



Meeting Real World Challenges: Testing Automatic Air Collision Avoidance System (Auto ACAS)

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LOCKHEED MARTIN





Why we need Auto Collision Avoidance Technology

Total Operations Losses

Midair Auto ACAS
24%

Auto GCAS **CFIT**
25%

**Ops
Other**
9%

TO/Landing
5%

PIFO
5%

PICL
10%

PARS

SDO
12%

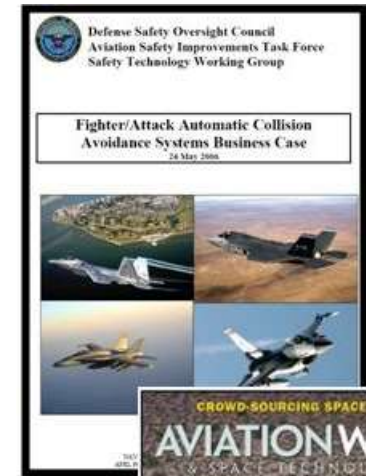
GLOC
11%



Preserving Combat Capability



- 1992–2004: US Fighter CFIT & Midair Collisions
 - 86 pilot fatalities
 - 156 aircraft (9 squadrons)
 - \$3.7B loss
- Over 20 years, Auto GCAS/ACAS on fighter aircraft (F-16, F-18, F-22, & F-35) projected to save:
 - 172 pilots
 - 209 aircraft
 - \$10.7 billion





Why Auto ACAS?





The Driving Philosophy of ACAT

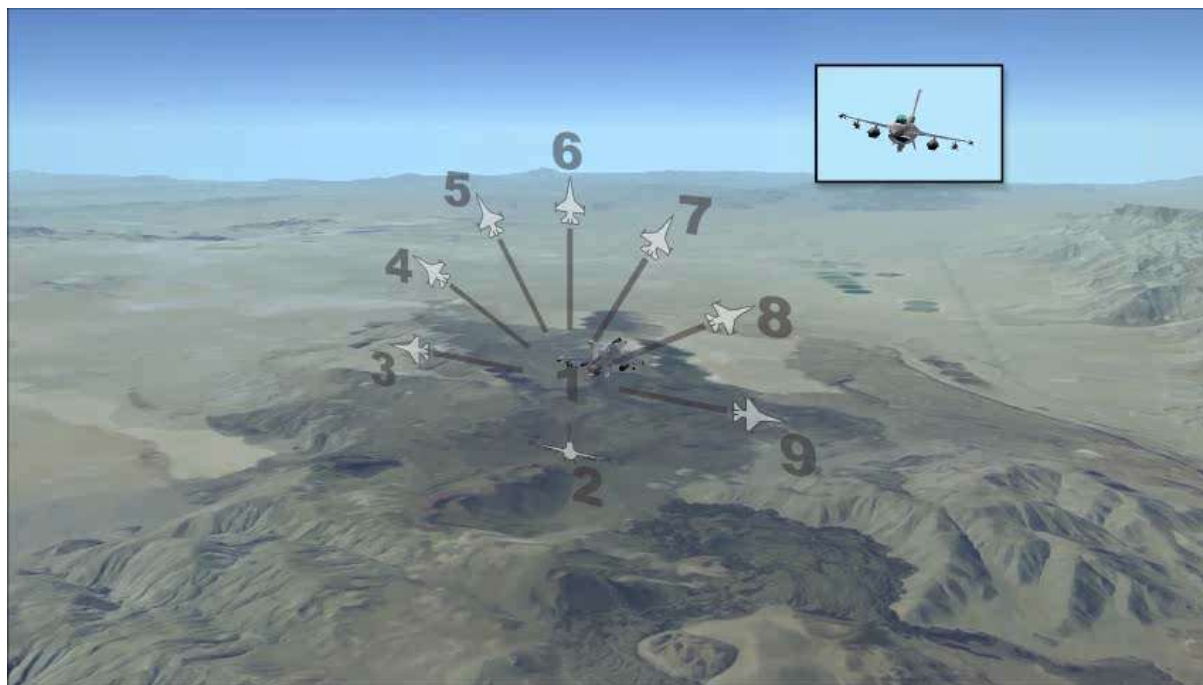
- **1st: Do no harm**
to the pilot or aircraft
- **2nd: Do not interfere**
with the mission, combat or training
- **3rd: Prevent collisions**
with terrain and other aircraft





