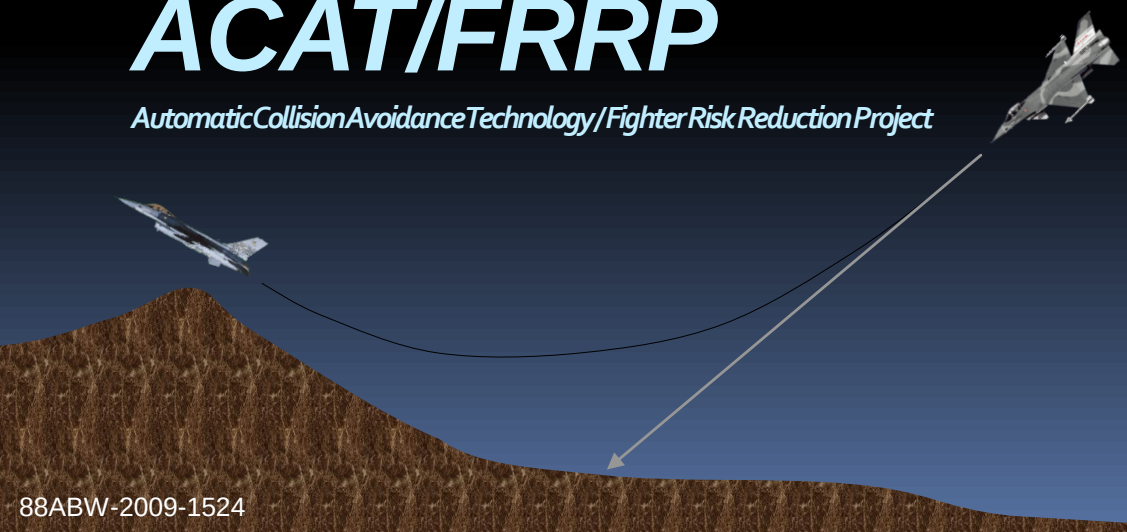
Flight Testing ACAT/FRRP

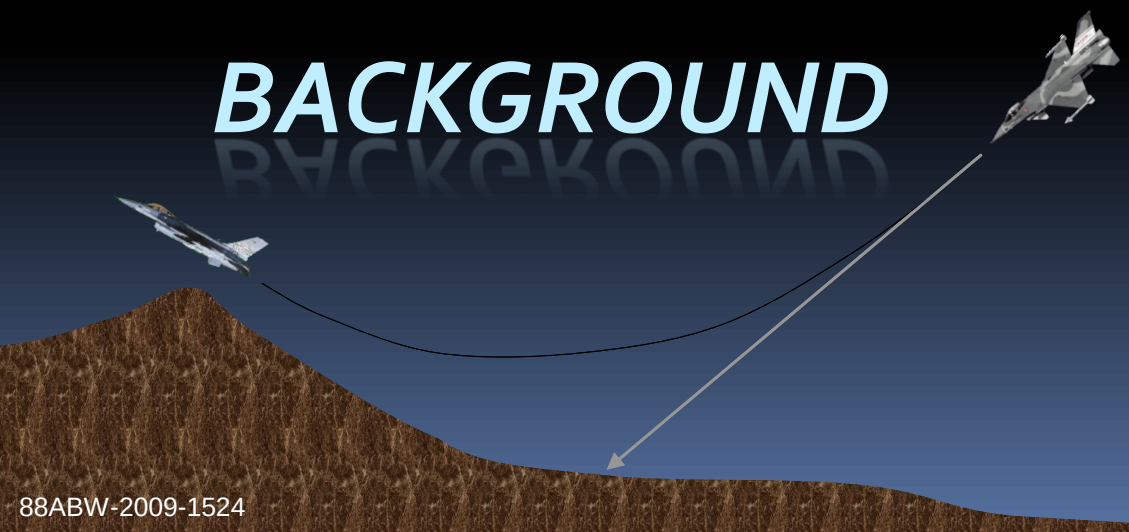
Automatic Collision Avoidance Technology / Fighter Risk Reduction Project



Mark Skoog
ACAT Project Manager
NASA/Dryden Flight Research Center

88ABW-2009-1524

BACKGROUND



Fighter Risk Reduction Project

- FRRP Goal
  - Common Modular Architecture for All Aircraft
  - Transition Technology from Research to Production ASAP to begin Mishap Rate Reduction
    - **5 Fatalities and 7 Mishaps Due to CFIT that were Preventable Since Project Start**
    - **23:1 ROI**

	Lives	A/C	$B	Type
USAF GCAS	62	81	3.7	F-16, F-22, F-35
USAF+USN	247	283	12.7	F-16, F-22, F-35, F-18

- Approach
  - Utilize the Small Team of Experts
  - Primary Products
    - Technology Guides
    - Modular Software Architecture
- Milestones
  - Flying May 2009 through Mar 2010

