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**SMI UAV CONFERENCE, LONDON, UK
(9-10 FEB 2004)**



MAJ Bryan Coon

Control Sciences Division (AFRL/VAC)

Air Vehicles Directorate

Air Force Research Laboratory

Air Force Materiel Command

Wright-Patterson Air Force Base, OH 45433-7542

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AIR VEHICLES DIRECTORATE

AIR FORCE MATERIEL COMMAND

AIR FORCE RESEARCH LABORATORY

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Air Vehicles Directorate



**SMI UAV Conference, London,
UK (9-10 Feb 2004)**

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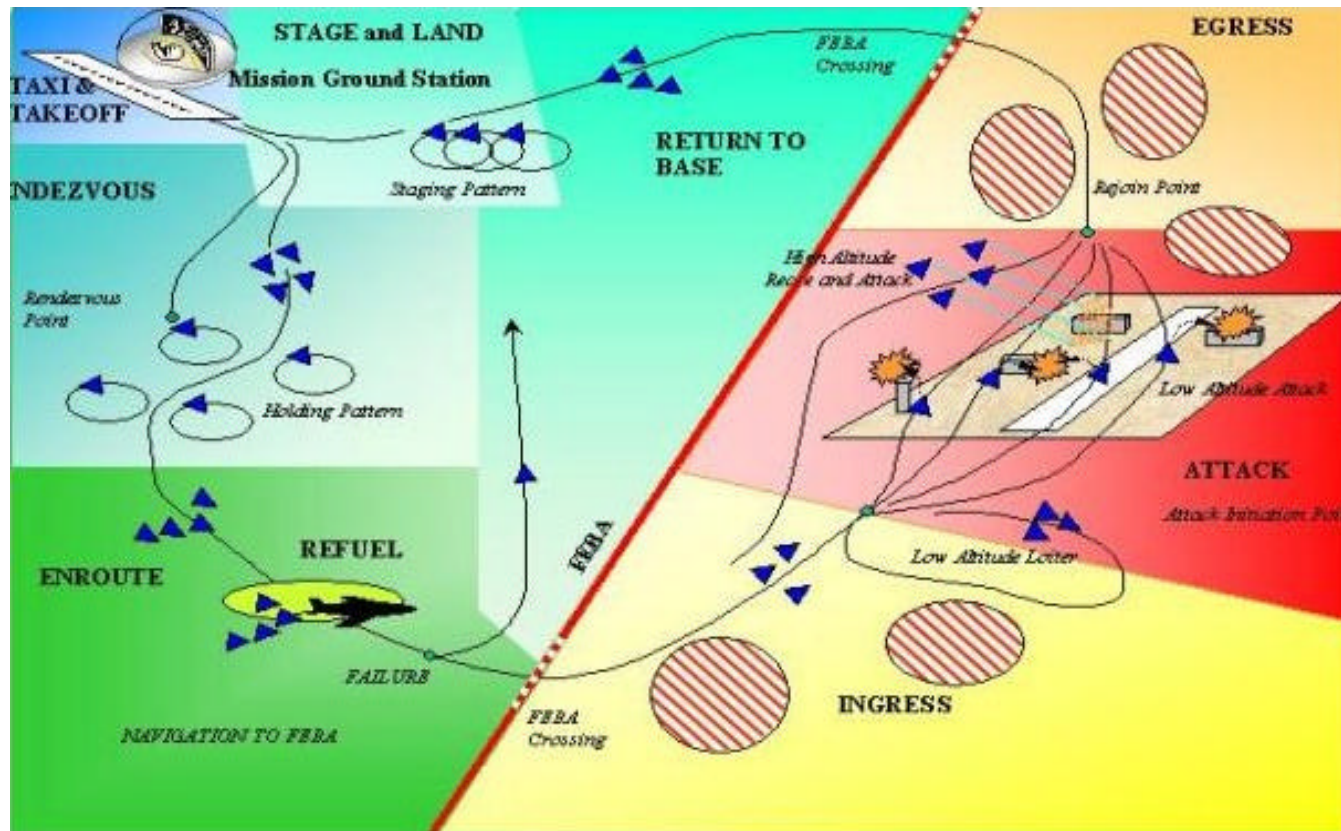


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Complete UAV Cooperative Aerospace Operations



*Enabling capability for seamless integration of
UAV's into the war fighter force structure*



*Airspace
Operations*

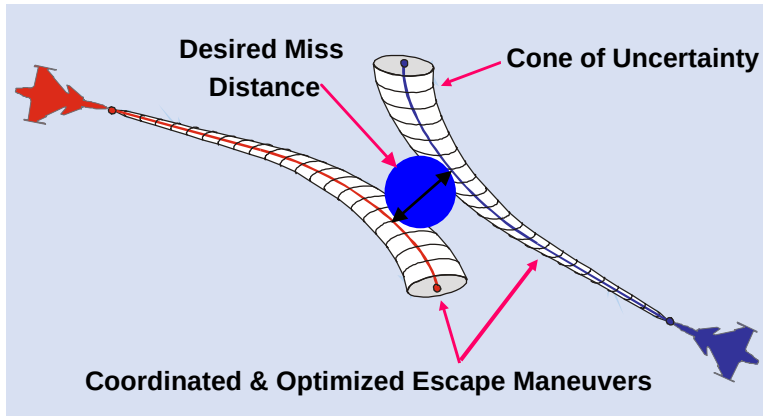
Persistent ISR

Strike UAV



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Airspace Operations Capabilities



- **Goals:**
 - Eliminate the 'specialness' associated with UAV's
 - Integrate seamlessly into emerging Air Traffic Control (ATC) System
- **Challenges:**
 - Capture the actions and procedures of pilots in the ATC (Normal and emergency)
 - Close proximity operations and real-time trajectory replanning, while also preventing mid-air collisions

Same Time, Same Base, Same Tempo



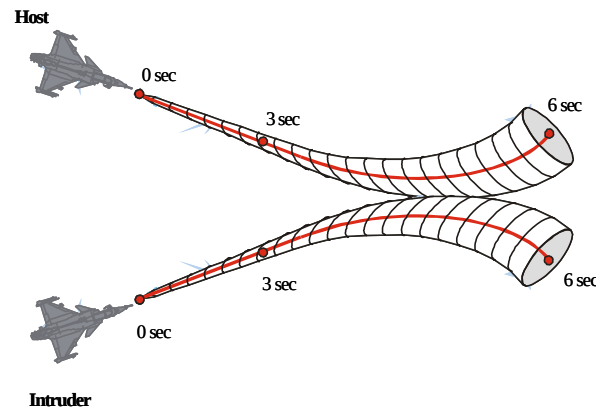
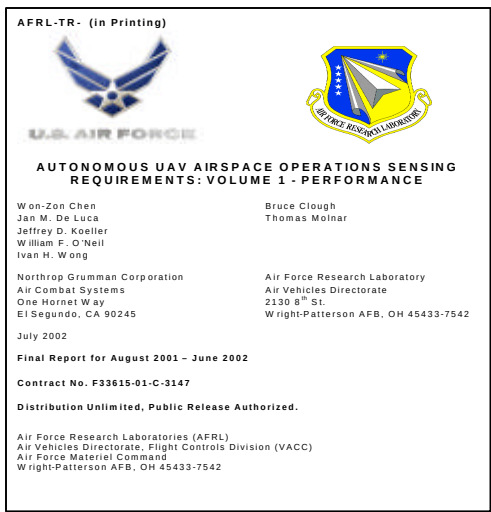
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VA Technologies that Enable Airspace Operations



