

SAE Salt Lake City
Tuesday, March 3, 2005

Barron Associates, Inc. Current Research

SAE International
Aerospace Control & Guidance Systems Committee

Salt Lake City, UT
March 3, 2005

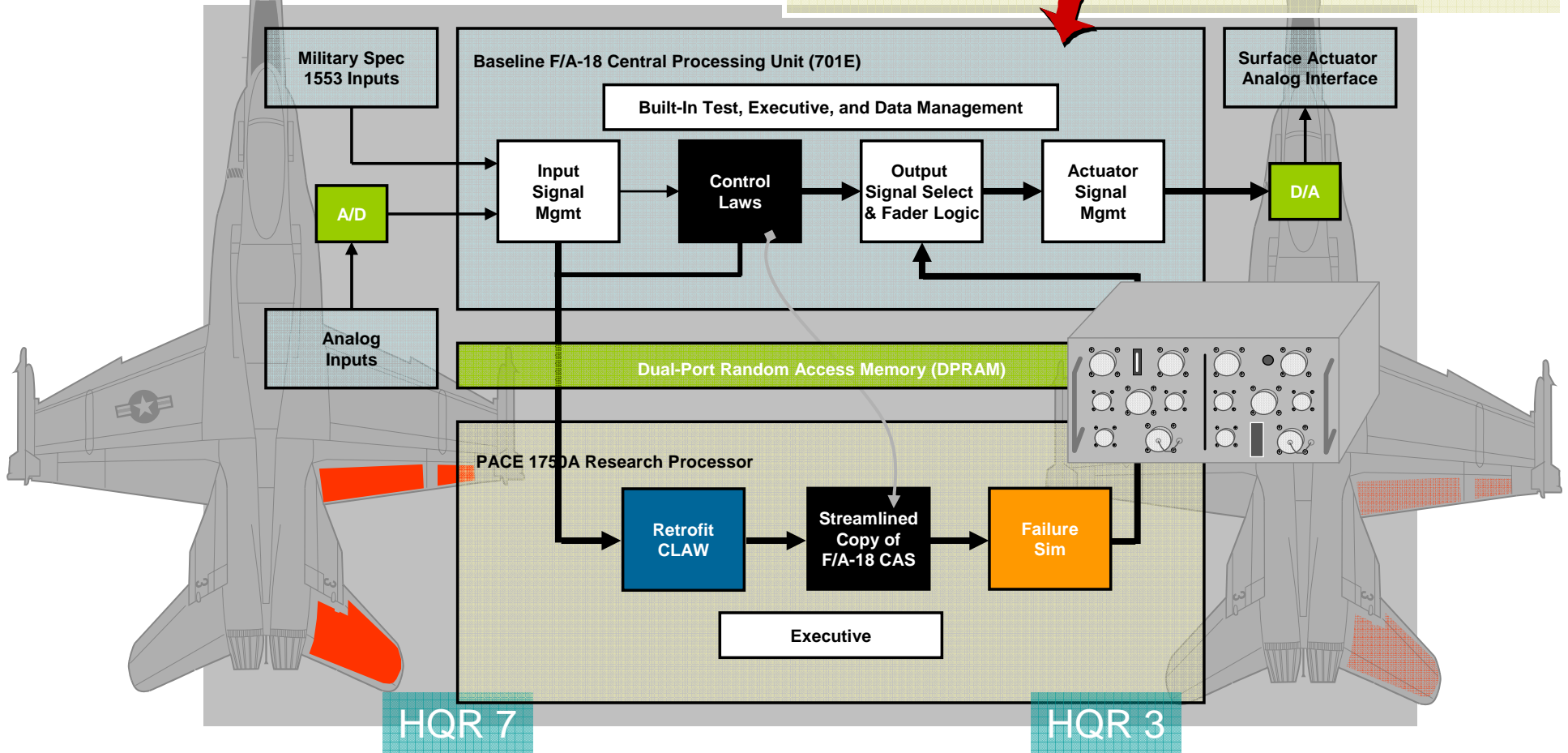
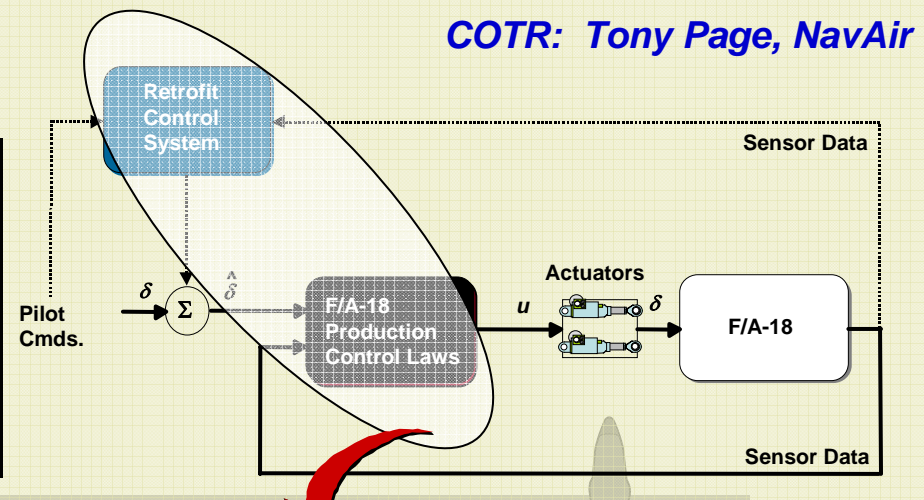
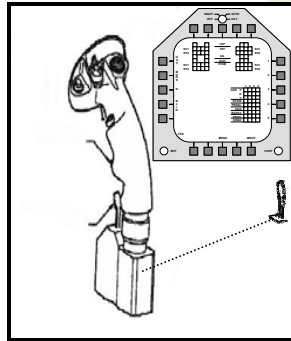
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F/A-18 Flight Controls Retrofit