Auto ACAS Overview

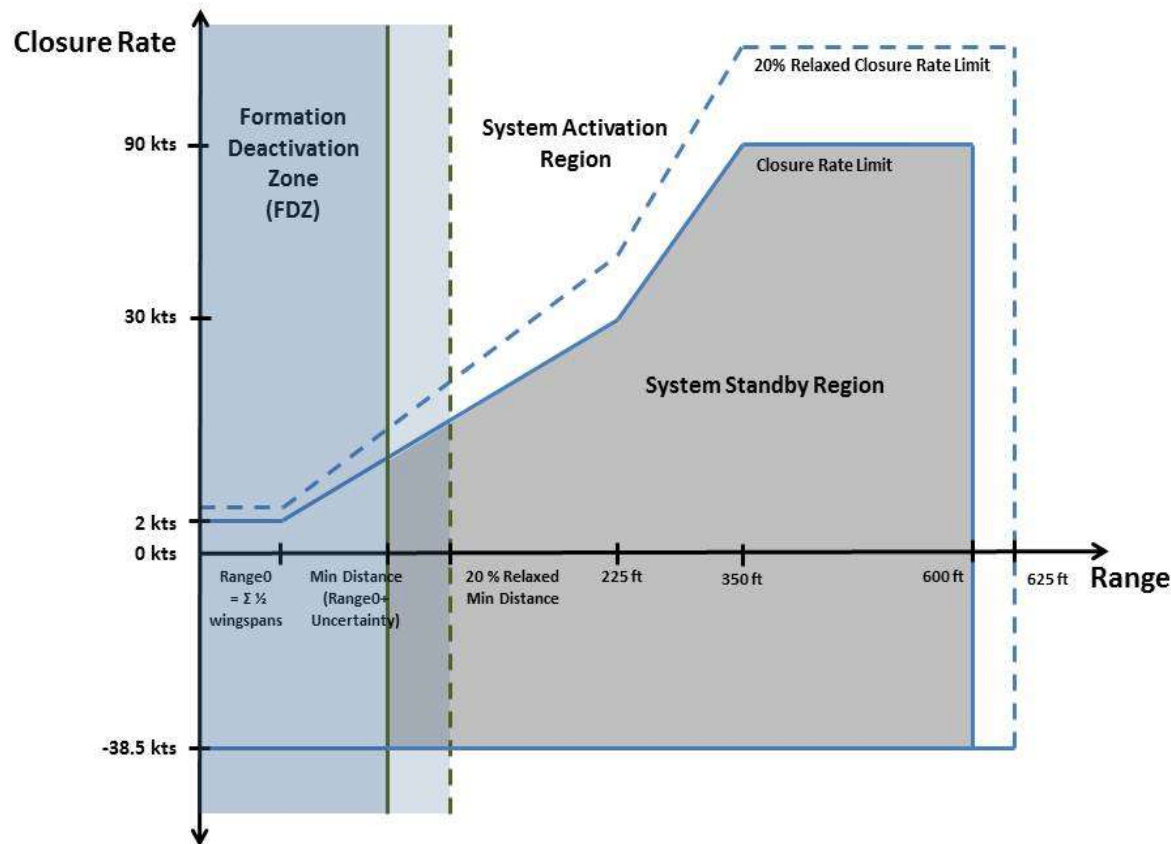
- Algorithm tracks 10 highest threat aircraft
- Constantly considering **9 possible escape maneuvers:**





Auto ACAS Overview

- Balancing collision protection and nuisance free operations.
- Ongoing challenge of ACAS development.