Technology Innovation Enabling Airspace Operations

- Autonomous Flight Control Sensing Technology
- Automatic Air Collision Avoidance System
- Control of Multi-Mission UAV Systems





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Airspace Sensing Requirements Generated



- **Report Written On Encouragement Of AIAA**
- **Established Sensing Performance Requirements For Commercial And Military UAV In US Airspace**
- **AIAA Presentation Sep 03**

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AUTONOMOUS UAV AIRSPACE OPERATIONS SENSING REQUIREMENTS: VOLUME 1 - PERFORMANCE

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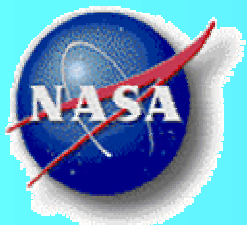


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Relationship to Access 5



ACCESS 5



Routine, safe, secure, and efficient HALE UAV operations in the National Airspace (NAS) within 5 years

- **Near term emphasis:**
 - Single operator – single vehicle
 - Commercial airspace
 - Limited set of airports
 - Longer timescale deconfliction

AFRL/VA



Make UAVs an integral part of military air operations:

“Same base, same time, same tempo”

Near term emphasis:

- Single operator – multiple vehicles
- Military airspace
- Mixed airspace, cooperative ops
- Short timescale collision avoidance
- Flight critical integration

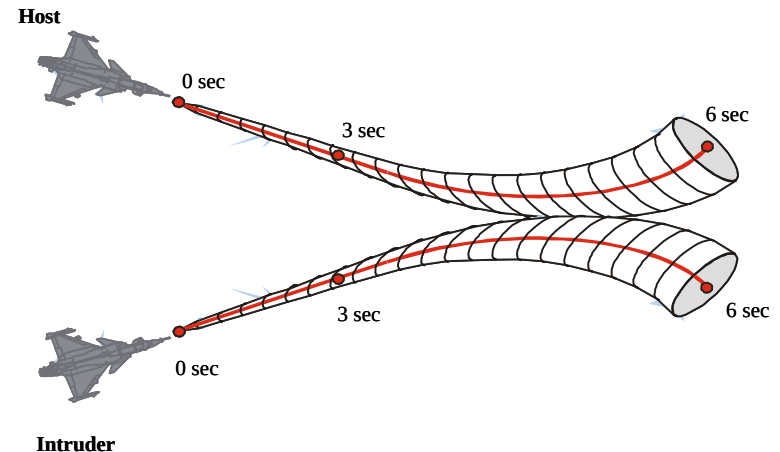
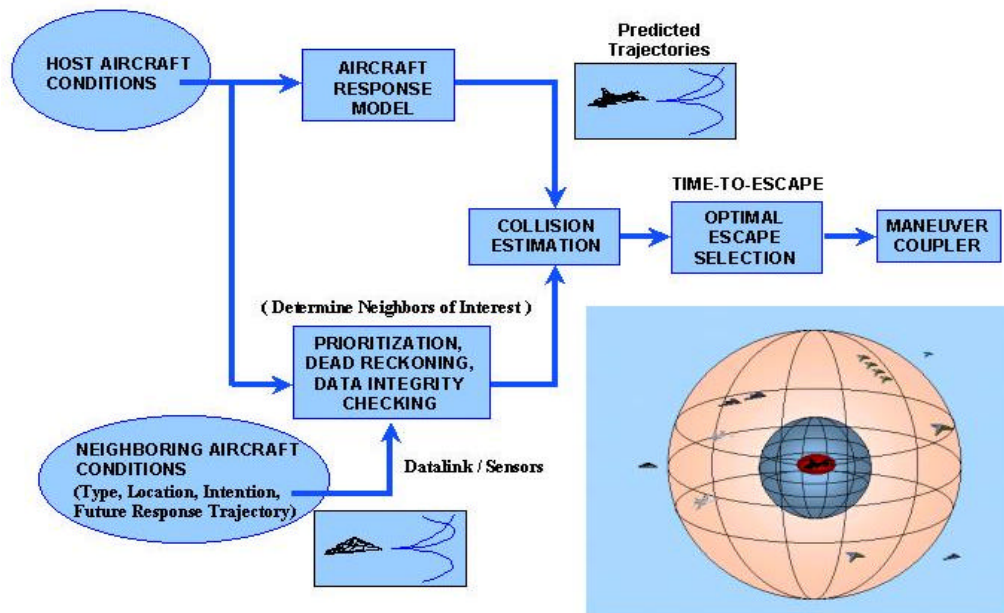


Automatic Air Collision Avoidance System (Auto-ACAS)



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Auto ACAS Focus: Algorithm That Uses Information About Location & Trajectory Of Self and Others to Predict Collisions and Plan/Execute Avoidance



