, AFRC SAF, Voice Comm System (DICES III), Test Director/Conductor Quick Look Display, Test Director/Conductor Displays (ZEUS/TECCS), Test Director/Conductor Display, Video, OS, Health & Status, Intruders SS Alerts, Omni Bands, Stratway+ Bands, Alerts, OS, Live Intruder(s), Intruders SS Stratway+ Bands, Alerts, OS, Intruders SS Alerts, Omni Bands, OS, Live Intruder(s), Trial Planning, Voice Comm System (DICES III), Note: Voice Comm Details are Presented on Separate Charts.]
Test Configuration #2: Full Mission

Oakland Center

Live Ownship
- T-34C

Live Intruders
- ADS-B
- TCAS II Instm
- High speed

CNPC Data Link
- C2
- Voice
- Health & Status
- Video
- Traffic (ADS-B and Radar)

Virtual/Constructive Intruders

Virtual ATC
(Pseudo Pilots)

Virtual Intruder(s)

UAS Pilot as Subject

Research GCS

Display of JADEM
Self Separation Alerts

VPN
Distributed Environment/Connectivity

ADS-B Out

Multi-Aircraft Control System
Research Objectives

- Evaluate the integrated Self Separation algorithms, GCS Traffic displays, and prototype CNPC systems in a realistic environment
- Evaluate UAS pilots’ ability to maintain well clear
- Gather objective and subjective pilot data to evaluate/validate Well-clear definition
- Analyze the performance of 4th generation CNPC systems
**Flight Test 3 Full Mission Scenario Evaluations**

**Test Requirements**

- **Test Requirements**
  - **Fire Line Route at 12k-15k MSL**
  - **Six encounters require maneuvering to prevent WCV; four with live intruders**
  - **Live Ownship**
    - T-34C UAS Surrogate controlled from the RGCS
      - CNPC equipped
      - ADS-B coop sensor
      - Lateral maneuvering (autopilot) via heading commands uplinked from the RGCS pilot
      - Vertical maneuvering via display cues of altitude commands uplinked from RGCS pilot
  - **Coop Live Intruder(s)**
    - ADS-B equipped
    - Multiple – 2
  - **Non-Coop Intruders will be simulated using DRR Rng, Az, and Elev models/filters in JADEM**
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<td>UAS Surrogate NASA GRC, T-34 Mentor</td>
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<td>Second / Backup Intruder</td>
<td>NASA AFRRC T-34</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Second / Backup Intruder</td>
<td>NASA AFRRC King Air</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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</tr>
</tbody>
</table>
CNPC Ground Stations

- CNPC ground station scheduled for installation the week of 7/6/15.
- Flight testing of RF coverage from the ground station is currently scheduled for 7/14/15

Modified route to be in more stable RF region. Holding pattern around WP1’ will enable good RF connectivity before start of data collection

Predicted RF coverage at 14k ft MSL

- To stand up a tower at ATF2.
Full Mission Flight Airspace

- Full Mission flown entirely within R-2508 Complex
- Airspace includes: R-2515 + Porterville, Bakersfield & Isabella MOAs
- Altitudes 12-15K ft MSL
- 40 min mission (T-34C ownship aircraft)
- 2-live intruders (King Air & T-34) performing 2 runs each
- 5-virtual intruders performing 1 run each
Project Simulation/Flight Activities

- FY12: UAS ADS-B Flight
- FY13: CNPC Radio Sim, Channel Sounding for Comm
- FY14: DAA/C2 White Papers, UAS CAS 1
- FY15: CPNC Gen 2 Radio, CNPC Gen 4 Radio
- FY16: Flight Test 3, Flight Test 4

- Target Sources: ADS-B Direct, ADS-B on Alternate Link, ADS-B on Remote
- Traffic Information System Broadcast (TIS-B)

- Full Mission Sim
- IHITL
- Preliminary MOPS, Final MOPS
- Alerting Times HITL, Part Task 6
- Part Task 5
- Distributed Demo

- Final MOPS
Backup
3 Self-Separation Algorithms under test

- **AutoResolver**
  - Directive SS Algorithm developed by NASA ARC SSI Team
  - Results displayed on Vigilant Spirit Control Station (VSCS) display
- **Stratway +**
  - Passive SS Algorithm developed by NASA LaRC SSI Team
  - Results displayed on VSCS display
- **Conflict Prediction and Display System (CPDS)**
  - Passive SS Algorithm provided by GA-ASI
  - Algorithm and Display integrated as one unit
Autoresolver’s recommended maneuver will appear at top center of display for **Corrective** and **Warning** alerts only.
Stratway Self-Separation Bands

- Self-separation bands indicate **headings** and/or **vertical speeds** that will result in a loss of well clear.
- Both bands are updated constantly to reflect the most up-to-date information.
CPDS

