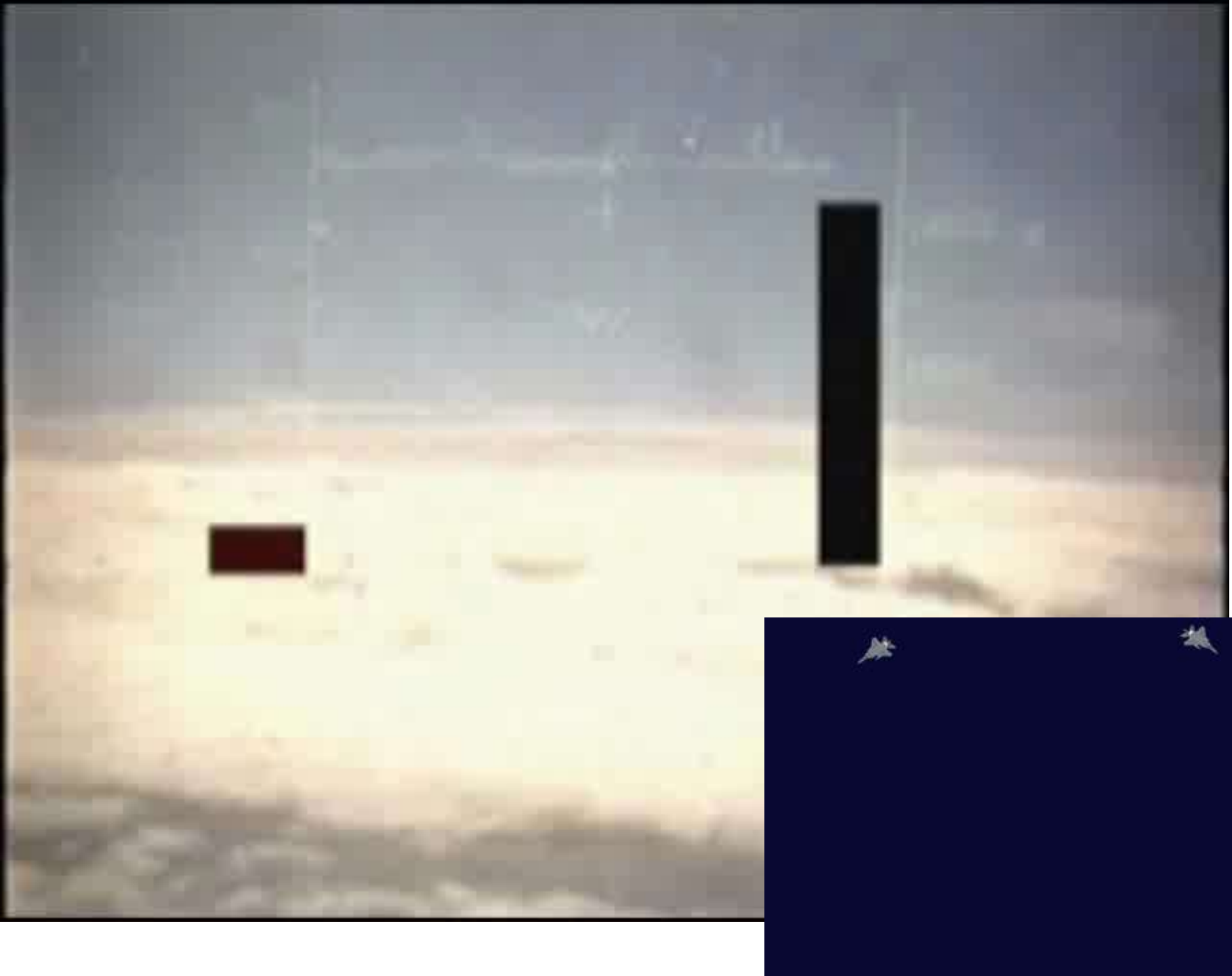


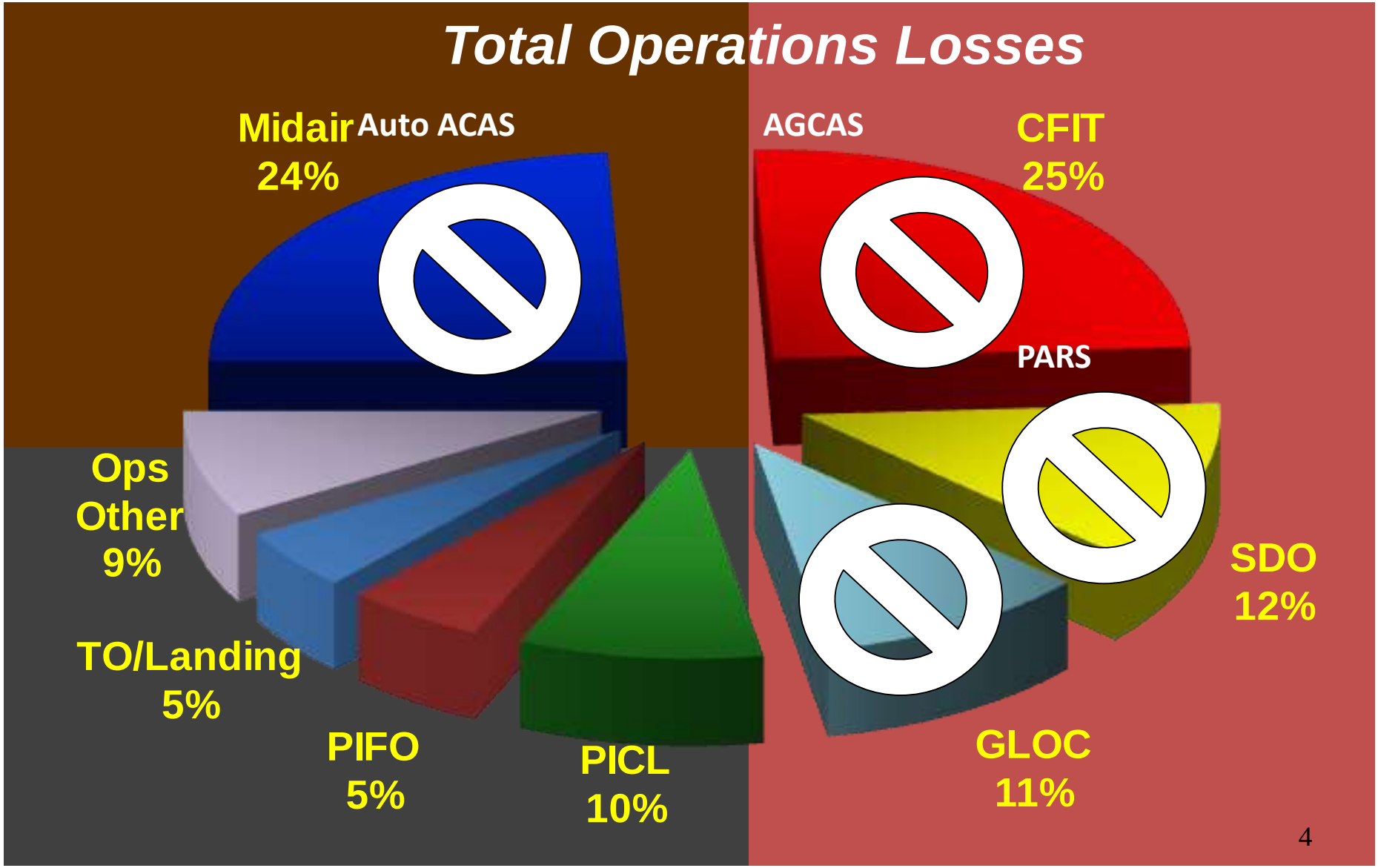
Why ACAS?

Automatic Air Collision Avoidance System Testing

Major Tucker “Cinco” Hamilton
USAF Experimental Test Pilot

31st Annual Symposium
International Test and Evaluation Association

Why we need
Auto Collision Avoidance Technology



Why ACAT?

- Controlled Flight into Terrain (CFIT) and Mid-Air collisions are leading contributors in lives lost and mishap cost.
- Between 1992 and 2004:

  42 USAF F-16 CFIT mishaps with **30 fatalities**

  24 USAF F-16 Mid-Air mishaps with **8 F-16 pilot fatalities**

Prevent CFIT: Auto Ground Collision Avoidance System (Auto GCAS)

Prevent Mid-Air: Auto Air Collision Avoidance System (Auto ACAS)

- For the USAF F-16 fleet alone, **projected to save:**
  - Auto GCAS: 10 lives, 14 aircraft, $530M
  - Auto ACAS: 2 lives, 10 aircraft, $300 M