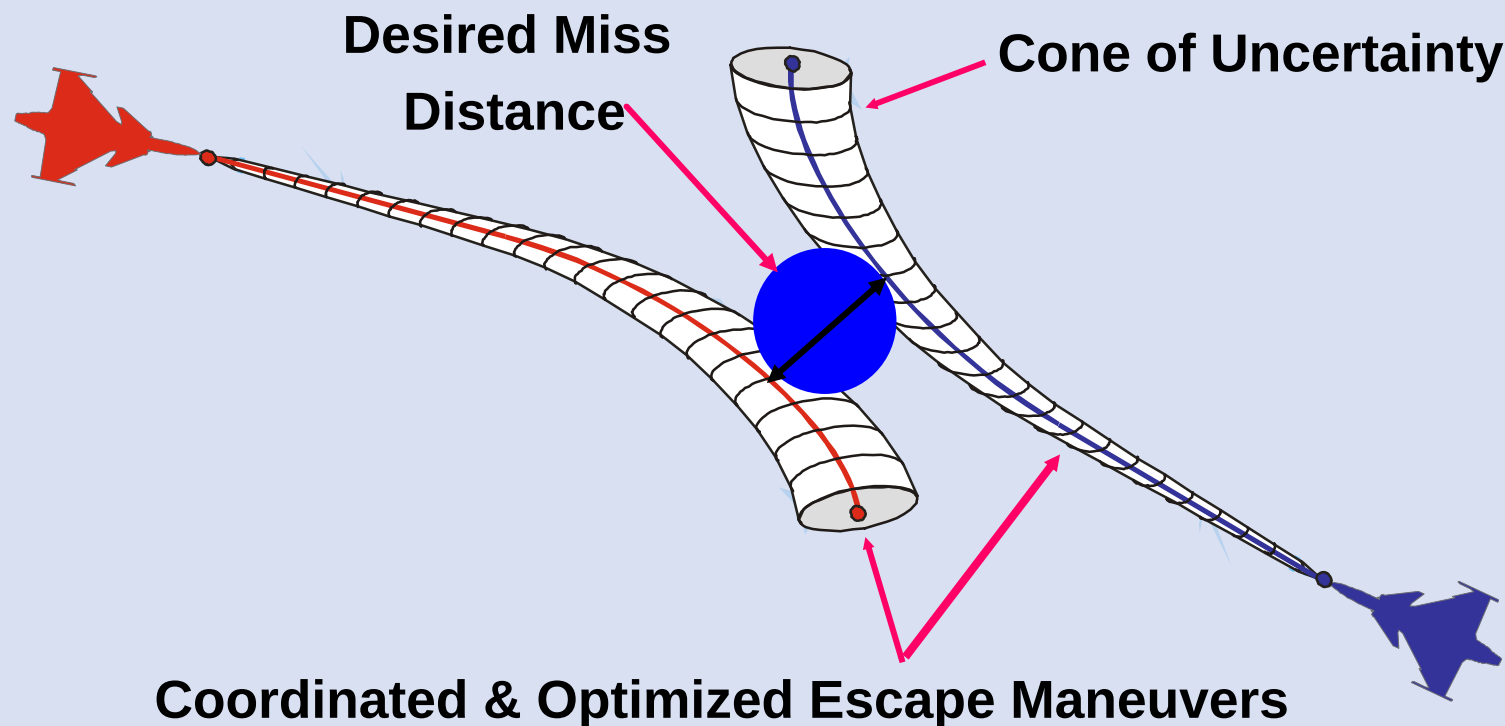


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Automatic Air Collision Avoidance System



Data latency and positional uncertainty is addressed by safety cones





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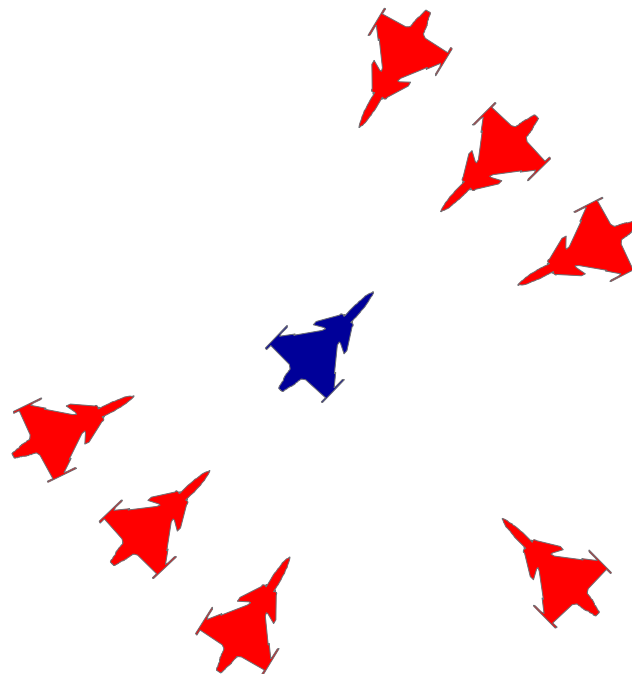
Auto-ACAS Flight Testing



33 Missions 43 Sorties 72.1 Flight Hours

Collision Runs

- 2-Ship Coop	33
- 2-Ship Non-Coop	9
- Virtual Fighter	327
- Virtual Multi-Ship	9
- Virtual UAV	7
- Pilot Activation	62



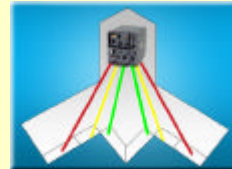
Algorithm operated successfully for all collision scenarios