NAVAIR SBIR Phase II and Phase III IDIQ

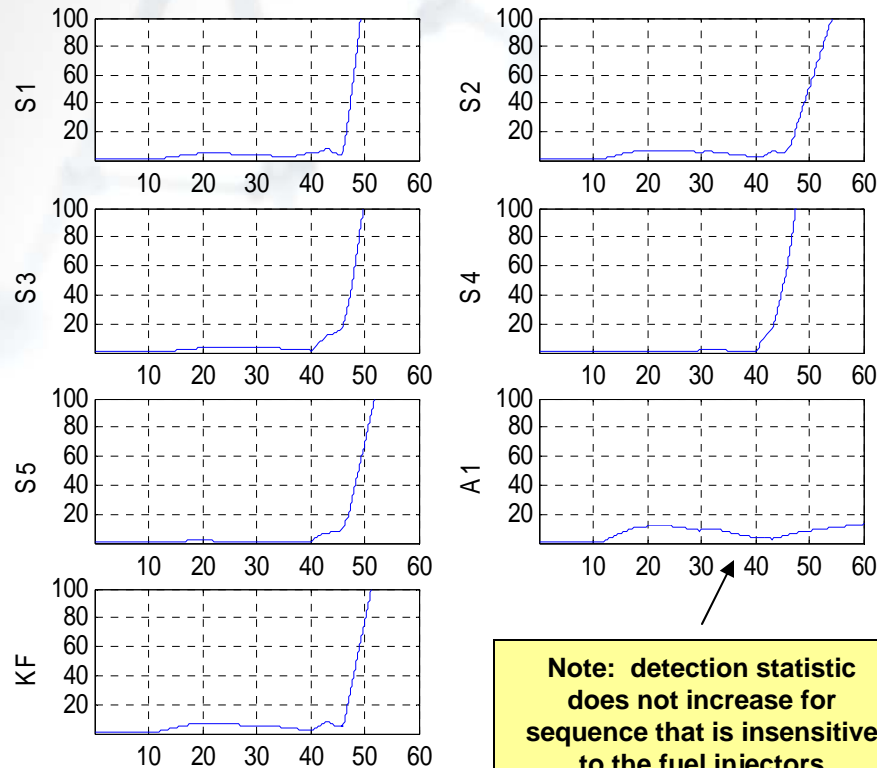
COTR: Tony Page, NavAir

Implemented in US Navy Fleet Support Flight Control Computer (FSFCC) for Seamless Integration with F/A-18