The Driving Philosophy of ACAT

- 1st: **Do no harm**

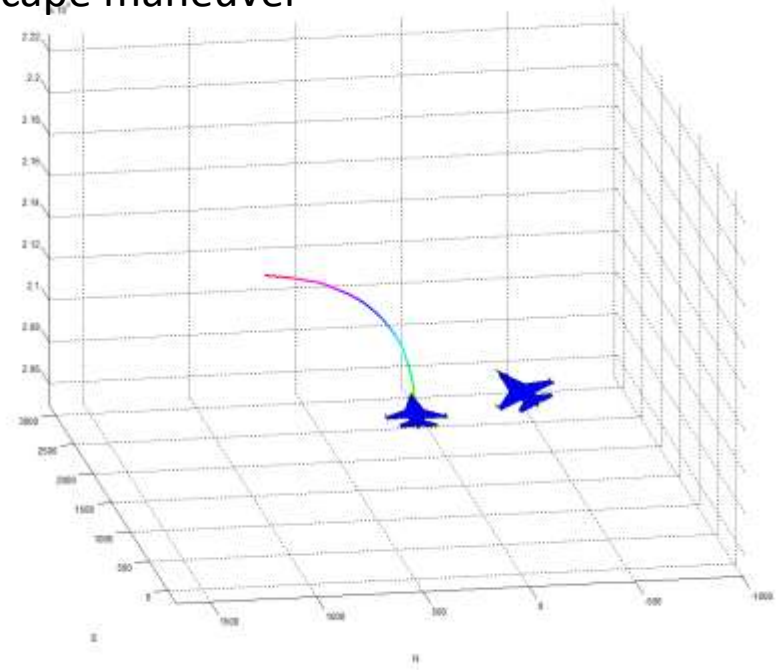
  to the pilot or aircraft
- 2nd: **Do not interfere**

  with the mission, combat or training
- 3rd: **Prevent collisions**

  with terrain and other aircraft

System Description

- Each aircraft:
  - Selects a 4.5 second ‘escape maneuver’ based on location of threat aircraft
  - Determines uncertainties related to ownship escape trajectory
  - Passes/receives escape trajectory and uncertainties to/from threat aircraft
  - If ownship’s escape cone touches a threat escape cone, ownship automatically performs the escape maneuver



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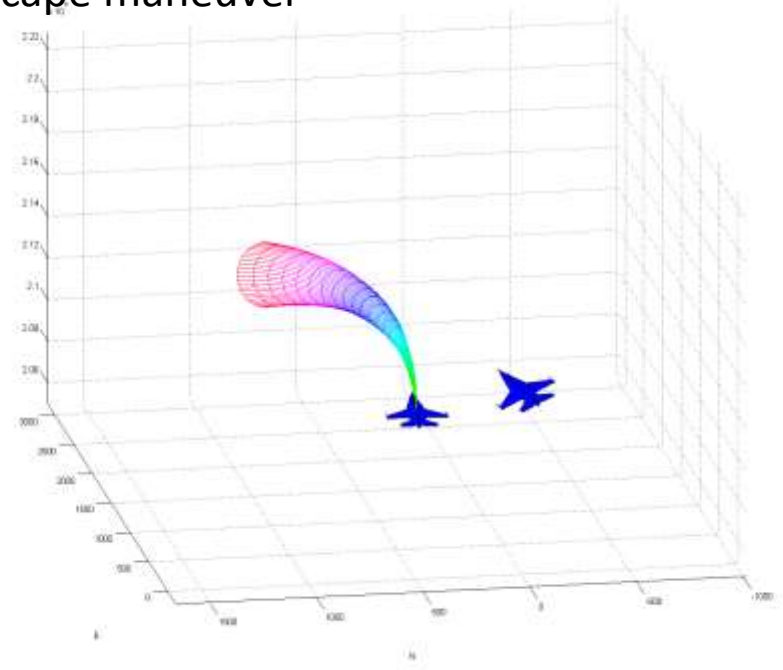

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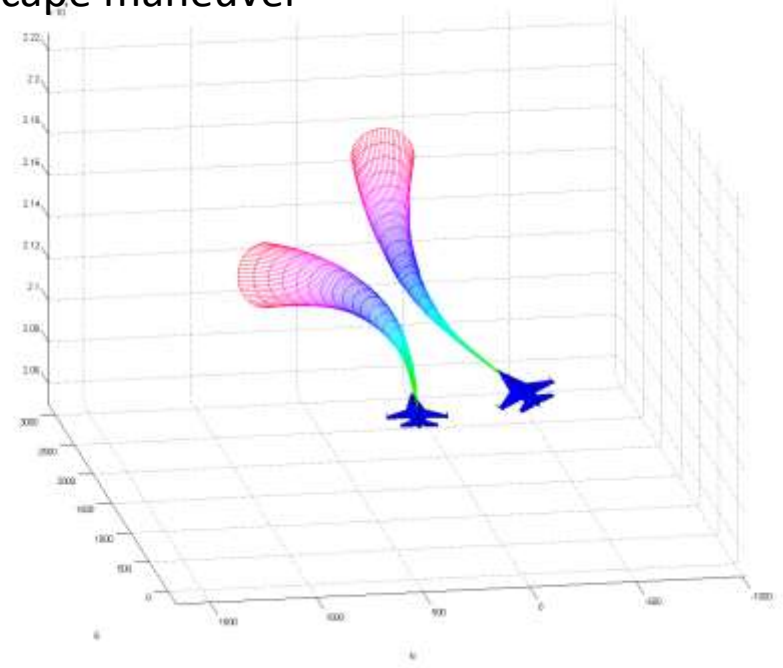