Control of Multi-Mission UAV Systems



Open System
Architecture
VMS Computer



Multimode
Fly-by-Light
VMS



Health
Management



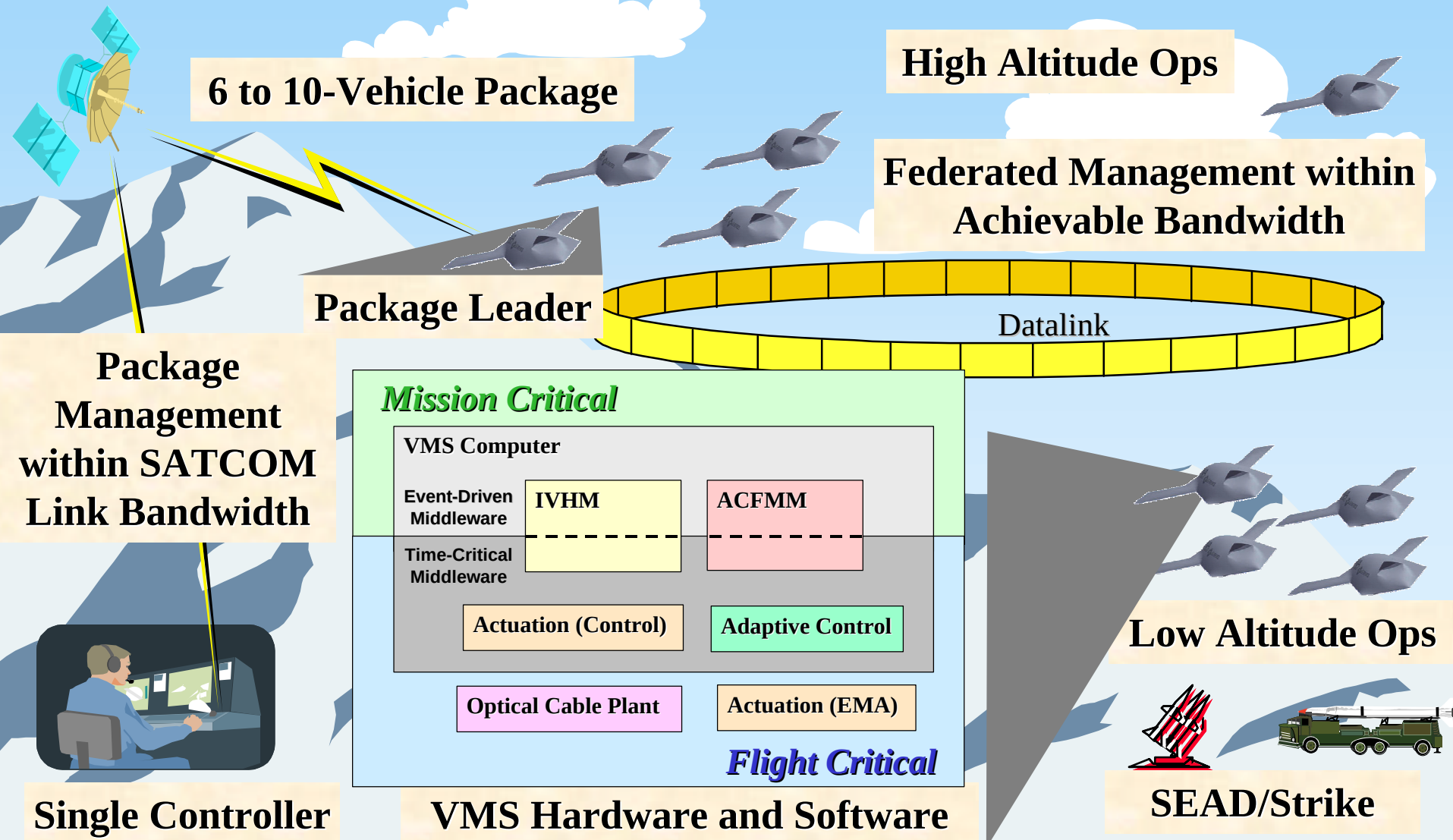
Adaptive
Control



Autonomous &
Cooperative
Flight/Mission
Management
(ACFMM)

- Compact, light weight, low cost VMS
- On-board, real-time, robust diagnostics
- Intelligent, adaptive flight control laws
- Intelligent, adaptive, cooperative flight management

Control of Multi-Mission UAV Systems



Objective: Demonstrate TRL 6 maturity of critical integrated technologies to achieve reliable, affordable, adaptive, autonomous control for effective multi-ship combat UAV operations

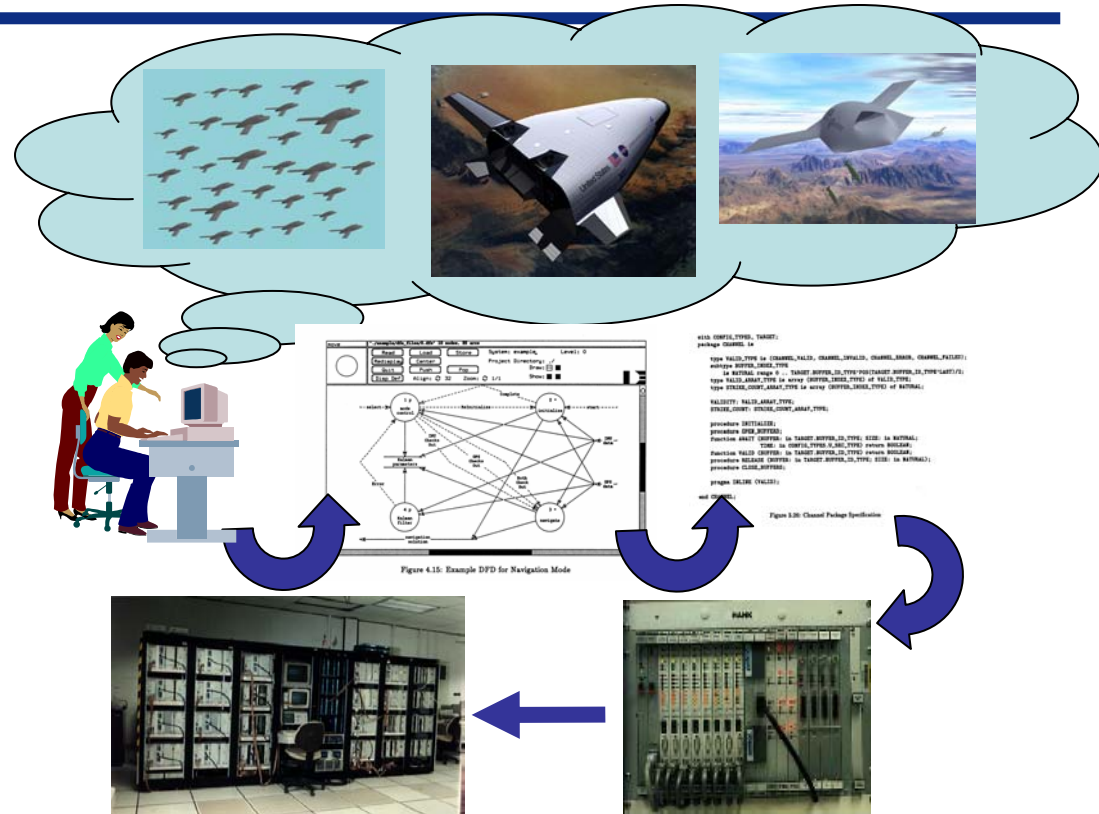


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Systems and Software Validation and Verification



- Emerging Functions
- Deficiencies Today
- New Processes
- Tech Devel Plan



Today: Software is a major cost/schedule driver for flight critical systems

Tomorrow: Advanced adaptive & autonomous algorithms can have nondeterministic behavior, making V&V difficult, if not unaffordable, given today's capabilities

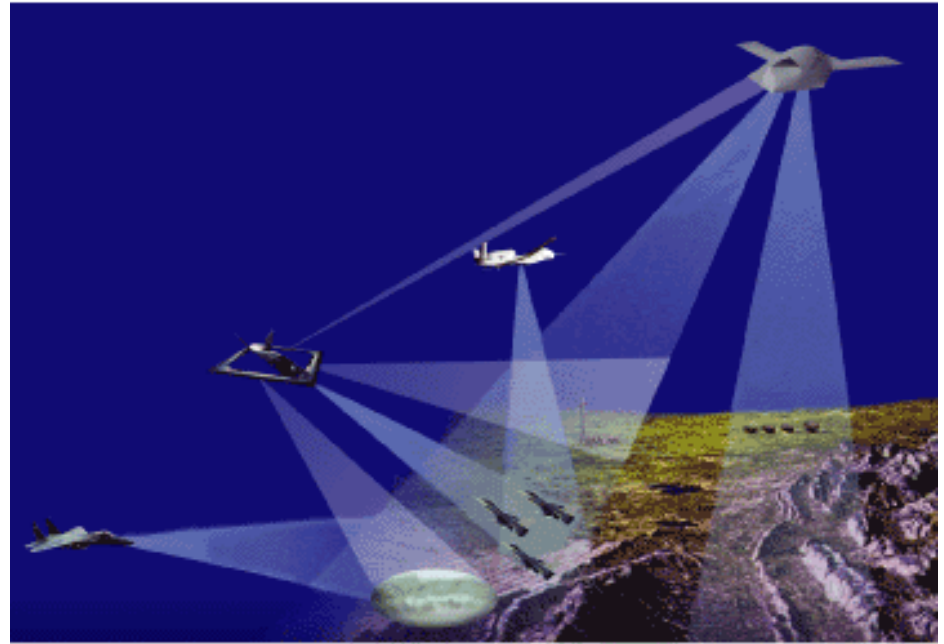


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Persistent ISR Capabilities



- Goals:
 - Air defense
 - Concealed ground targets
 - Moving & stationary
 - TBM defense
 - Battlespace awareness
- Challenges:
 - 360 degree coverage
 - On Station 24/7
 - Multi-function/Multi-sensor
 - Foliage penetration
 - Integrated/Fused data