Auto ACAS Flight Test

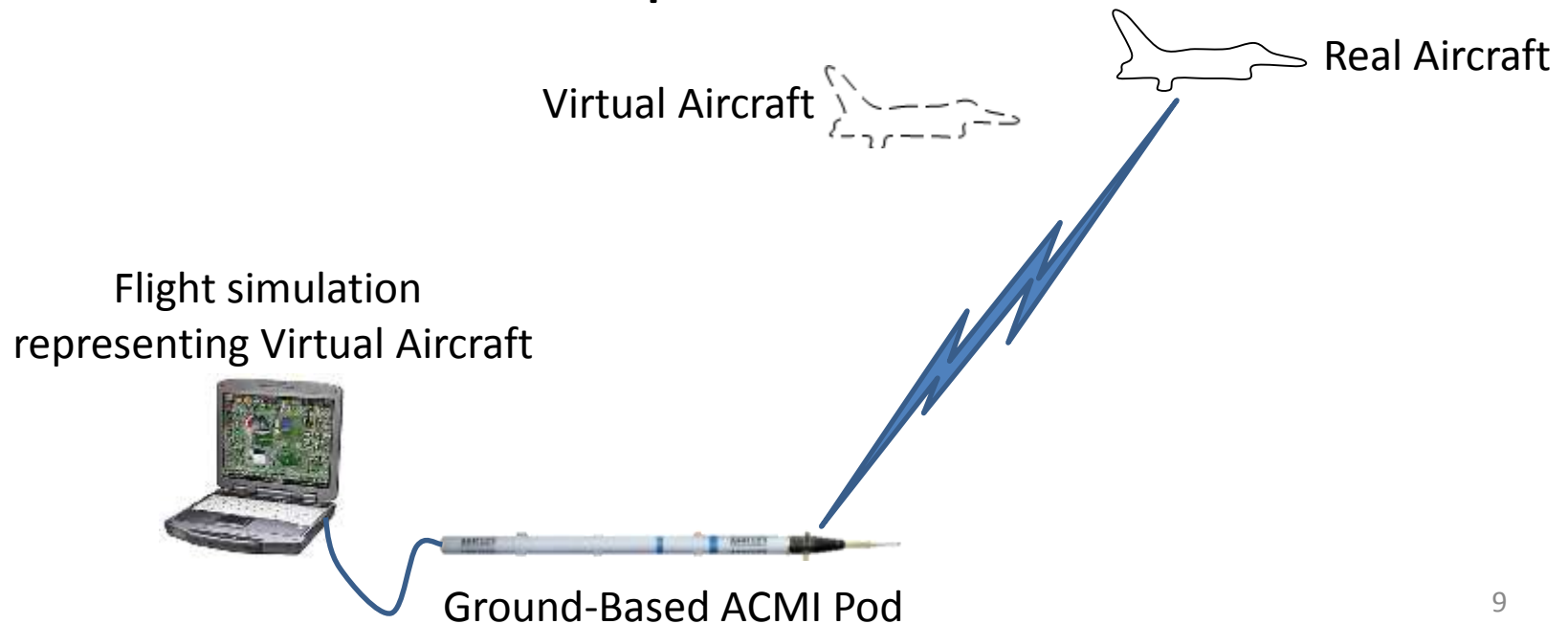
The Crux of the Problem

- How do you test a collision avoidance system without causing a mid-air?
- Difficulties:
 - **Effective evaluation vs. safe flight testing.**
 - **New test execution techniques.**
 - **Innovative safety planning**



1 vs. Virtual Testing

- As safety build up to two ship testing with the system active, **testing was first performed against a virtual target** transmitted by a ground-based ACMI pod.

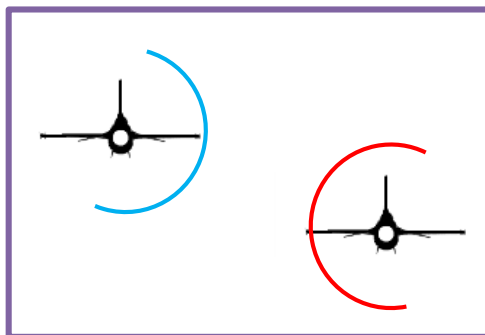




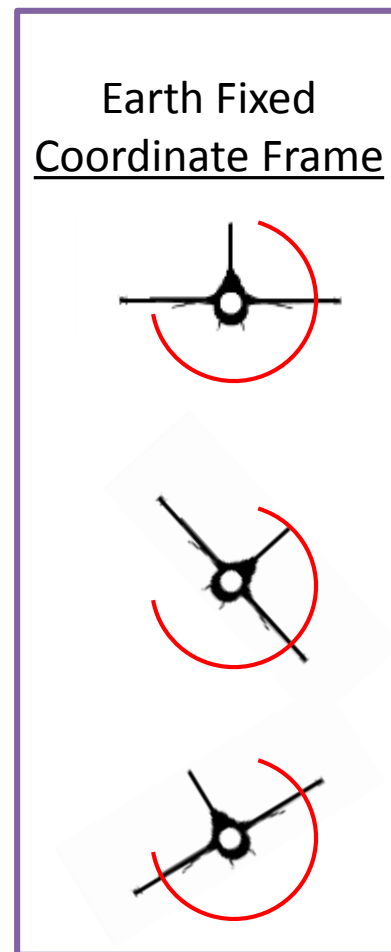
1v1 Flight Test

Don't Trust the System

Exclusion Zones and Bunt Inhibit



- Exclusion Zones (EZ)
 - Prevents a roll and pull maneuver into the defined region
 - Algorithm is unaware of exclusion zones
- Bunt Inhibit
 - Prevents a bunt from being executed by the algorithm