Mountain Home Air Show, September 15, 2003

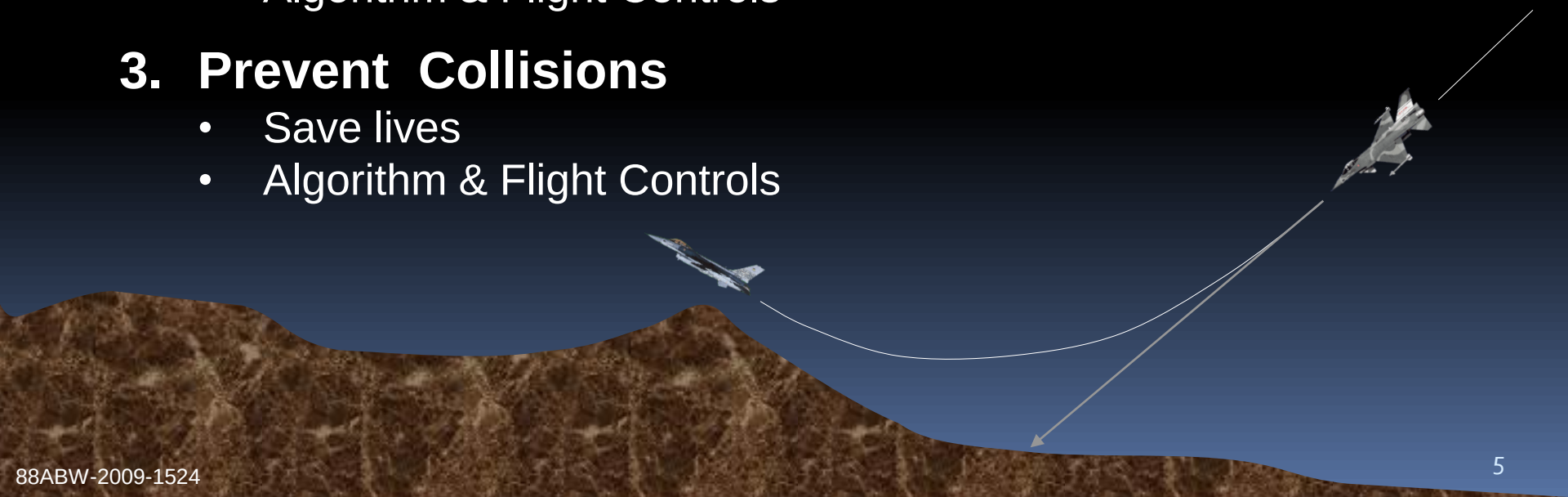
15 Jun 07
Night Spatial Disorientation

Background

- Auto-Collision Avoidance Development
  - *22 Years of Development on the AFTI/F-16*
  - *Ground & Air Collision Avoidance*
  - *AFRL Managed*
  - *Over 2500 Auto-Recoveries in Flight*
  - *Over 40 Evaluation Pilots*
  - ***Prevented the Loss of the AFTI/F-16 in 1995***
  - ***Findings***
    1. *Do No Harm*
    2. *Do Not Interfere*
    3. *Prevent Collisions*
    - ***Collision Avoidance is a Crosscutting Technology***

Design Criteria
In Order of Priority

1. **Do No Harm**
   - Only maneuver the aircraft if there is reasonable certainty that it will **not** make the situation worse
   - Integrity Management
2. **Do Not Impede the Pilot from Performing Mission Operations**
   - Nuisance free flight
   - Algorithm & Flight Controls
3. **Prevent Collisions**
   - Save lives
   - Algorithm & Flight Controls



Auto GCAS Common Architecture

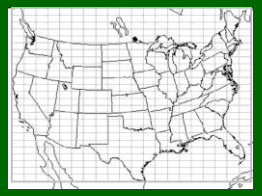
Integrity Management

Sense Own-State

- *Sufficient to support trajectory estimation*

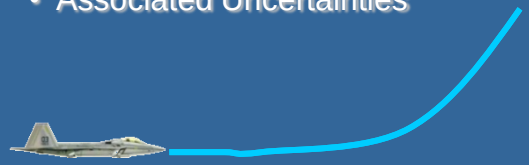
Sense Terrain

- DTED
- Map Handler



Predict Evasion Trajectories

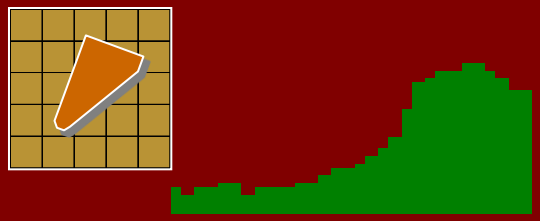
- Evasion Types
- Maneuvering Capability
- Evasion Trajectory Estimations
- Associated Uncertainties



Trajectory Predictions

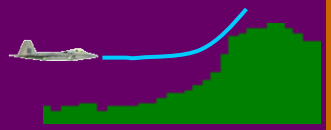
Predict Collision Threat Representation

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



Determine Need to Evade

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



Pilot Controls

- Mode Selection
- Interface

Evade

- Integrity Check
- Execute Evasion

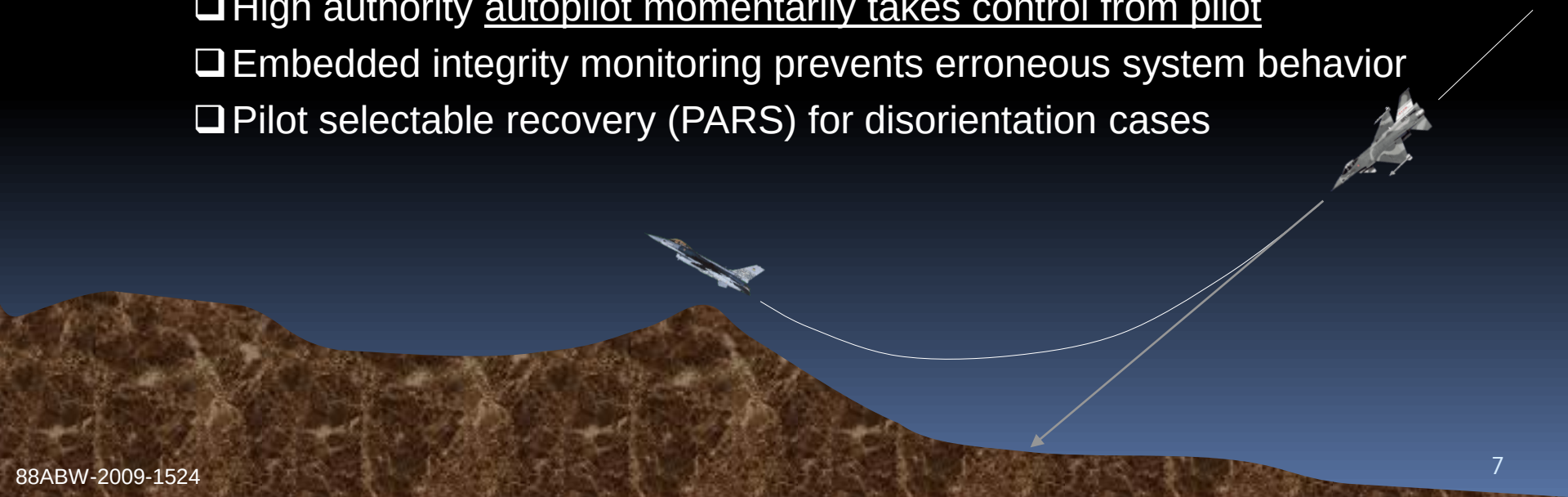
Integrity Management

Notify

- Alert
- Record
- Recall

Auto GCAS Description

- **Automatically Prevents Collision with the Ground**
  - Avionics Project Future Aircraft Trajectory Over Digital Terrain
  - Avionics Request an Evasion Maneuver at Last Instance
  - Flight Controls Automatically Perform Recovery
    - ❑ Recovery model easily tailored to different aircraft
    - ❑ No additional sensors required
    - ❑ High authority autopilot momentarily takes control from pilot
    - ❑ Embedded integrity monitoring prevents erroneous system behavior
    - ❑ Pilot selectable recovery (PARS) for disorientation cases