**Detect and track every target that moves
on the ground or flies in the battlespace...
*anywhere, at any time***



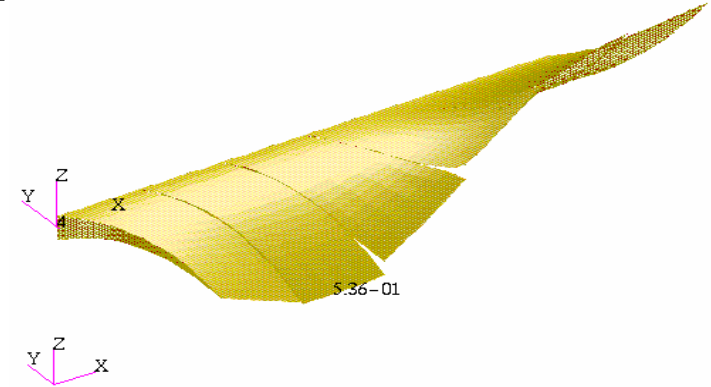
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VA Technologies that Enable Persistent ISR

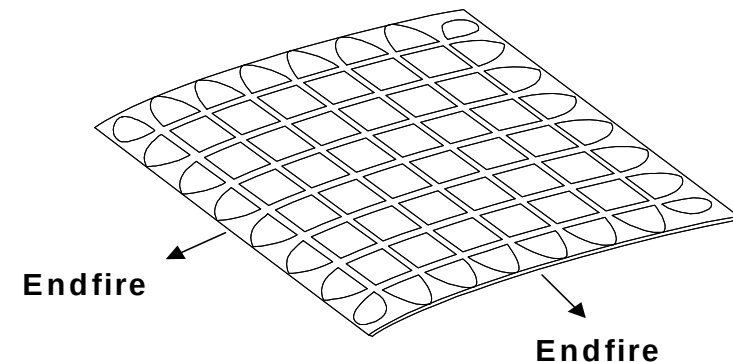
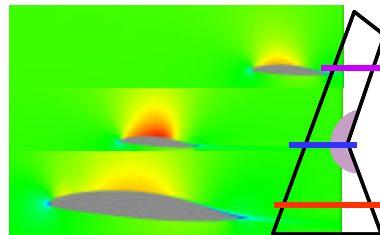


Technology Innovation Enabling Persistent ISR

- Advanced Aerodynamics
- Structurally Integrated Antennas
- Adaptive Structures



default_Deformation :
Max 5.36-01 @Nd 5282





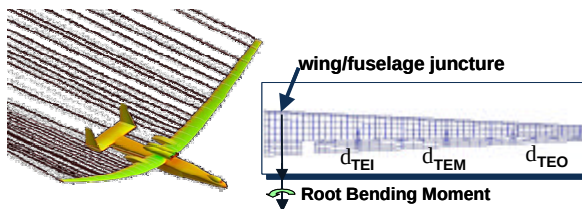
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Advanced Aerodynamics Enables Persistence



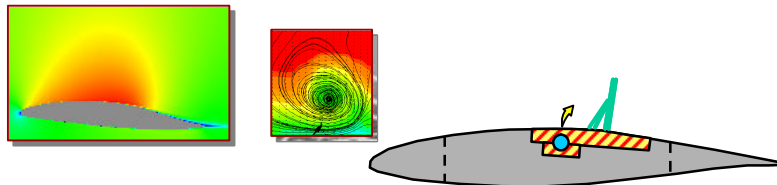
Active Aeroelastic Wing Deformation Management

- Aerodynamic Efficiency
- Manage Structural Loads
- Gust Load Alleviation

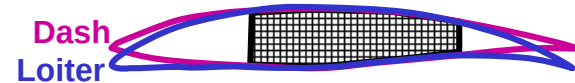


Active Separation Control

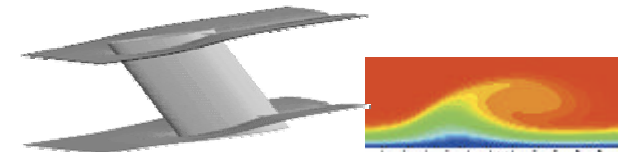
- Aggressive Airfoil Design
- Shock-Induced Separation



Physical Shape Change for Multipoint Optimization



Transition Control (Swept Wing Laminar Flow Control)



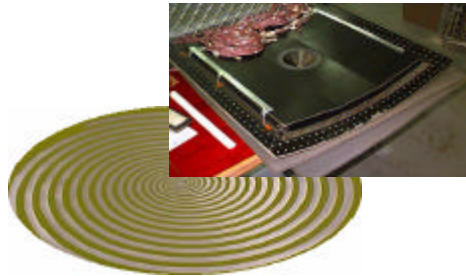
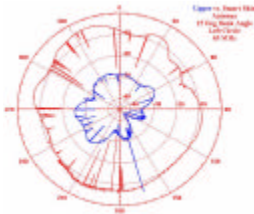


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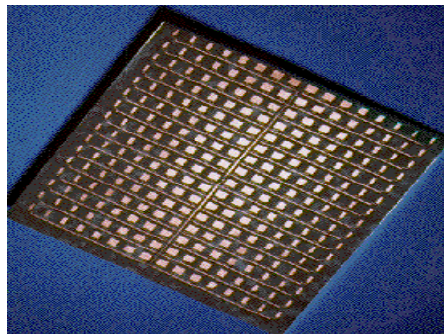
Structurally Integrated Antennas



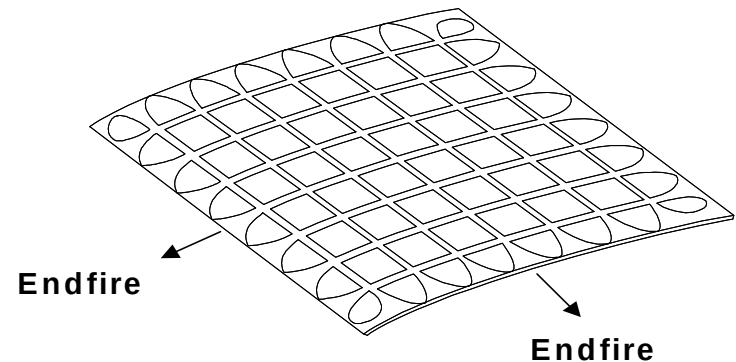
**Wide-Band COMM Antennas Eliminate
Blade Antennas and Dishes**