Fault Detection and Isolation for Dynamic Systems

*Transport Aircraft Flight Control Systems
Marine Diesel Engine Applications*



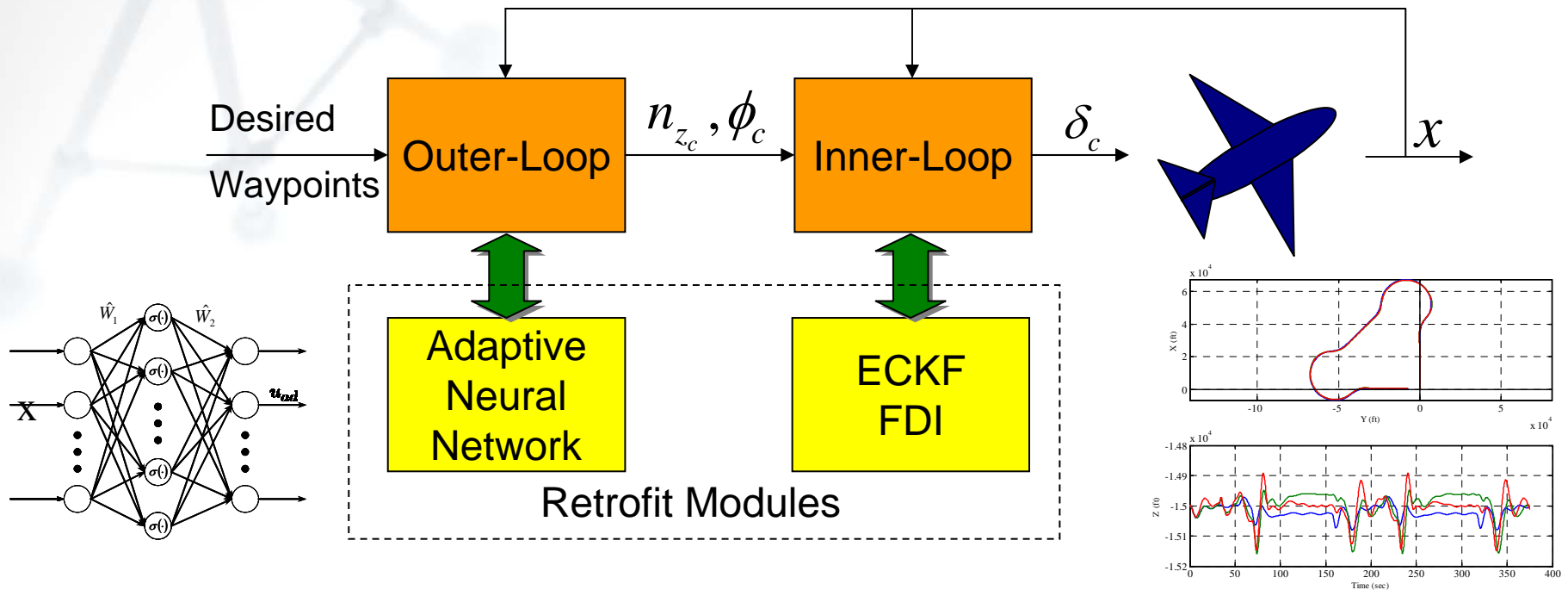
**Fuel Injection Volume Low Fault
at t = 40 seconds**

Flight Testing on NASA's Transport Remote Piloted Vehicle by FY '06

Robust fault isolation is achieved by rigorously exploiting analytic redundancy within the system

No complex fault isolation logic is required – no faulted training data is required

Adaptive Retrofit for Transport Aircraft



Outer-Loop Adaptation

- Track reference model
- Adapt multi-layer neural network to minimize tracking errors
- Inject augmented Guidance Error Signals

Fault Detection and Isolation

- Extended constrained Kalman filter (ECKF)
- Detects and isolates sensor and surface faults
- Informs inner-loop controller of system deficiencies