Collision Avoidance
Description

- Advanced Data Transfer Equipment (ADTE)
  - Advanced Data Transfer Unit (**ADTU**)
    - Collision Avoidance Algorithms
  - Advanced Data Transfer Cartridge (**ADTC**)
    - Digital Terrain Elevation Data (DTED)

Integrity Management

Sense Own-State
- *Sufficient to support trajectory estimation*

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

Trajectory Predictions

Evade
Integrity Check
Execute Evasion

Integrity Management

Determine Need to Evade
- Minimum Approach
- **Integrity Check**
- **Time to Evade**
- **Command Evasion**

Pilot Controls
- Mode Selection
- Interface

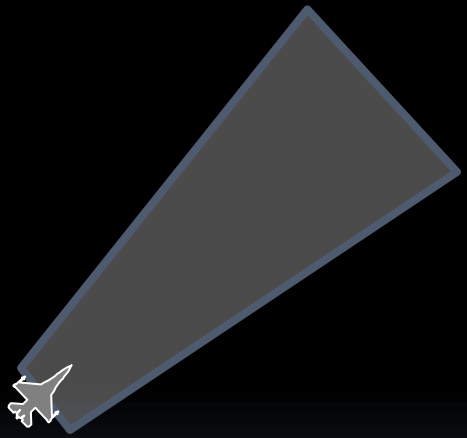
Sense Terrain
- **DTED**
- **Map Handler**

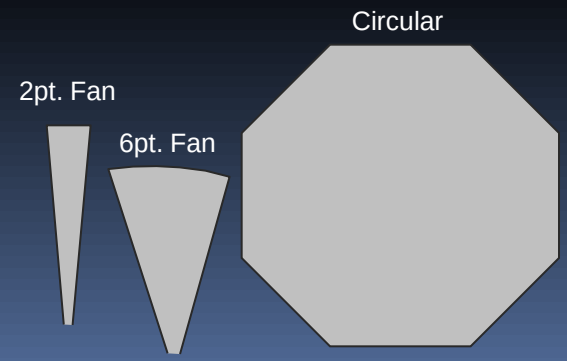
Predict Collision Threat Representation
- Scan/Track Pertinent Threat
- **Simplify Threat Profile**
- **Associated Uncertainties**

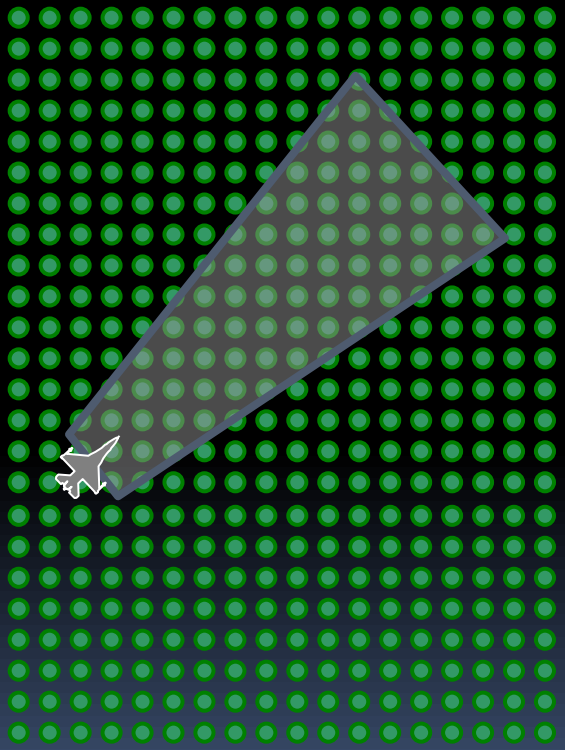
Notify
- Alert
- Record
- Recall

Scanning Process Overview

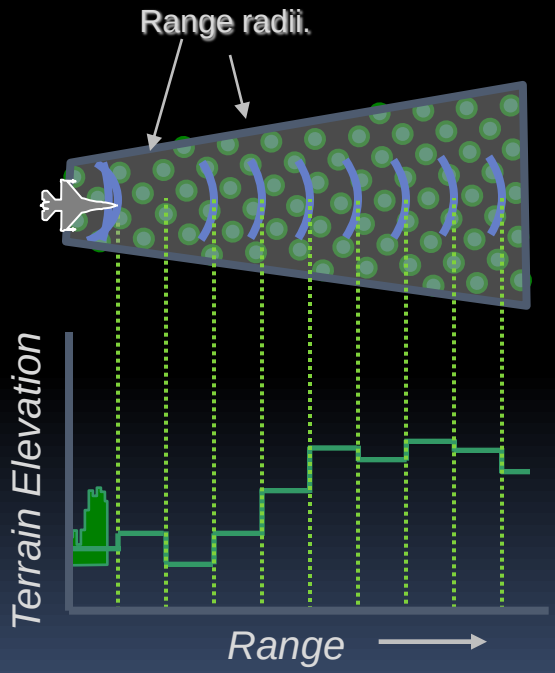
1. *Generate Scan Shape*
2. *Collect Terrain Points*
3. *Generate 2-D Profile (max height in each range bin)*