**Light weight, low-cost
X-Band Array
Integrated into Aircraft
Skins**



**End-fire Technology
Enables Large Low Band
Antenna in Wing**





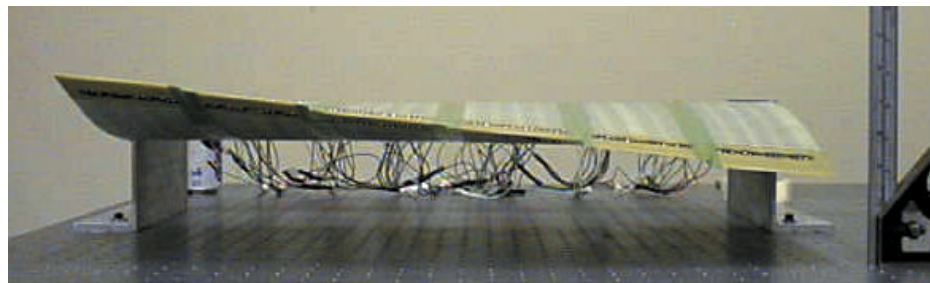
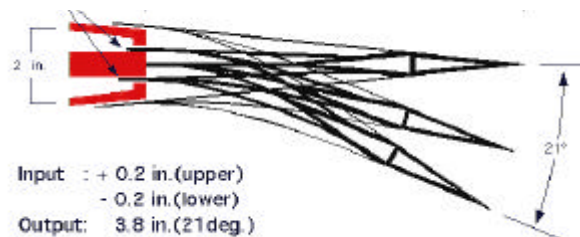
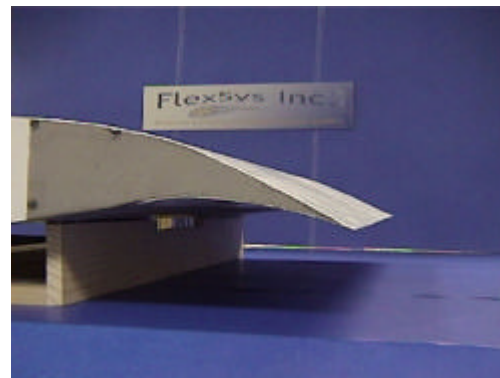
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Adaptive Structures

- **Shape changing airfoils**

- Enables aero performance across broad flight regime
- Provides control when room for control surfaces is limited
- Improves maneuver performance





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Strike UAV Capabilities



Capability First Gen Strike UAV

- J-UCAS X-45
- SEAD/DEAD
- Initial Aerial Refueling
- Initial "SEE/AVOID"
- Multiple vehicle per operator



Capability Second Gen Strike UAV

- Deep Strike
- Full Aerial Refueling Capability
- Electronic Attack
- Reduced footprint
- Flexible Mission Control
- Dynamic Mission Planning

Capability Advanced Strike UAV

- Directed Energy
- Collaborative "Swarms"
- Seamless Airspace Operations
- Interactive Autonomy
- Mixed Operations
- Information fusion
- "Self-Situational Awareness"
- Beyond J-UCAS ???



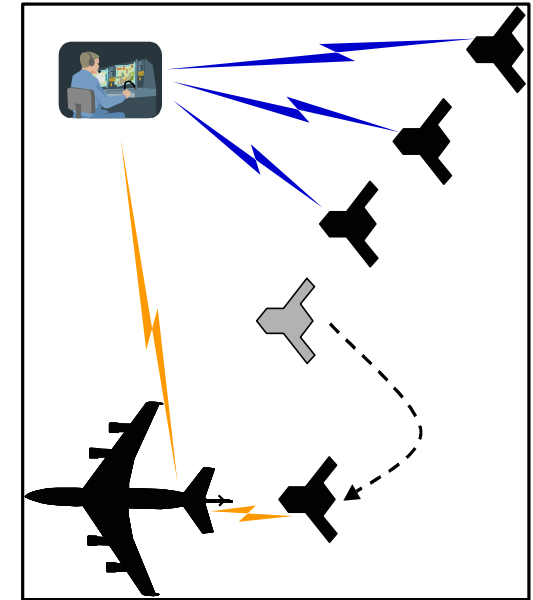
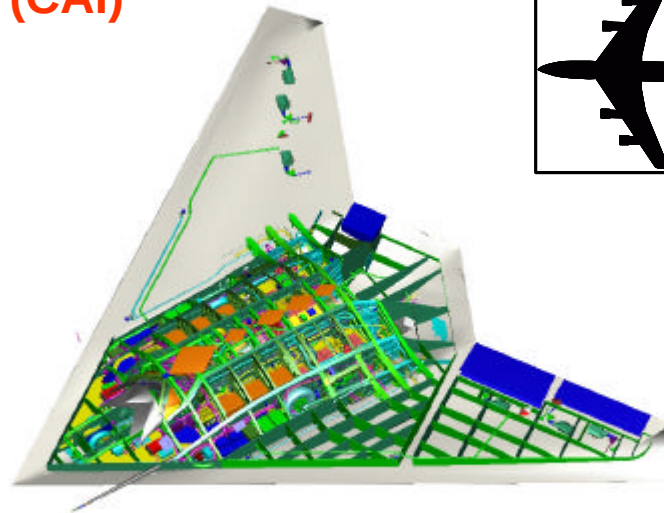
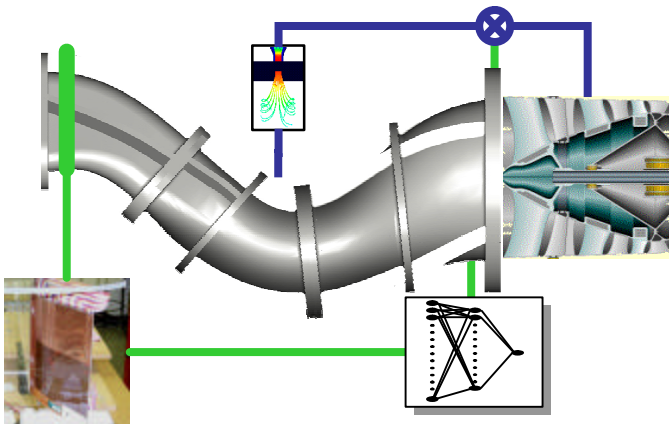
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VA Technologies that Enable “Strike UAV”