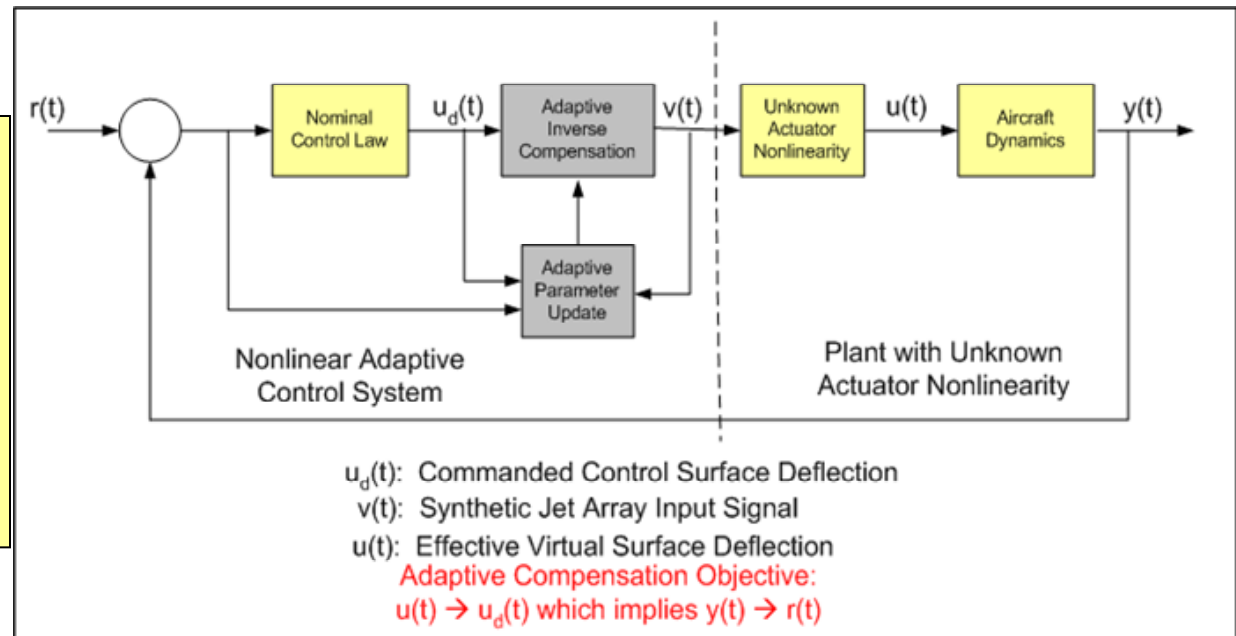
Active Flow Control Using Synthetic Jet Actuators

Adaptive inverse techniques for controlling arrays of synthetic jet actuators

COTR: Dr. Sharon Heisi, AFOSR

Objectives:

- “Virtual” shaping of airfoils at low angles of attack
- Delaying flow separation at high angles of attack



Innovations:

- Concept for an arrangement of synthetic jet arrays that facilitates virtual shaping of an airfoil at low angles of attack
- Practical, implementable adaptive control algorithm based on adaptive inverse techniques that have been proven effective in many previous applications in systems with unknown actuator nonlinearities
- An adaptive actuator failure compensation approach that optimizes the performance of the control system in the presence of unknown failures

AFOSR Phase I STTR with the University of Virginia and the University of Wyoming



CAV GUIDANCE & CONTROL REQUIREMENTS STUDY

AFRL, Barron Associates, Ping Lu/Iowa State
Dr. D. Doman, Program Manager, Funded by DARPA



OBJECTIVE

- Assess potential IAG&C benefits for CAV

TECHNICAL CHALLENGES

- 3-D trajectory generation
- Limited control authority & redundancy
- Modeling and identification of ablation effects, other uncertainties
- Achievement of tight terminal objectives

APPROACH

- Develop adaptive real-time implementable terminal and entry guidance algorithms
- Develop bi-conic CAV simulation model with ablation effects (on mass properties & aero data)
- Test algorithm performance in 6 DOF CAV simulation
- Assess ability to meet 3m CEP/specified impact angle capability with/without adaptive G&C