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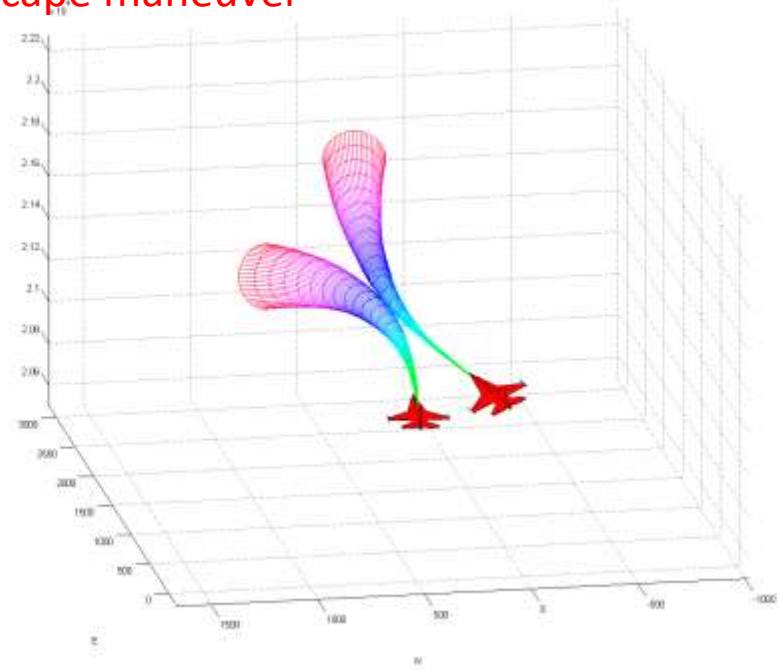
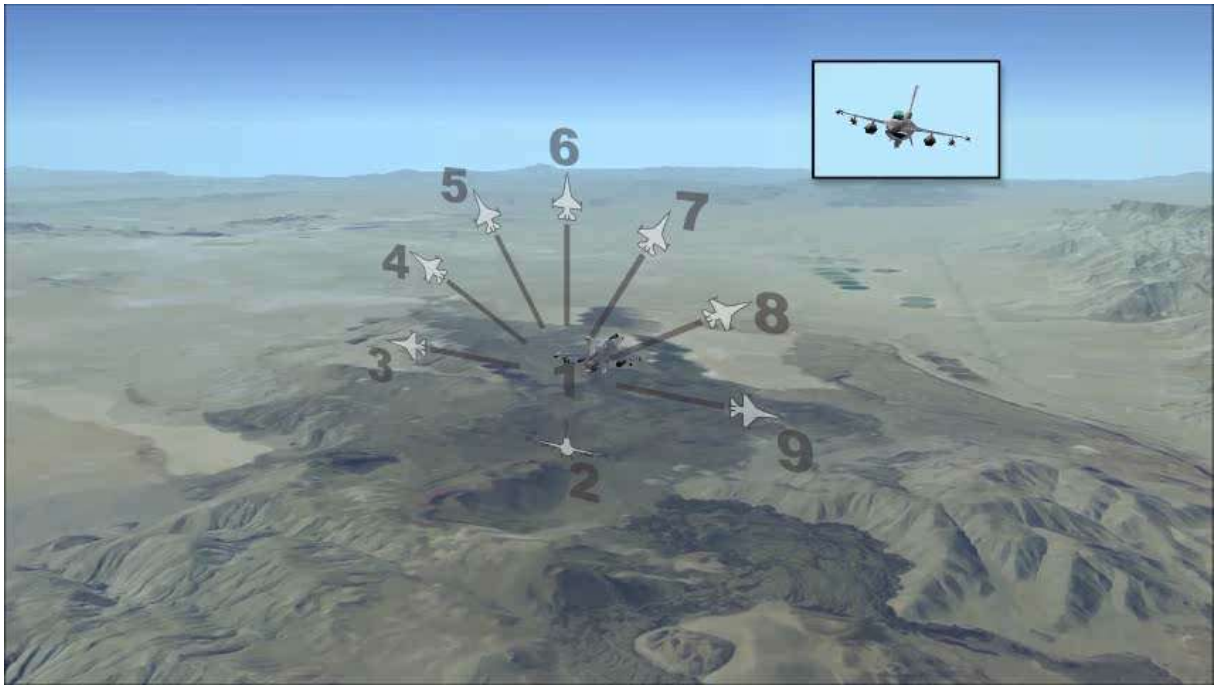