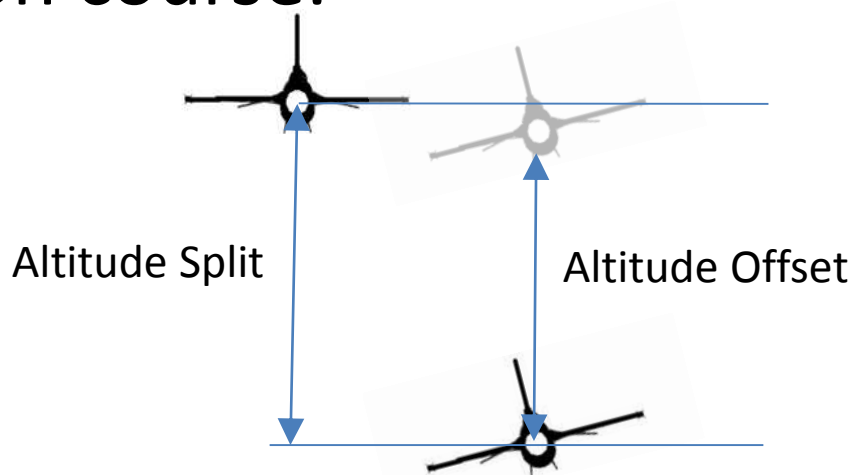




1v1 Flight Test

Don't Rely on the System

Test collision avoidance system without being on a collision course.



- Altitude Split
 - Actual altitude difference, metal to metal
- Altitude Offset
 - Pilot selected, trick the system



1v1 Flight Test Don't Cause a Mid-Air

Time To Zero Altitude Split (TZAS)

$$\frac{\textit{Altitude Split}}{\textit{Alt. Split Rate}}$$

- Philosophy: Aircraft must meet in 4 dimensions (x, y, z, and time) to collide.
- Deconflict in one of those dimensions
- Control Room called abort when TZAS < 3 sec
- Also used Lateral Offset (1 wingspan)

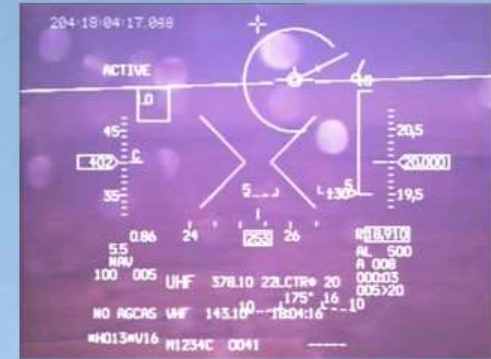


Auto ACAS Test Execution

- Flight testing effort was **54 sorties** (32 missions)
 - No unexplained system behavior
 - Positive deconfliction was achieved on all activations
 - Some additional work to achieve nuisance-free operations



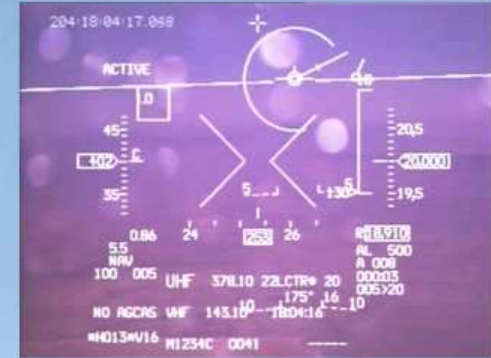
3 Ship Dual Activation



18 ; 04 ; 17 ; 11



3 Ship Dual Activation



18 ; 04 ; 17 ; 11



3 Ship Rejoin



18;57;42;24



3-Ship Rejoin with Overshoot



19:00:05:17



Lessons Learned

- Simulators: Value and Limitations
- Test specific HOTAS functionality
- Adhere to your safety plan!