Bi-conic CAV



INTELLIGENT, REAL-TIME ENTRY PATH PLANNING REQUIRED

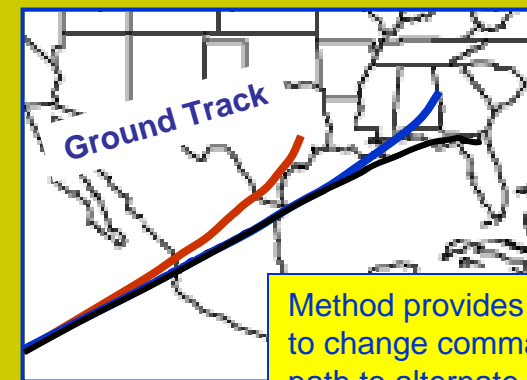
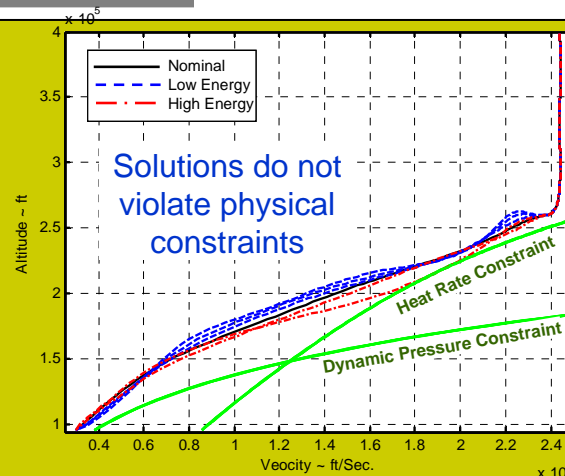
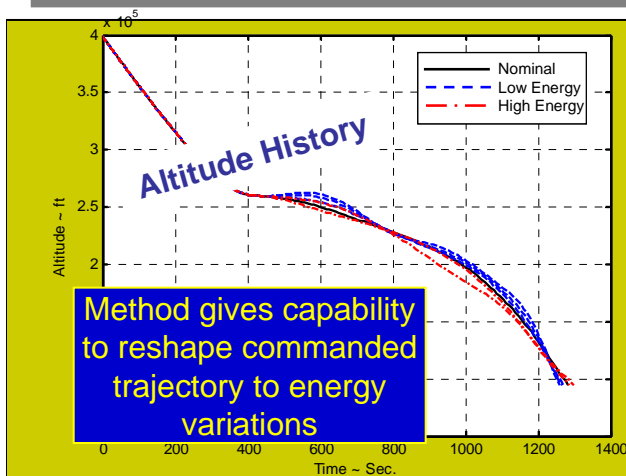
- Limited control authority requires very tight tolerances on terminal guidance handoff
- Aero uncertainties/ablation effects
- Capability to hit moving target, change to different target, or call off mission

OUR APPROACH

- Novel method for in-flight trajectory optimization
- Model trajectory as a small number of critical parameters that define its shape
- Search for optimal set of parameters – can be done in real-time w/o loss of accuracy

PRELIMINARY RESULTS

- CEP requirements cannot be met without adaptation - both in entry and terminal guidance phases

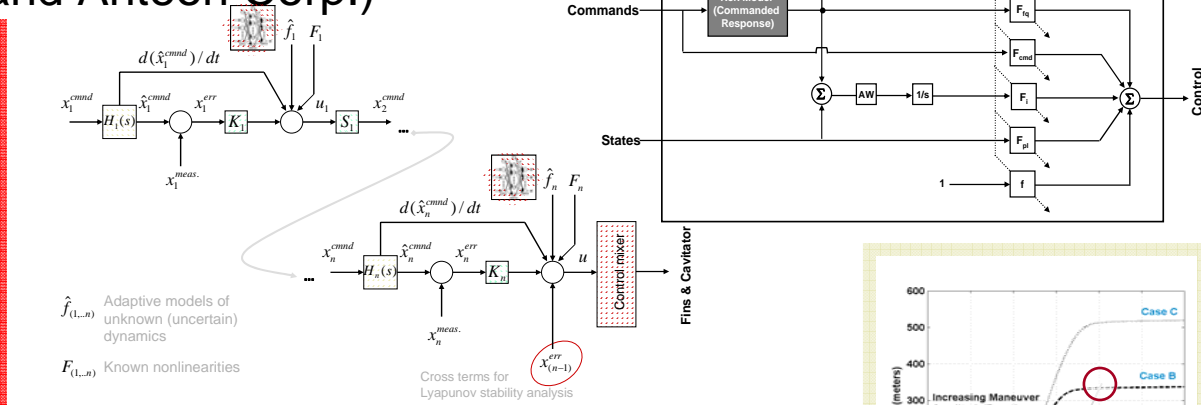


High-Speed Supercavitating Torpedo

ONR SBIR Phase I (with Musyn and Anteon Corp.)