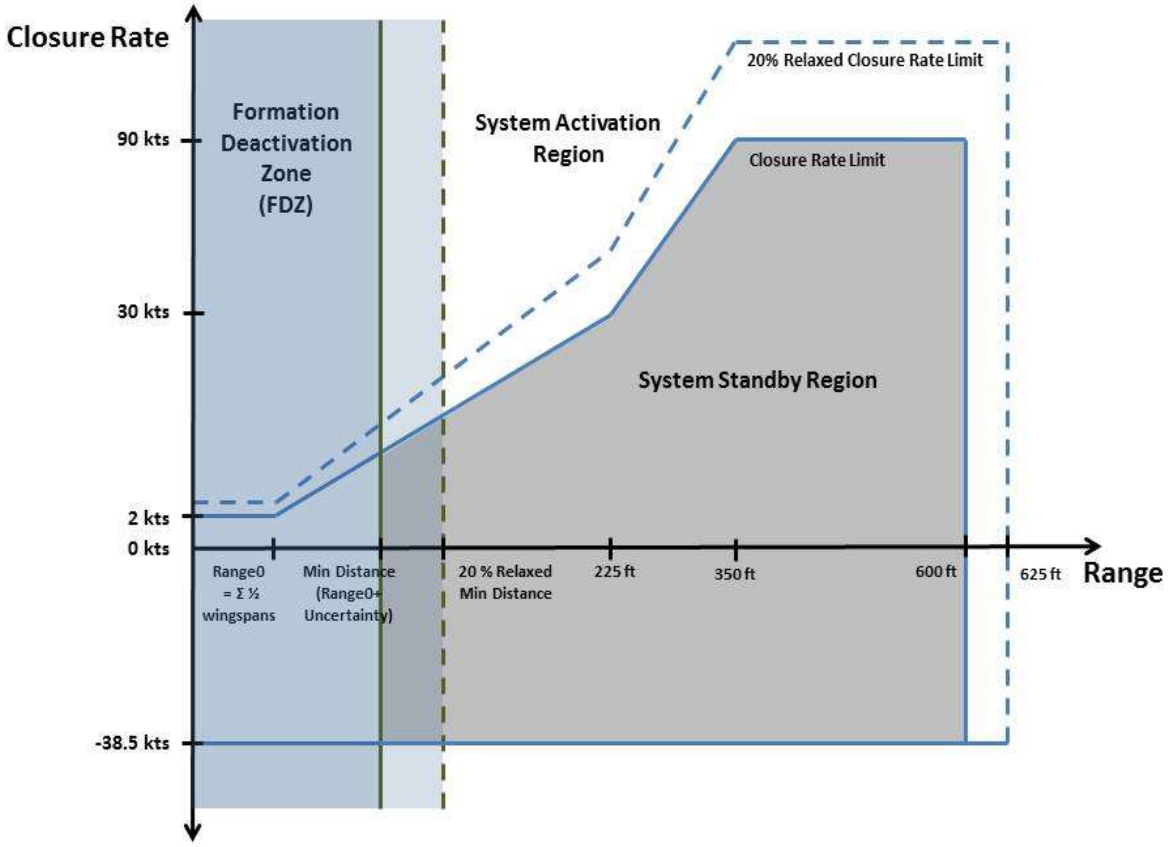
ACAS Overview

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



ACAS Overview

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



The Crux of the Problem

- How do you test a collision avoidance system without causing a mid-air?
- Difficulties:
  - Competing objectives of **effective evaluation vs. safe flight testing**.
  - Required **new test execution techniques**.
  - Required **innovative safety planning** in order to test safely.

Auto ACAS Test Program

- Initial Flight Test Demonstration
  - 2003: Joint effort between the USAF and the Swedish Försvarets Materielverk
- USAF TPS Test Management Projects
  - 2011: HAVE POSIT
    - Characterized data dropout rate between ACMI pods
    - Executed Pilot Activated Maneuvers
  - 2012: HAVE POSIT II
    - Nuisance and Collision Avoidance testing with one aircraft activating
- 416th Flight Test Effort (Summer 2011-Current)
  - Simulation Test Events (Jan 2012 – Current)
  - March – August 2014 – Full system flight test
  - 50 test sorties

Tools For Use

- VISTA
- P5 Pod
- USAF TPS TMP
- Simulators

Tools For Use

- VISTA
  - Test new flight-control laws
  - System will NOT allow excursions from safety envelope
- Simulators
  - Pilot selectable maneuvers
  - Pilot has complete control to turn-off
  - Ability to disengage coupler when flying close formation

LESSON LEARNED: A demonstrator concept provides path to bring systems to test early

Tools For Use

- VISTA
- P5 Pod
- USAF TPS TMF
- Simulators

- Readily available
- Aircraft interface known
- Aircrafts
- Simulator from interactive ground station

LESSON LEARNED: Find your “P5 pods”

Tools For Use

- VISTA
- TPS
- USAF TPS TMP
- Simulators

- Test Pilot School has the expertise and energy to tackle tough Flight Test challenges
- Accelerated test timeline: reduced cost/schedule/on-time