➢ CDTI provides the operator with a 2-D plan view of ownership and surrounding airspace traffic when present. It also provides SA of potential conflicts.
Flight Test 3 – Configuration 1B
Voice Communications Architecture

VHF-1
(Mission Discrete)

Live Intruder

VHF-2
(SPORT)

UHF-1
(SPORT)

CNPC
Data Link
- C2
- Voice
- Health & Status
- Video
- Traffic (ADS-B)

GRC S-3B

RGCS
VHF-1
UHF-1

C2
RGCS Pilot

Local Radio

Test Conductor

Test Director

Remote Radio Keying

Mission Net
(VHF)

AFRC
Test Team

Test Team Net
(Dices)

Non AFRC Test Team

Non-Test Agencies:
412 TW, SPORT, Weather

AFRC
Position

Other Position

Non-Test Agencies

T/R

T/R

T/R

R

T/R

Telephone
(Dices)
Example Ikhana Circuit / Setup Tasks (Each Run)

- Ensure can meet next IP timing (adjust pattern / speed as required)
- Downwind tasks:
  - Update Next Lost Link Start Point (far end of run line, beyond CPA),
  - Update ILLH to match run, Set Control Point on IP
  - MD give abbreviated card review
- Inbound leg to IP:
  - Final adjustments (timing / track); get ON PARAMETERS at IP
  - Keep on Track & Maintain Ground Speed to the CPA
  - At IP... Call: **IP inbound, altitude, *Special procedure is reviewed (*abort)**

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Data Collection – Configuration 1A

AFRC/GA-ASI

Ikhana

Ku Payload Link (SAA Data)

SAAP (SAA Data)

GCS CPDS/IOServer

Quad Video

Central Data Repository

GW Data Collector

GW Data Logger

Test Logs

Stratway+

JADEM

THALES

AFRC

Honeywell

King Air C90

TPA 100 (TCAS II Data)

GRC

S-3B

AFRC Bldg. 1440

AFRC/AFRC Alliance Link Bldg. 4800

ADS-B Data

ASR Data

MSF Multi-Source Correlator

GRC

Ownship

Intruders

ADS-B Data

ASR Data

MSF Multi-Source Correlator
Data Collection – Configuration 1B

- **Ownship**
  - CNPC Link (SAA Data)
  - CNPC Ground Station
  - CPDS/IOServer
  - CNPC 1U Rack Mounted Computer
  - GW Data Logger
  - GW Data Collector
  - VSCS

- **Research Computer (SAA Data)**
  - Central Data Repository (ARC)

- **Intruders**
  - Honeywell T-34C
  - TPA 100 (TCAS II Data)
  - Intruders

- **Ownship**
  - GRC
  - S-3B

- **Honeywell**
  - King Air C90

- **Research Computer**
  - AFRC
  - ARC

- **Central Data Repository (ARC)**
  - Test Logs
  - Stratway+
  - JADEM

- **GW Data Collector**

- **ADS-B Data**
  - AFTC Bldg. 1440
  - AFTC/AFRC Alliance Link Bldg. 4800
  - MBE Multi-Source Correlator

- **ASR Data**
  - THALES
FT3 Directory Structure

UAS-NAS Project

FT3

Software

FT3 Config 1A

FT3 Config 1B

Date_P1
FT3 Directory Structure

- FT3 Config 1A
- FT3 Config 1B
- Date_P1
  - ARC
  - AFRC
  - GRC
- Gateway Data Logger
- Gateway Data Collector
- SaaProc/JADEM
- Stratway+
- CPDS
- RGCS
- THALES
- C90
- Test Logs
- Surveys
- S-3B Research Computer
- CNPC
  - Trial_1_MM_DD/YYYY
  - Trial_2_MM_DD/YYYY
  - Trial_1_MM_DD/YYYY
  - Trial_2_MM_DD/YYYY
  - Trial_1_MM_DD/YYYY
  - Trial_2_MM_DD/YYYY
  - Trial_1_MM_DD/YYYY
  - Trial_2_MM_DD/YYYY
  - Trial_1_MM_DD/YYYY
  - Trial_2_MM_DD/YYYY
  - Trial_1_MM_DD/YYYY
  - Trial_2_MM_DD/YYYY
  - Trial_1_MM_DD/YYYY
  - Trial_2_MM_DD/YYYY
Flight Test 3 – Configuration 1A/B
Voice Communications Architecture

AFRC

Ikhana (Config 1A)

GRC S-3B (Config 1B)

Voice Comm System (DICES III)
- TC / TD Workstation
- RSO Stations

AFRC SAF

Voice Comm System (Simphonics)
- Multiple Stations

ARC DSRL

Voice Comm System (DICES III)
- Multiple Stations

AFRC LVC Lab