Summary

- Control system design & analysis (adaptive receding horizon and neural-network adaptive backstepping)
- High-fidelity simulation and Monte-Carlo analysis (demonstrated benefits of adaptation over nonadaptive control laws for model uncertainties)
- HSSV Design Req'm'ts and Engagement Scenario Sim.

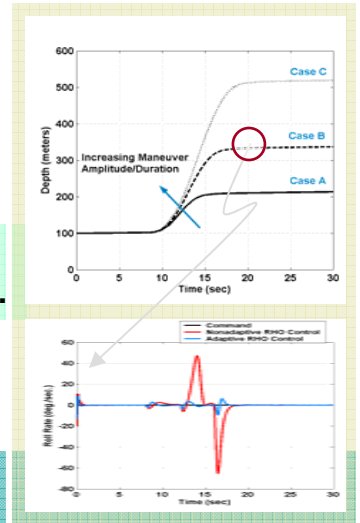


Cavitator Base Drag: Nominal Fin F&M Coefficients: Nominal	Roll Axis	Pitch Axis	Yaw Axis
Roll Doublet (+30 deg./sec., 8 sec. Manoeuvre)	Good	Good	Good
Pitch Doublet (+10 deg./sec., 8 sec. Manoeuvre)	Good	Good	Good
Yaw Doublet (+10 deg./sec., 8 sec. Manoeuvre)	Good	Good	Good

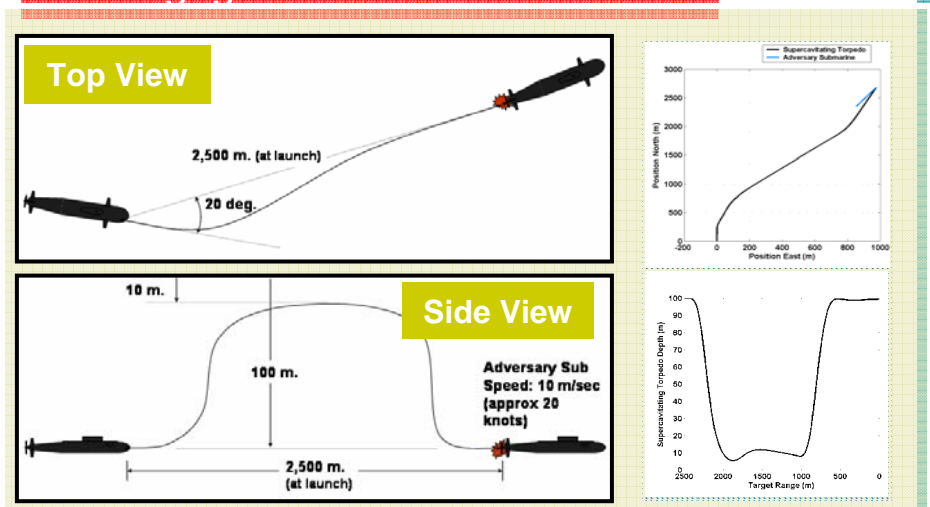
Cavitator Base Drag: +15% Fin F&M Coefficients: O(+45%)	Roll Axis	Pitch Axis	Yaw Axis
Roll Doublet (+30 deg./sec., 8 sec. Manoeuvre)	Good	Good	Good
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High-Fidelity Sim. & Monte Carlo Eval.