LESSON LEARNED: TPS Students/Staff are a valuable resource

LESSON LEARNED: Early DT can mitigate technical risk

Tools For Use

- VISTA
- PFD
- Provide system functionality to aircrew
- USAF TPS
- Evaluate pilot comfort (nuisance evaluation)
- Simulat

LESSON LEARNED: Simulators have their value and limitations

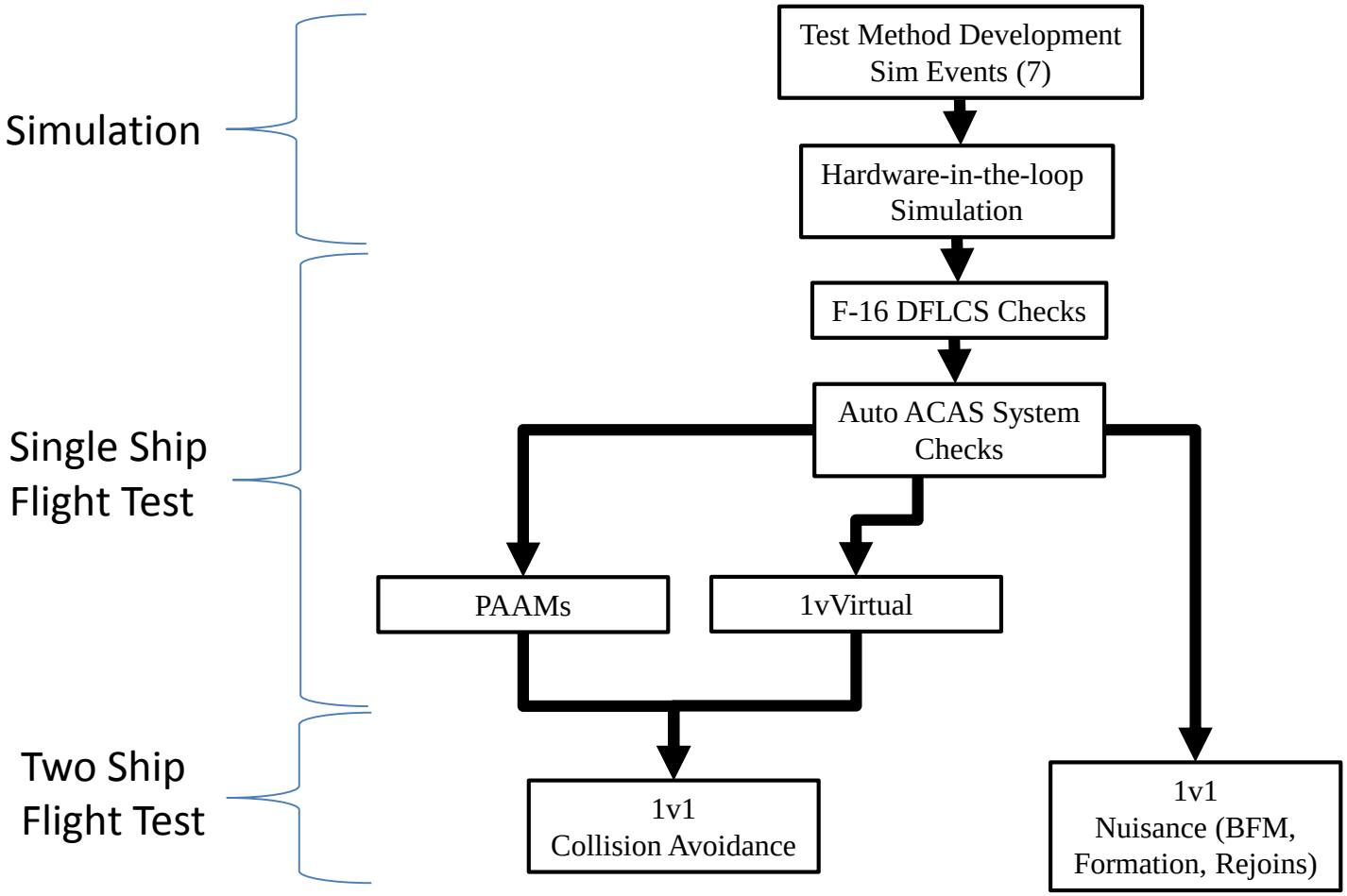
TPS #1 Test Summary

- P5 has LOS dropouts, but can support Auto ACAS
  - Recommend: Faster update rates may facilitate less dropouts
- Avoidance Maneuvers were acceptable
  - Design space for faster onset rates and larger load factor maneuvers
- ~$250K, 6 months