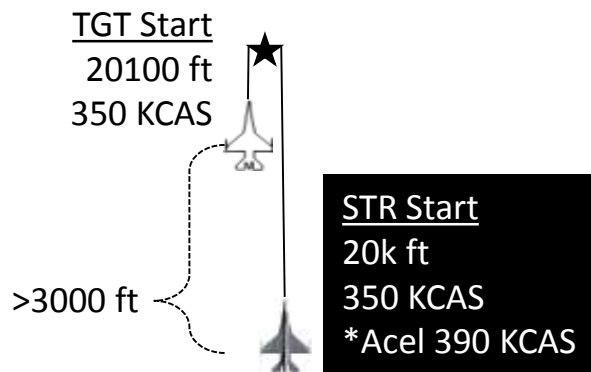


Background

- Auto ACAS had completed:
 - All single ship testing
 - One Cooperative Nuisance (BFM, formation) two-ship mission
 - One Non-Cooperative (Legacy ACMI) Collision Avoidance and Nuisance (BFM, formation, rejoins) two-ship mission
- Mission of incidence was our **first Cooperative Collision Avoidance Mission**

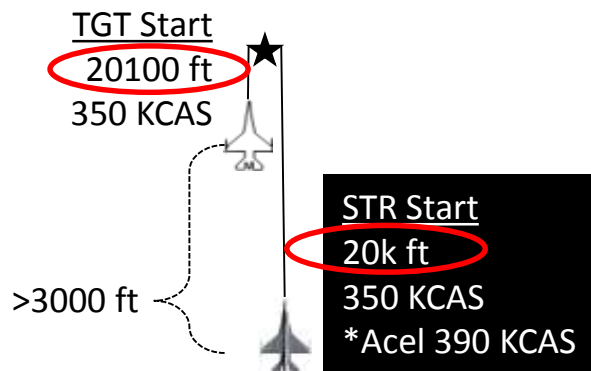


Incident





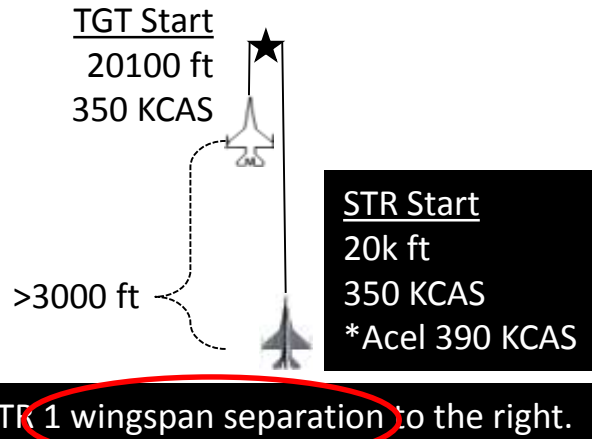
Incident



- Vertical deconfliction- **100' altitude split** assured with altimeter calibration and TZAS