Phase II



Real-Time Hardware Sim. Dev. & Testing

Real-time Hardware Sim. Dev. & Testing

Actuator Integration & WT Testing

Input Signals

Fin & Cavitator

Roll Rate

Pitch Rate

Yaw Rate

Control

Roll Parameters

Pitch Parameters

Yaw Parameters

Roll Reference Adaptive Control Law (May 9 Function)

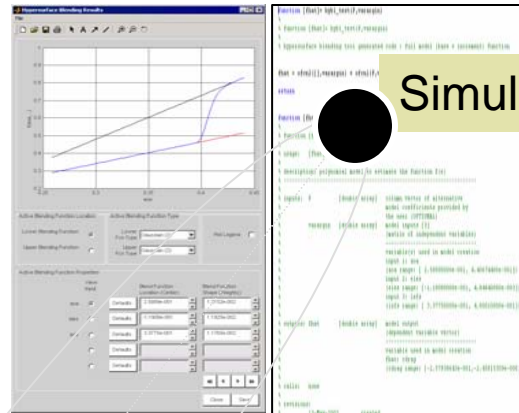
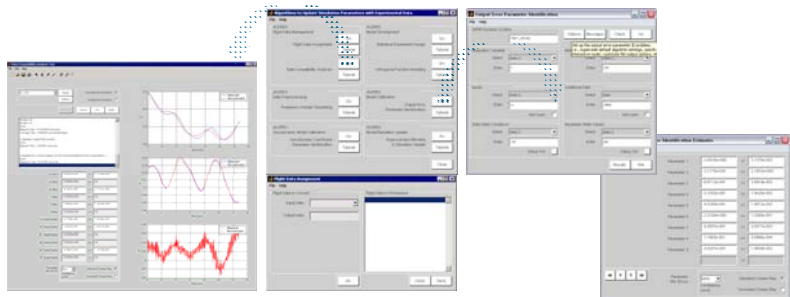
Pitch Reference Adaptive Control Law (May 9 Function)

Yaw Reference Adaptive Control Law (May 9 Function)

Control

M&S and Scientific Software

AUSPEX MATLAB ENVIRONMENT
Data modeling, model calibration,
and simulation updating ...

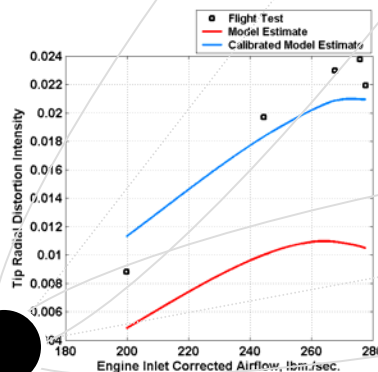


Simulation

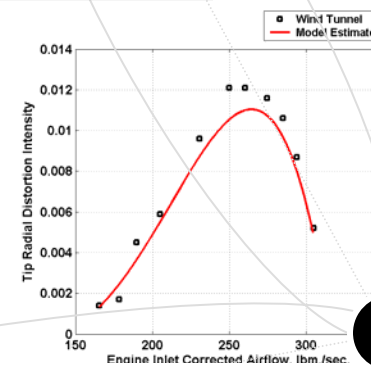


Example ...
IHS Test
Data Analysis

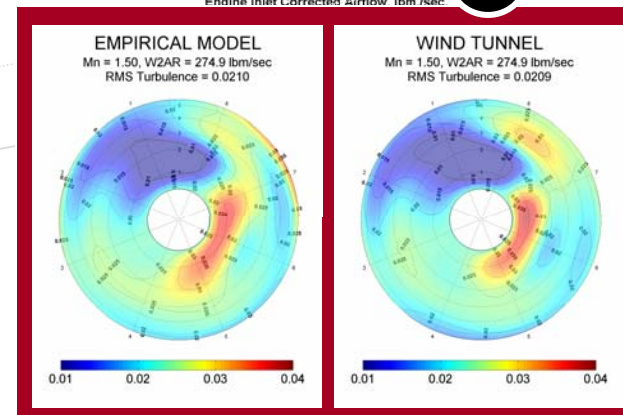
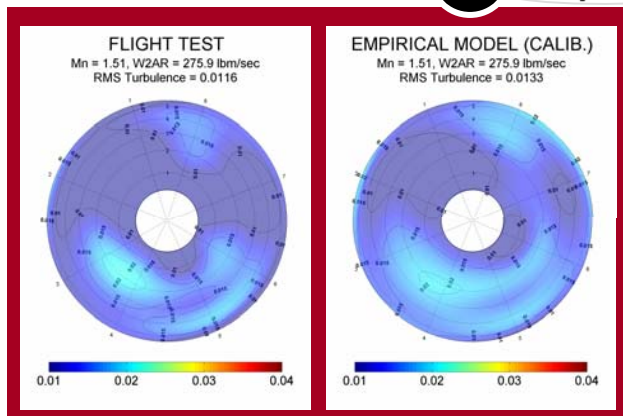
Example ...
F/A-18 Flight Data Analysis
Data Compatibility, Aero
Modeling, and Simulation
Updating with Flight Data