TPS #2 Test Summary

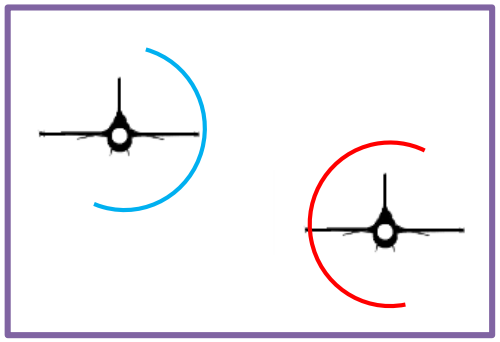
- Preplanned Engagements (29 Automatic Activations)
  - System was able to detect and communicate with threat aircraft
  - Every time system projected a breach of DSD, an AAM was produced
  - Minor changes needed in PVI, duration & selection logic
- Formation Logic (60 test points flown)
  - Algorithm adhered to designed boundaries
  - 12 nuisance activations
- ~$200K, 6 months

416 Flight Test Squadron Build-up Approach



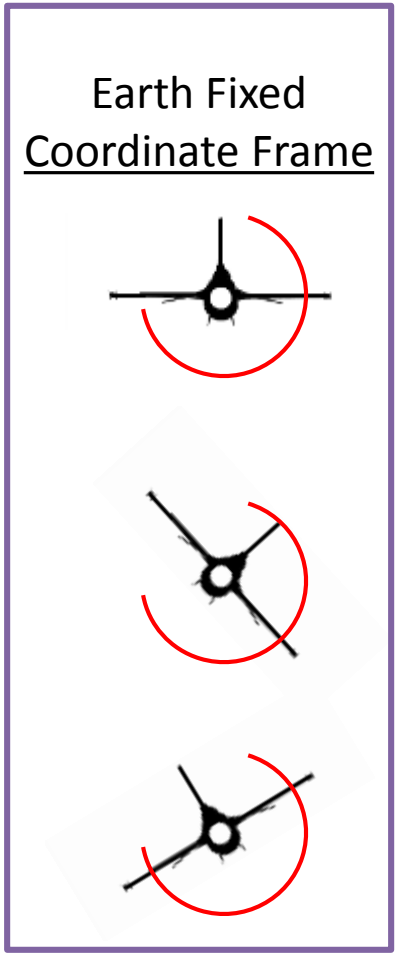
***This allows us to reduce the risks of testing a new system.**

Exclusion Zones and Bunt Inhibit

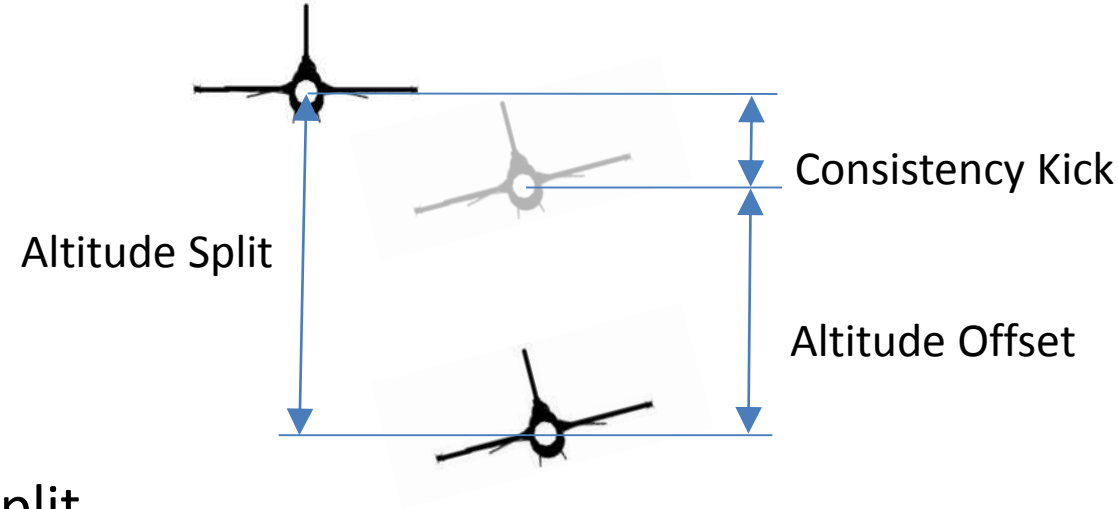


- Exclusion Zones (EZ)
  - **Prevents a roll and pull** maneuver into the defined region
  - Algorithm is unaware of exclusion zones
- Bunt Inhibit
  - **Prevents a bunt** from being executed by the algorithm