Technology Innovation Enabling Strike UAV's

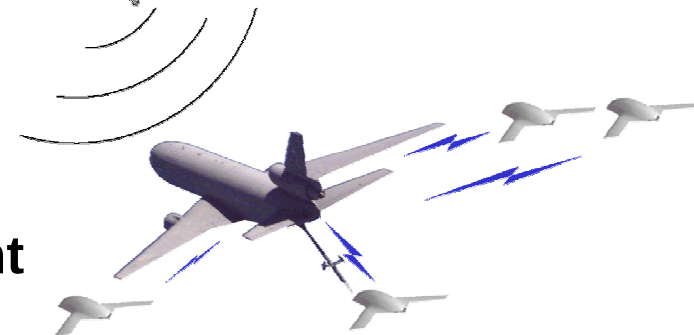
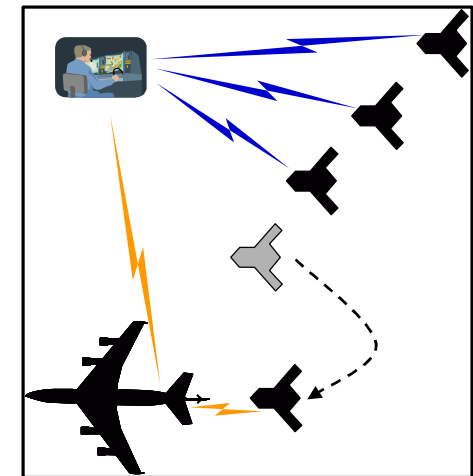
- Automatic Aerial Refueling
- Structurally Integrated Compact Inlet Technology
- Composites Affordability Initiative (CAI)





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Auto Air Refueling (AAR)



- VA is the World's Leader in AAR
- Operationally Relevant (Navigation & Sensing Based Solutions)
- Meet J-UCAS Transition Schedule (New Joint AAR Initiative is Underway)



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AAR Tech Challenges

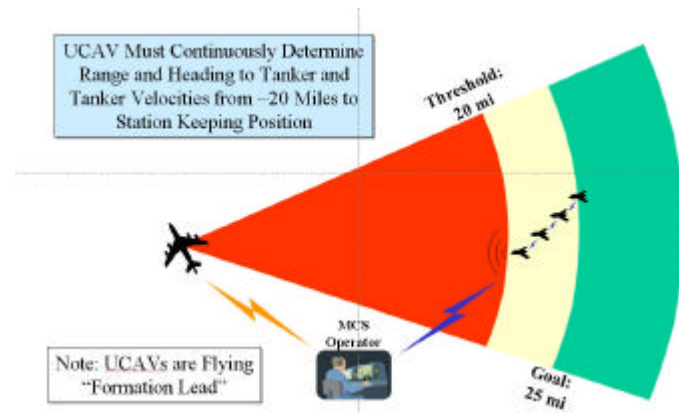


See Far

- **Determine Tanker Location from “Far Away”**
 - Detect/Track Tanker in Tanker Cell
 - Approx 50 Mile Range

See Near

- **Determine Relative Position with Tanker**
 - Using Position/Velocities to Close Control Loop
 - High Confidence in Position Accuracy



Command and Control

- **Assure J-UCAS Accurately Responds Boomer Break-Away Commands**
 - Commands are Flight Critical

Real World Considerations

- **Fitting Solutions into a Low Probability of Detect/Intercept Environment**
 - Latency, Drop-Outs, Re-Encryption, and Limit Power Settings

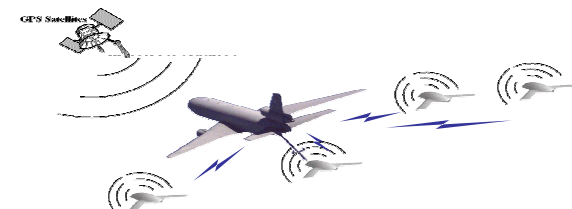
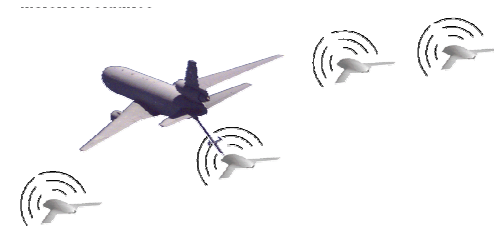


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Technical Approaches



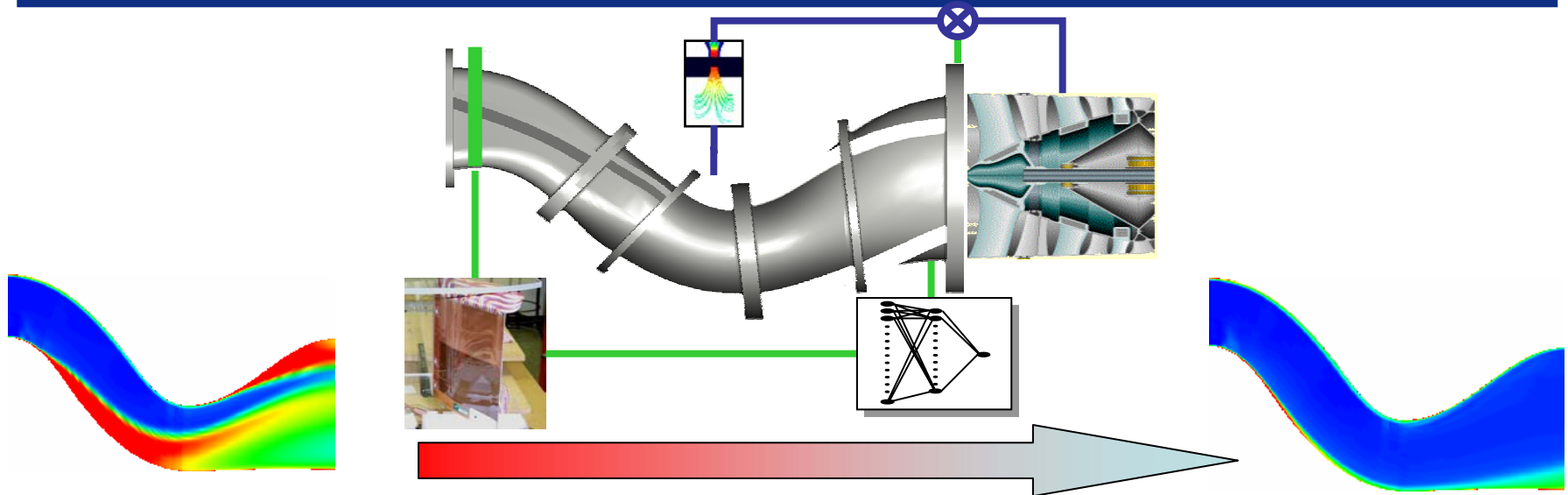
- Precision Navigation – Use Precision GPS/INS
 - Rendezvous with tanker
 - Maneuvering Around Tanker
- Sensor Based Approach
 - Limited Rendezvous Capability
 - Maneuvering Around Tanker
- Hybrid Design – Standard GPS + Sensor
 - Rendezvous with Tanker – GPS
 - Maneuvering Around Tanker – Sensor





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Structurally Integrated Compact Inlet Technology (STRICT)