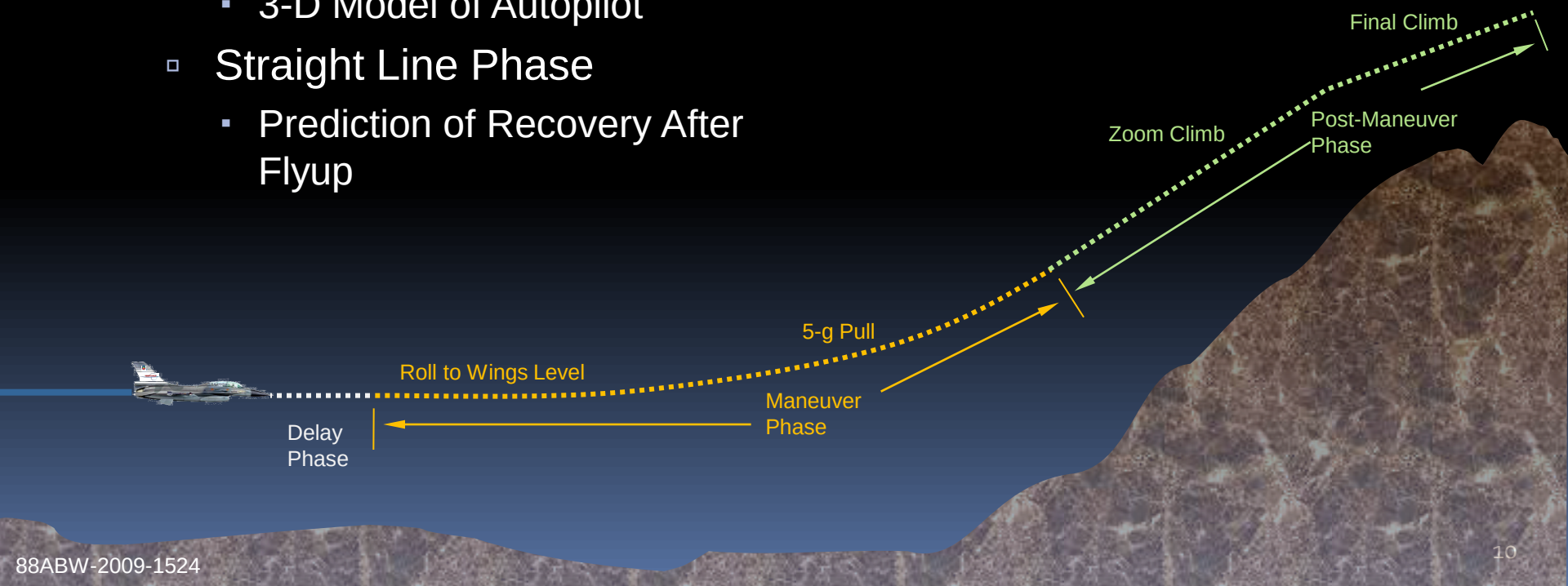
Digital Terrain Elevation Posts



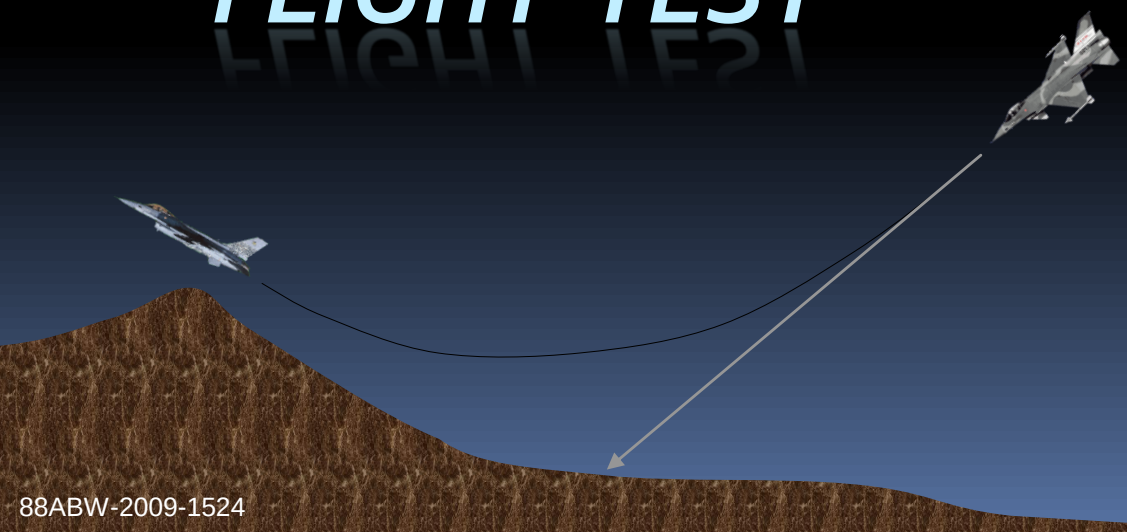
Trajectory Prediction

- **Model Recovery**
  - Delay Phase
    - 3-D Integration of A/C States
  - Maneuver Phase
    - 3-D Model of Autopilot
  - Straight Line Phase
    - Prediction of Recovery After Flyup