***This allows us to test the system without trusting that it is working properly or performing well.**



Altitude Offsets

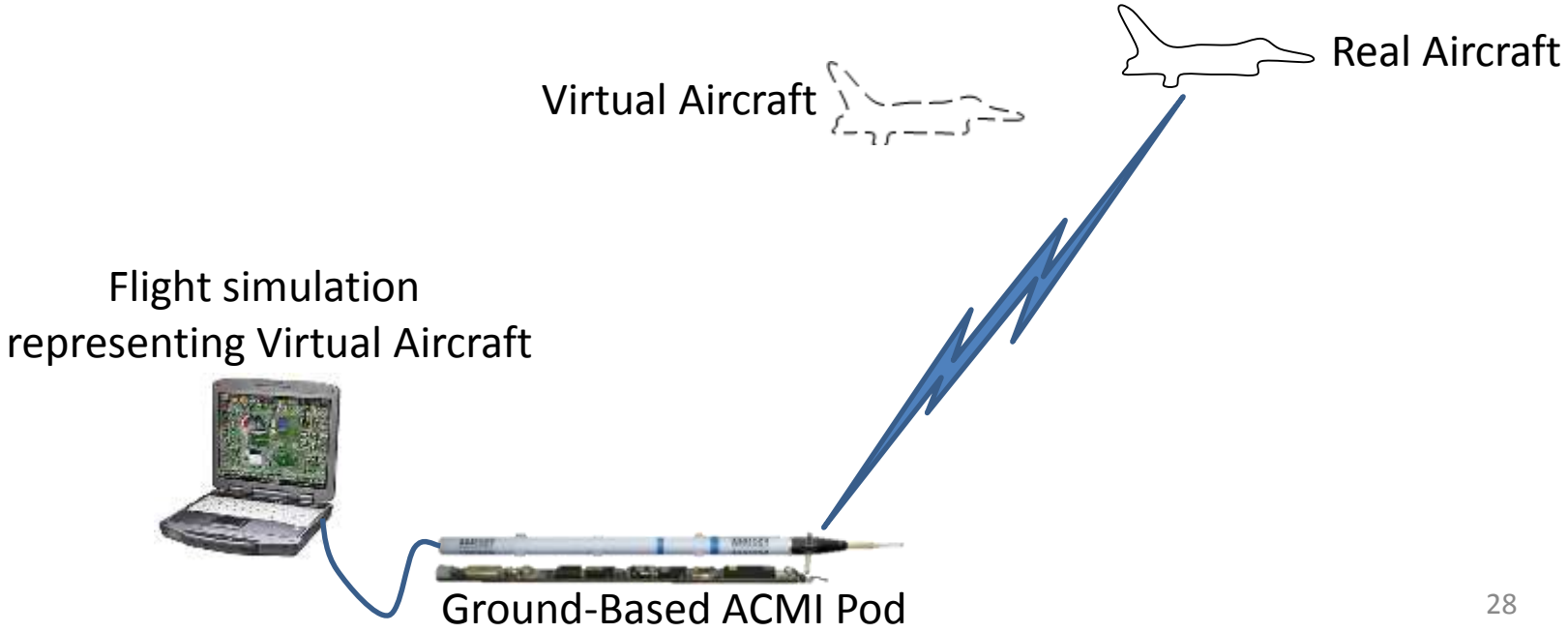


- Altitude Split
  - Actual altitude difference between ownship and threat aircraft
- Altitude Offset
  - Tricks both aircraft's algorithms into thinking one aircraft is higher or lower than reality
- Consistency Kick
  - Small distance between the ownship virtual representation and the threat aircraft, used for test efficiency during flight test

***This allows us to test a collision avoidance system without ever putting aircraft on a collision course.**

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.



Test Execution

- Flight testing effort was **54 sorties** (32 missions)
  - No unexplained system behavior
  - Positive deconfliction was achieved on all activations
  - Additional work to achieve nuisance-free ops
- Flight test results were used to update system design
- ~$2M, 12 months

3 Ship Dual Activation

18 ; 04 ; 17 ; 11

3 Ship Dual Activation

18 ; 04 ; 17 ; 11

3 Ship Rejoin

3-Ship Rejoin with Overshoot

Lessons Learned

- Early DT in system design
  - Reduced technical risk
- Test Pilot School Test Management Program
  - Students can tackle/support test efforts
- VISTA critical to risk & cost reduction
  - Simulators have their value & limitations
- P5 pod provides modular, simple solution for integration on fighter aircraft
  - Where are your programs “P5 pods”?

These efforts saved ~30 months & millions of dollars

Closing Thoughts

We need to innovate to field effective systems quickly and within our fiscally constrained environment

If this system was in my jet…my wingman would have survived

QUESTIONS?


USAF TEST PILOT SCHOOL
ED
835
VISTA
048
USAF Test Pilot School
Do No Harm
Do Not Interfere
Prevent Collisions


DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA
AFRL
THE AIR FORCE RESEARCH LABORATORY
Do No Harm
Do Not Interfere
F-16 Auto ACAS
TEST TEAM
Prevent Collisions
NASA
AEROSPACE SYSTEMS
DIRECTORATE
LOCKHEED MARTIN
AD INEXPLORATA