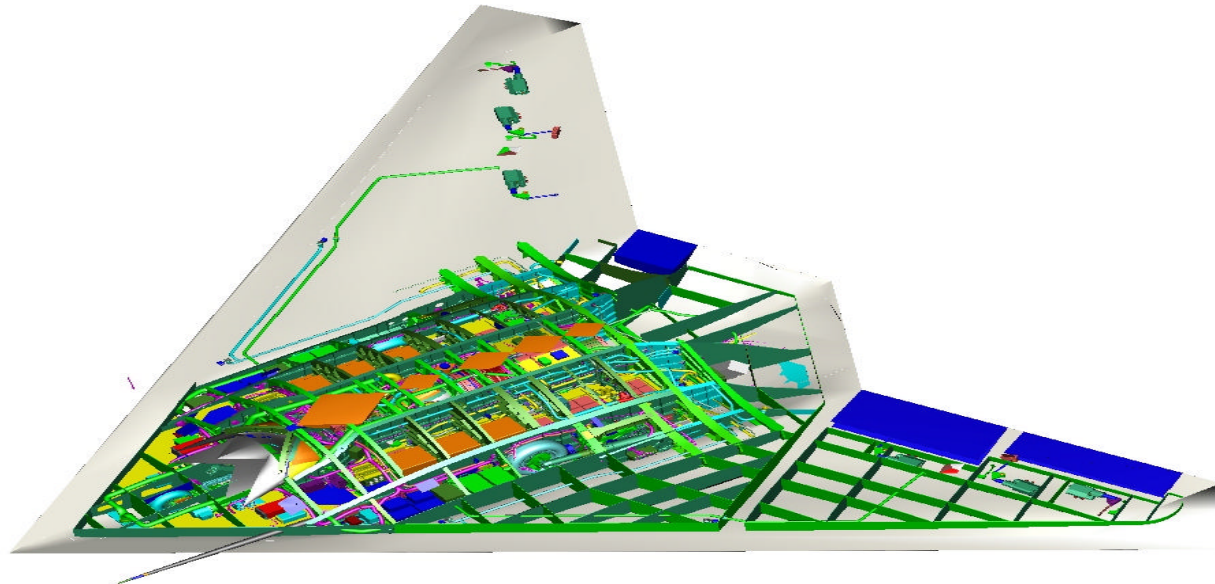


- **STRICT is VA's first step into Active Integrated Inlet Technology:**
 - Reduced weight – downsize vehicle or reduce volume of the engine
 - Increase installed thrust
 - Reduce high-cycle fatigue
 - Latitude in center of gravity location



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Composites Affordability Initiative (CAI)

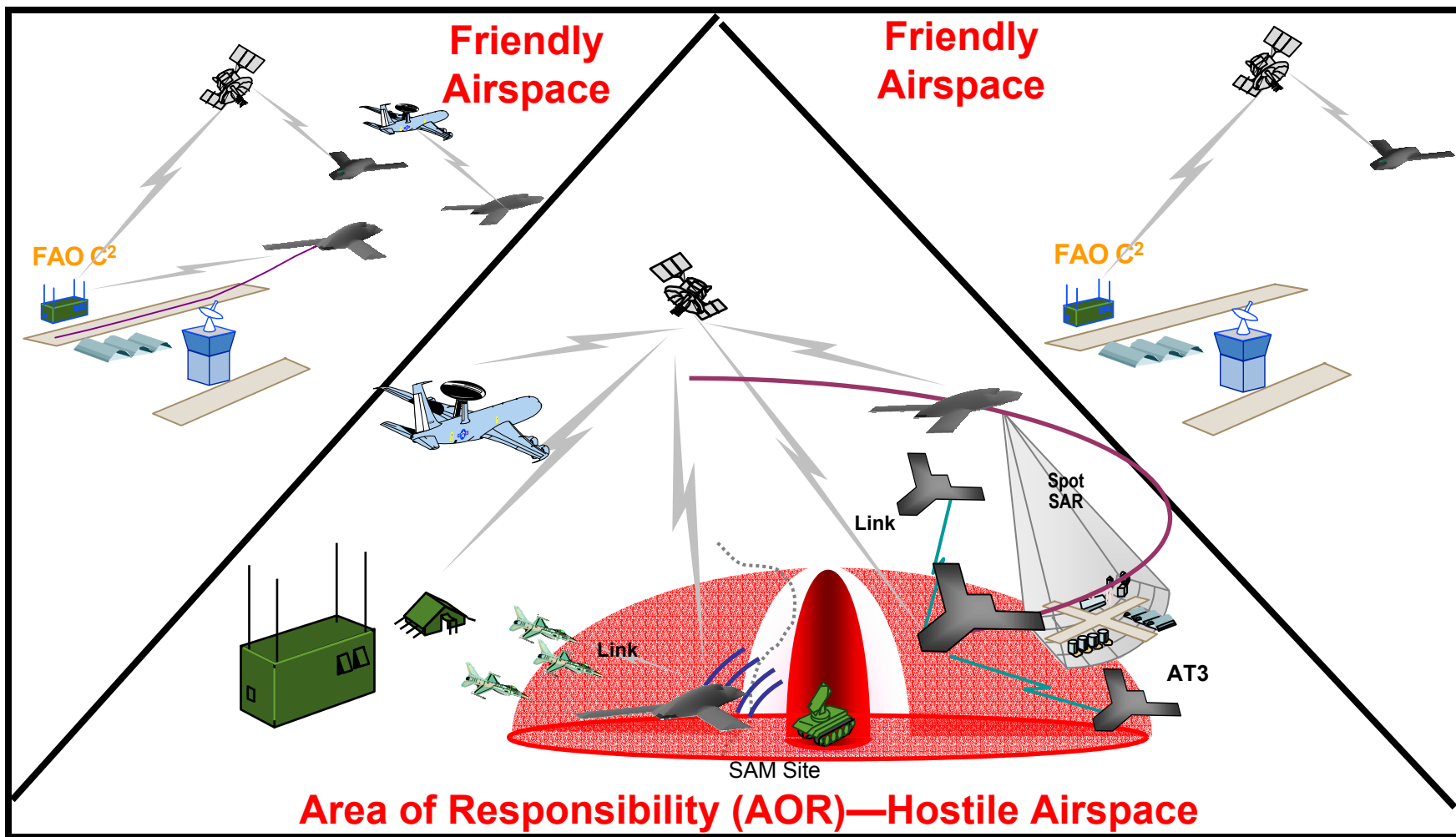


- **Improve structures technology that will lead to:**
 - **Paradigm change – We no longer have to pay to reduce weight**
 - **Reduced cost to manufacture, operate, and support**
 - **Increase range, payload, and performance by reducing weight**



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Complete Mission Operations





Air Vehicles Directorate



... 100 years of flight and counting ...



“We give the Air Force its Wings”



U.S. AIR FORCE



Backups



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Autonomy Continuum