- **Model Aircraft**
  - Mass Properties
  - Configuration
  - Available Thrust



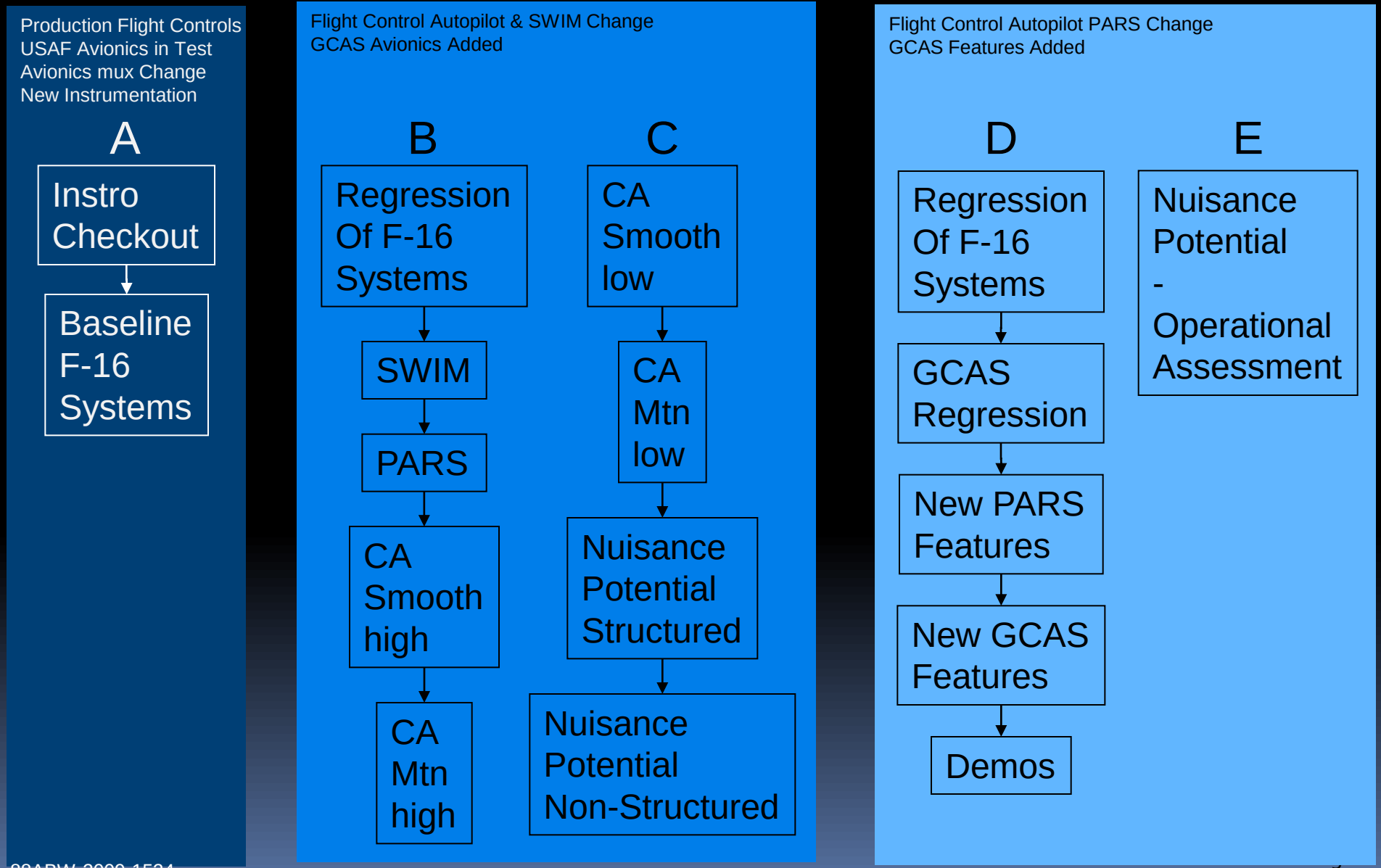
FLIGHT TEST



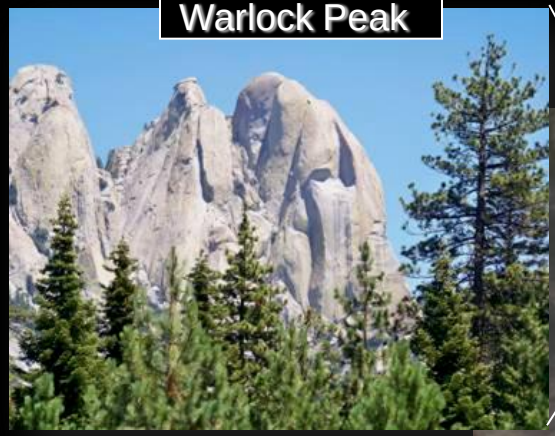
Auto GCAS Test Objectives

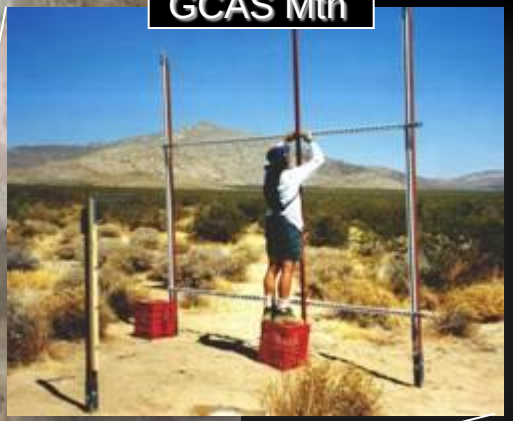
1. Collect data on individual subsystem contributions to overall Auto GCAS error budget
   - Navigation Solution
   - Digital Terrain Elevation Data
   - Autopilot Precision
2. Evaluate the ability of Auto GCAS to stay within pilot physiological limits during a recovery
3. Evaluate Auto GCAS in an operationally representative envelope
   - Collision Prevention Across Flight Envelope
   - Evaluation of Mission Impact

Block Test Flow



Test Sites





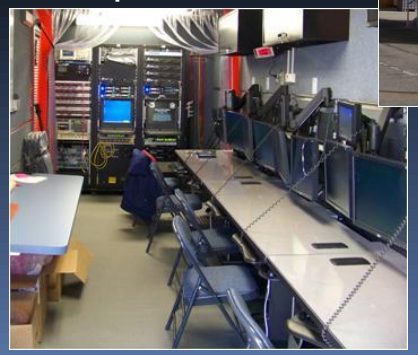
14

Test Resources

Flight / Real-Time

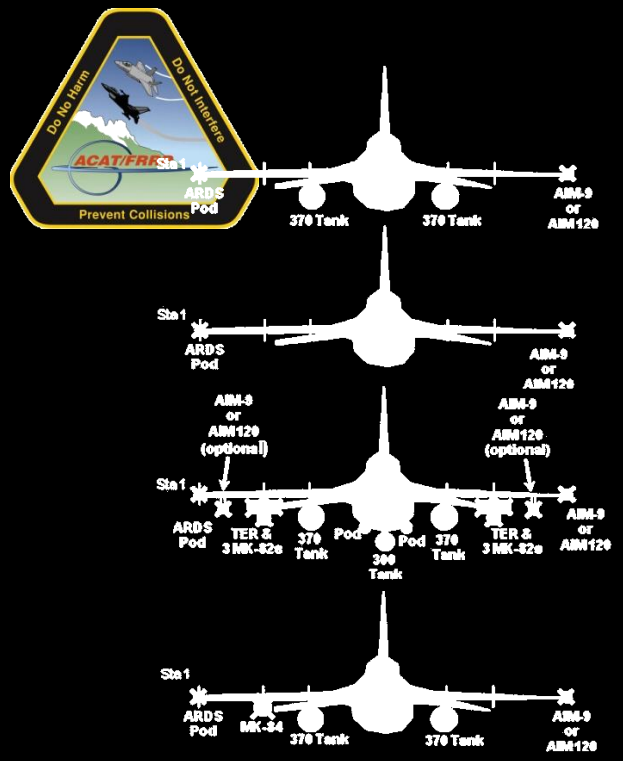
- Test Aircraft
  - F-16D Block 50
  - M5.1 Baseline
    - In Flight Test
    - Auto-GCAS Modifications
- Instrumentation
  - On-Board Recording
    - Hardwired
      - PLA
      - Speed Brake
    - Total Mux
    - Ethernet
    - HUD Video
    - Voice
  - Real-Time
    - Hardwired PLA & Speed Brake
    - Select Mux
    - Select Ethernet
    - HUD Video
    - Hot Mike

- **Mobile Mission Control Room (MMCR)**
  - Front End
    - Mobile
    - Antenna
    - Chapter 10
    - Decryption
  - Control Room
    - Modified Trailer
    - 8 Workstations
    - IADS
    - Dual UHF Radios
    - Multi-RV A-Cs
    - Indep. Generator