Flight Test



Wind Tunnel



Example ...
F/A-22 Wind Tunnel and Flight Data Analysis
Inlet Flow Descriptor Modeling
WT Model Update/Calibration with Flight Data

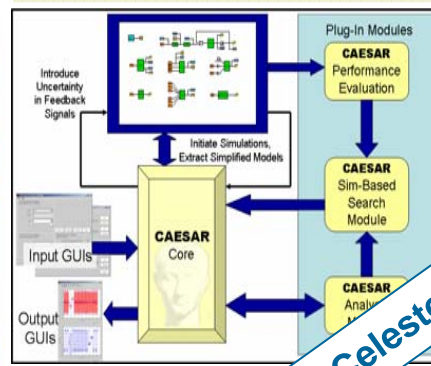
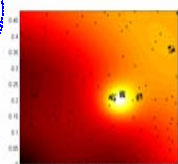
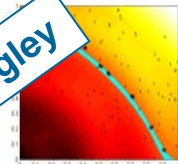
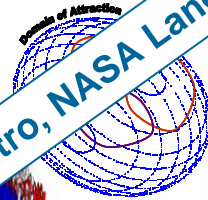
Analysis Methods, Software Tools, and Novel System Designs

V&V Through the Control Law Life Cycle



RASCLE
Simulation-based
Analysis

Analysis Method



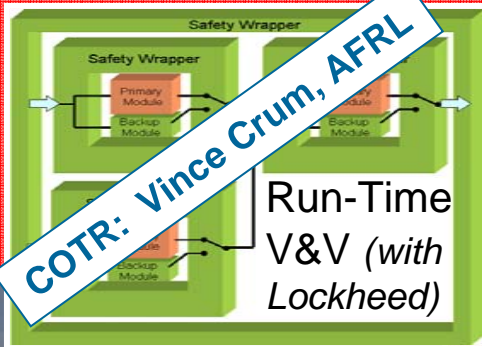
COTR: Celeste Belcastro, NASA Langley

Flight Testing



Automated Off-Line Test
Of Stability, Robustness,
and Performance (with *MuSyn*)

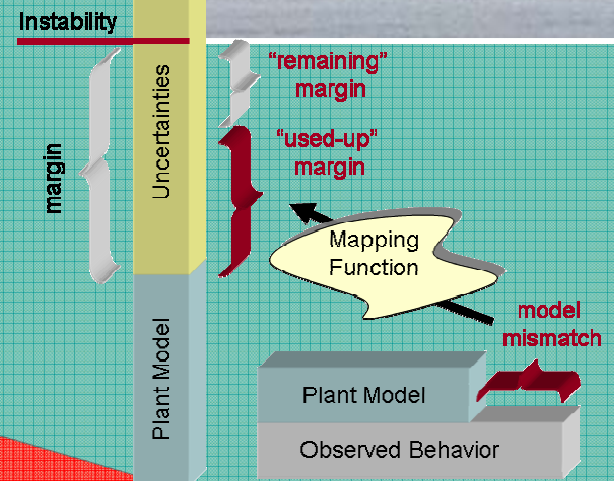
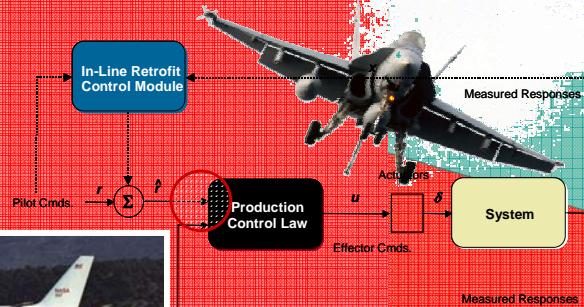
Real-Time
Monitoring of
Safety Margins
(with *MuSyn*)



COTR: Vince Crum, AFRL

Run-Time
V&V (with
Lockheed)

Retrofit Flight
Controls



Production Vehicles