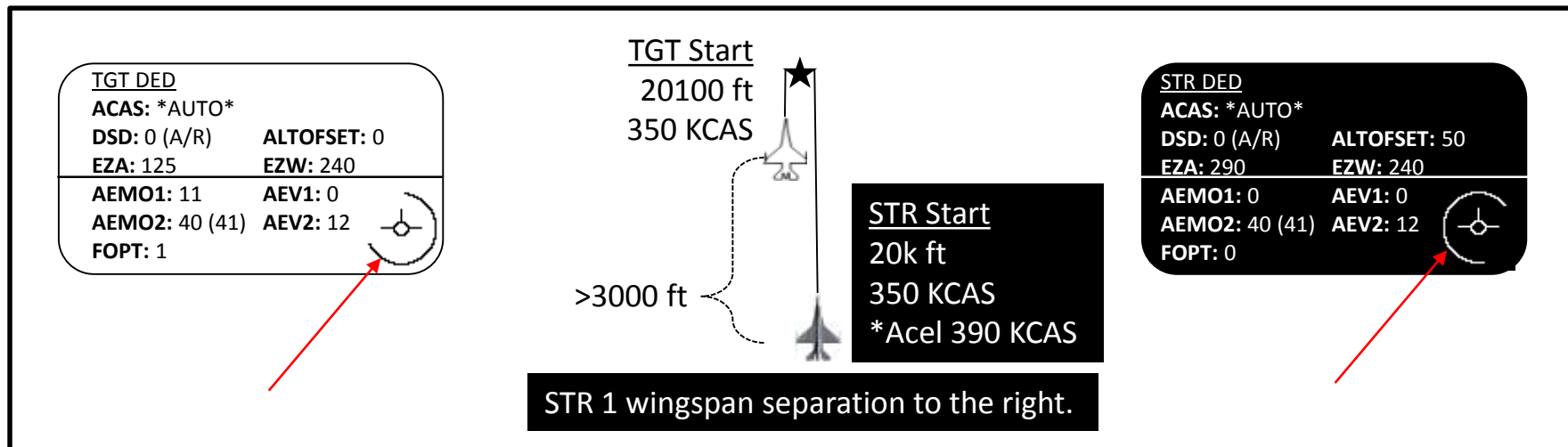
Incident



- Vertical deconfliction- **100' altitude split** assured with altimeter calibration and TZAS
- Lateral deconfliction- **33' lateral split** (F-16 wingspan)



Incident



- Vertical deconfliction- **100' altitude split** assured with altimeter calibration and TZAS
- Lateral deconfliction- **33' lateral split** (F-16 wingspan)
- Exclusions zones & Bunt Inhibit- Ensure left/right and high/low **separation maintained throughout maneuver**
- RCP Pilot & Control Room- **Verify settings/parameters**



Video





Video





So What Happened?

- Target AEMO1 was set to 0 instead of 11= **No bunt inhibit!**
 - FCP pilot miss-set the parameter
 - RCP pilot and control room didn't catch the mistake
- Target algorithm **chose a bunt escape maneuver** as it's best option.
 - RCP recognized that the PVI was displaying bunt as the current selection but thought it was inhibited.
- Target FCP **pilot failed to paddle off the maneuver.**
- Shooter recognized the bunt and **performed evasive maneuvering.**



Lessons Learned

- Safety planning doesn't do much good if it's not executed!
- Groupthink- who's really responsible?
- Test pilots- more is not always better.
- When possible- multiple safety layers!
 - Would there have been time to avoid if there had been no lateral separation?



What's Next for ACAT? Integrated Collision Avoidance

- Auto ACAS technology demo complete
- Integration of Auto GCAS and Auto ACAS

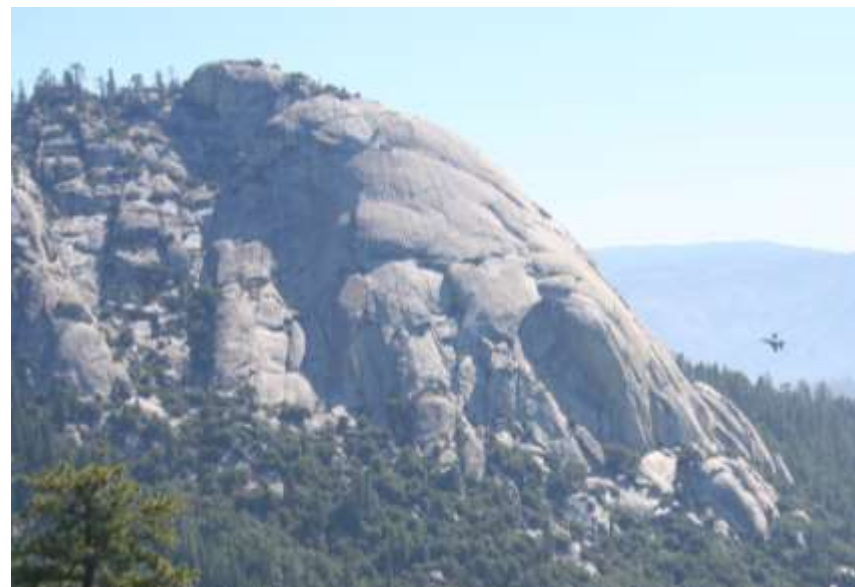




What's Next for ACAT?

Ground Collision Avoidance

- Auto GCAS Being Fielded on 640+ USAF F-16s
 - Do not Interfere
 - Prevent Collisions



- Analog Pre-Block 40 F-16 (1400 aircraft worldwide)
 - Hybrid Computer: Auto GCAS Capable
 - Flight Test Winter 2015



Questions?