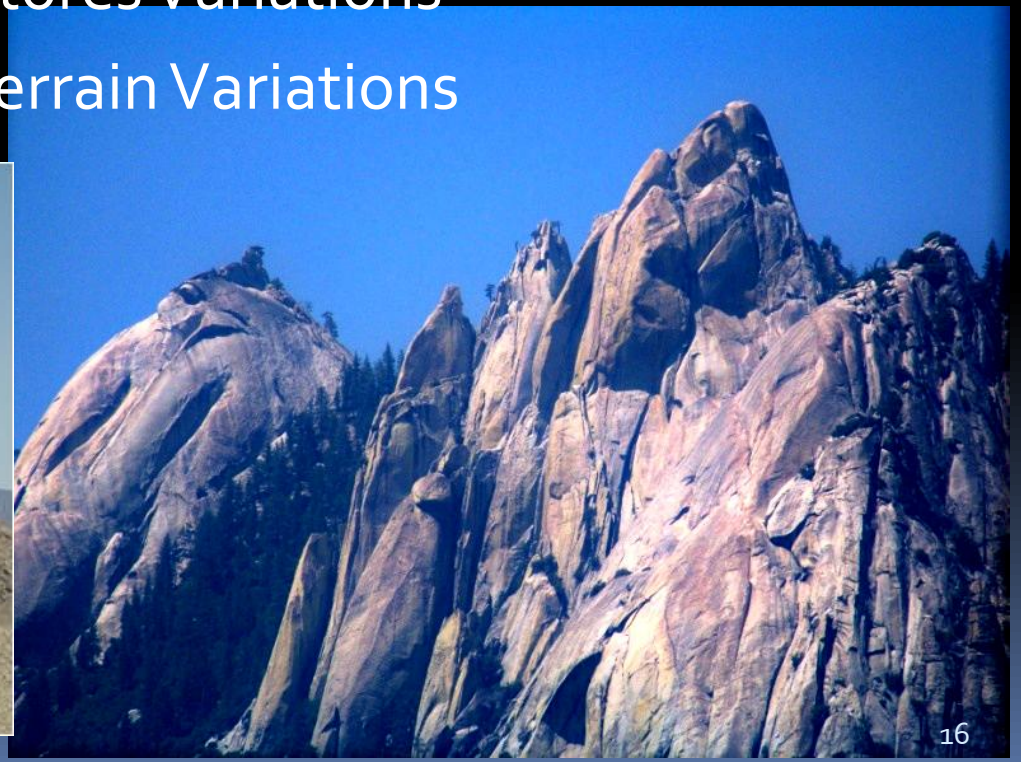


15

Flight Test Scope



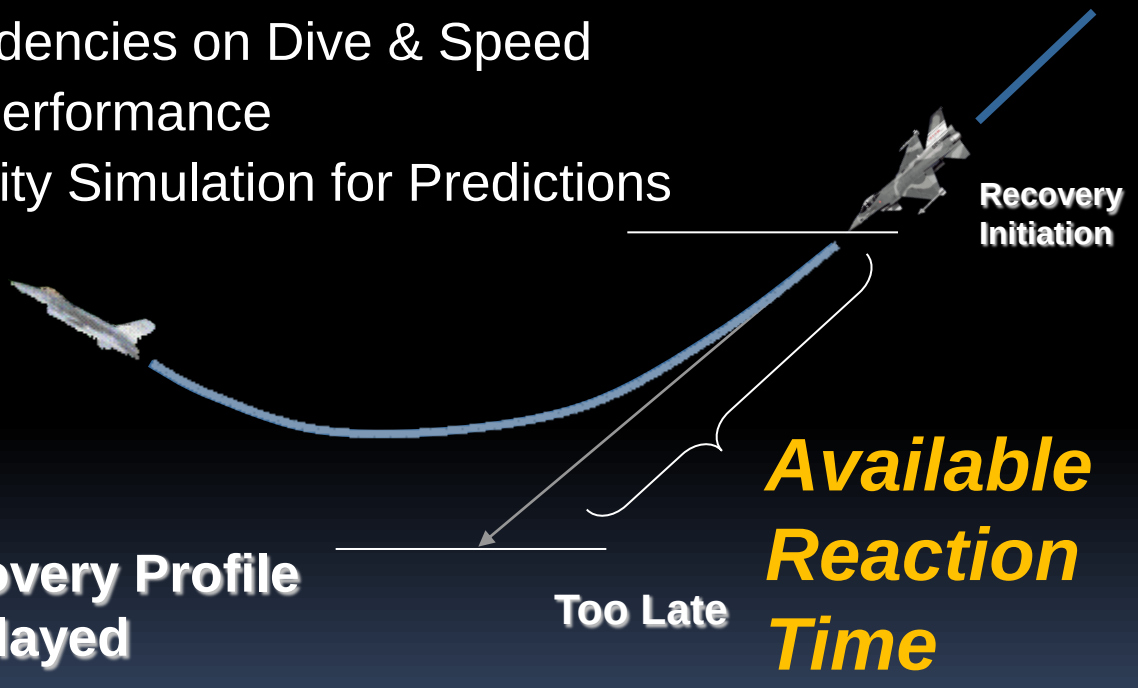
- Envelope
  - 200 knots to Vmax
  - To 90° Dives
  - Upright to Inverted
  - Stores Variations
  - Terrain Variations



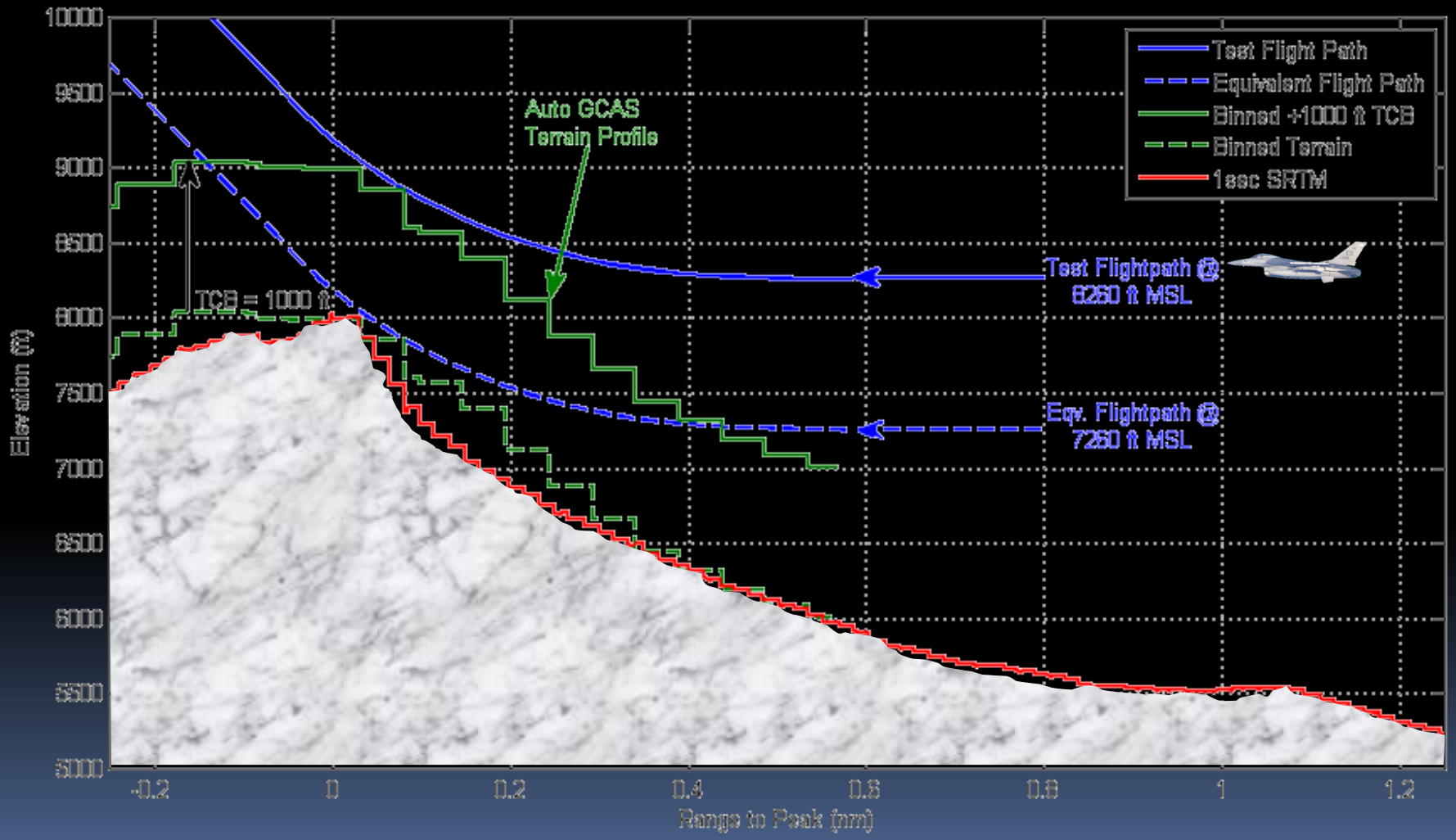
Test Safety Philosophy

Time is a Better Metric than Distance

- **Measure of Performance**
  - **Available Reaction Time**
  - Normalizes Dependencies on Dive & Speed
  - Accounts for A/C Performance
    - Uses High-Fidelity Simulation for Predictions

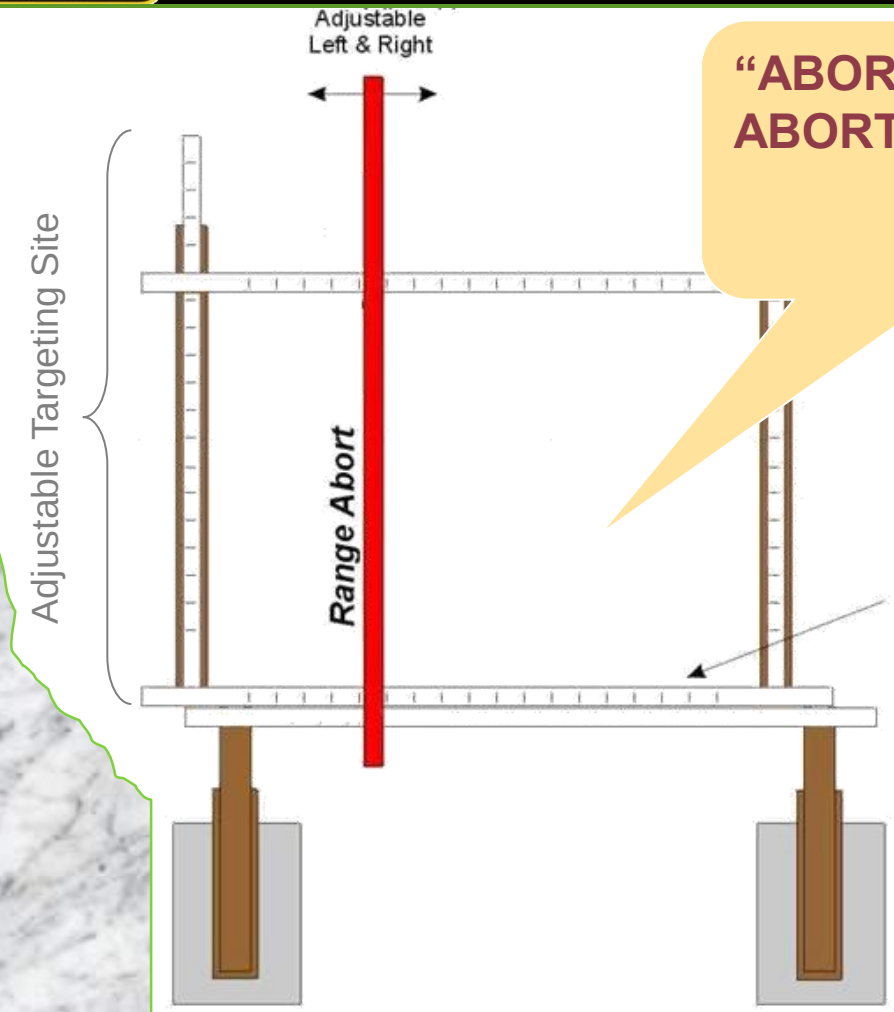


Test Example

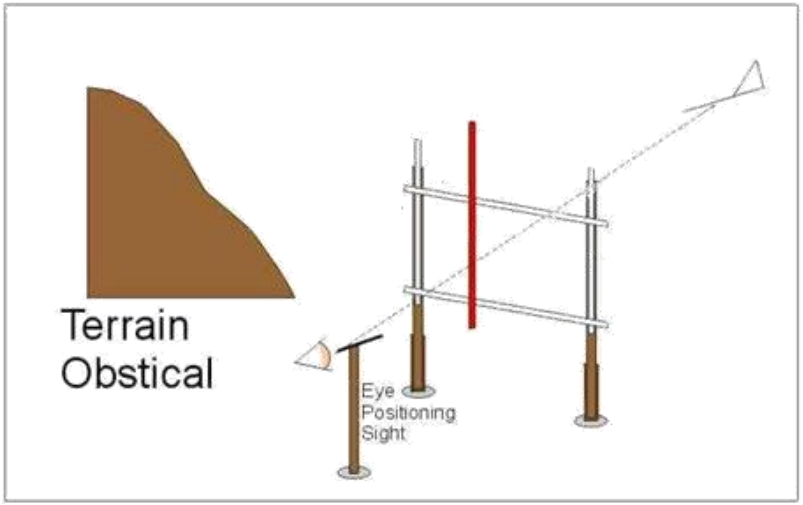


18

The Contraption Concept



"ABORT, ABORT, ABORT!"



Smooth Terrain Test Approach

- Technical
  - Validate Simulation & PARS
  - Collect Data where Sim is Poor
  - Verify PARS Nuisance Potential Evaluation
  - Demonstrate Mishap Prevention

} Runs Conducted at Lower Available Reaction Time

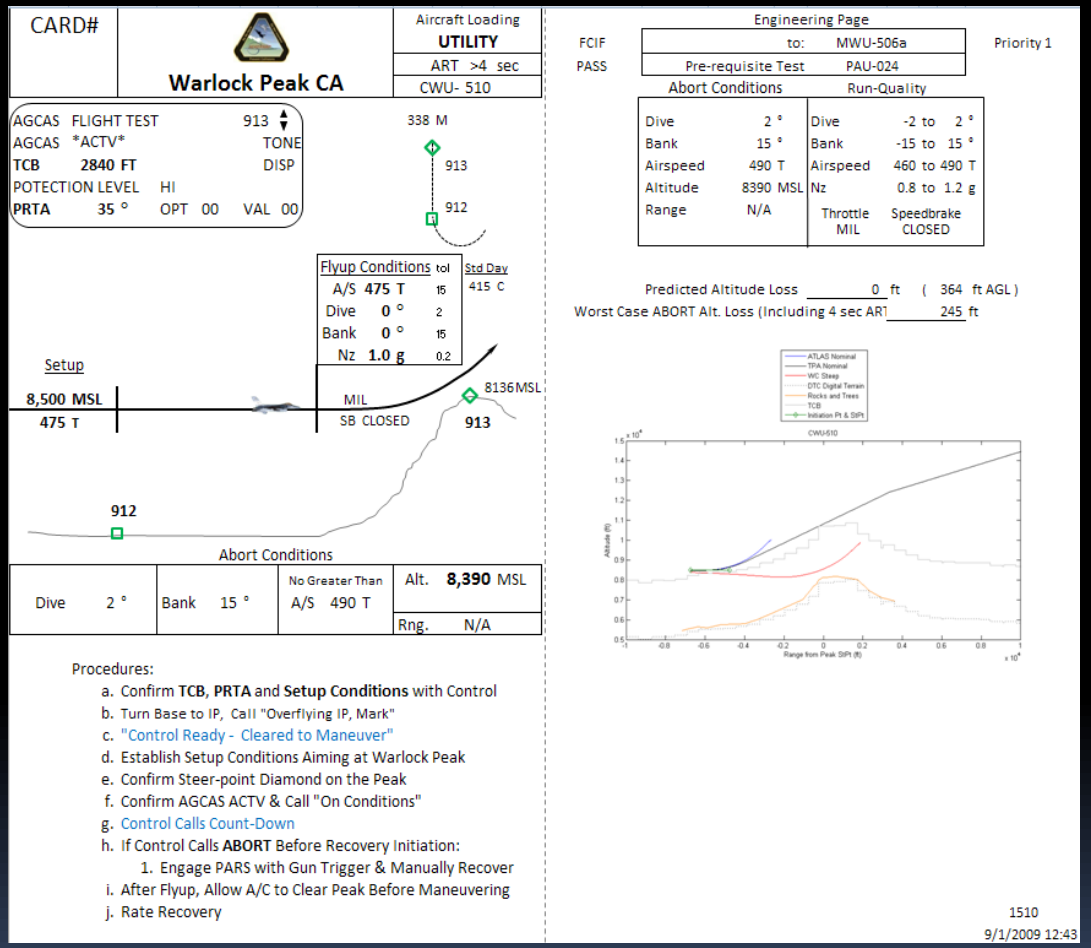
- Safety
  - Simulate all Runs First
  - Execute initial Runs with ≥ 4 Seconds of Available Reaction Time prior to Build Down
  - Build Down Specific "Mishap" Runs to **No Lower than 1.5 sec. of Available Reaction Time**
    - 3, 2, 1.5 sec. Progression/Sequence
    - Sequence Stopped as Crew Reaches Comfort Threshold
  - Crew will Monitor **Ground Proximity**
  - Control Room will Monitor Abort Parameters
    - Altitude, Dive, Bank, Airspeed (KCAS/KTAS), System Status

Typical Collision Avoidance Run

Warlock Peak Procedures

a. Confirm **TCB, PRTA, and Setup Conditions** with Control
b. Turn Base to IP, Call “Overflying IP, Mark”
c. “Control Ready – Cleared to Maneuver”
d. Establish Setup Conditions Aiming at Warlock Peak
e. Confirm AGCAS ACTV & Call “On Conditions”
f. Control Calls Count Down
g. If Control Calls ABORT Before Recovery Initiation:
   - Engage PARS with Gun Trigger & Manually Recover
h. After Flyup, Allow A/C to Clear Peak Before Maneuvering
i. Rate Recovery

Example of Current Version of Run Card




Smooth

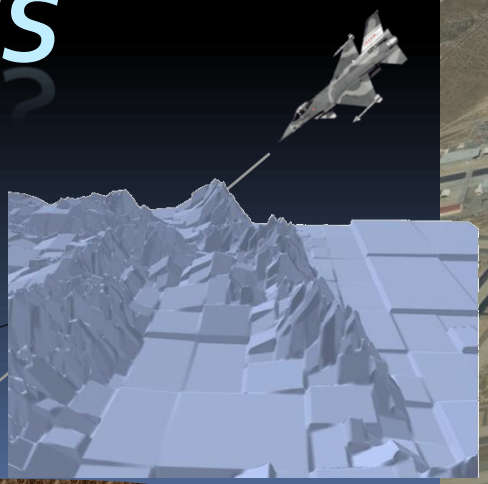
Mountain

Abort


Low Alt Eval


No Harm
Do Not Interfere
ACAT/FRRP
Prevent Collisions

QUESTIONS




ACAT/FRRP
840