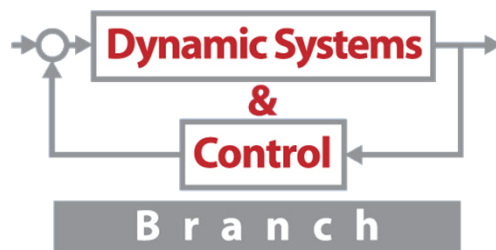


Flight Dynamics & Control at LaRC Update

ACGSC Meeting 110
October 10, 2012

Carey Buttrill



(D316)



(D317)



Outline

- Learn to Fly
- Sierra Nevada's Dream Chaser
- AirSTAR Future Directions
- Aviation Safety



Safety

Sr. Safety Eng.
Safety Eng.

RESEARCH DIRECTORATE (D3)

Director

Deputy Director

Deputy Director for Program Development
Director for Facilities & Laboratories Ops.
Assoc. Director for Resource Management
Director for Program Development
Associate Director for Facilities Operations
Assoc. Director for Laboratories Ops.
Executive Secretary

Chief Engineers (CE) & Tech Leads

CE for Testing Technologies
CE for Test Ops Excellence
CE for Hypersonics
CE for Aerodynamics
CE for Materials & Structures
CE for Acoustics
CE for Airborne Systems
CE for Measurement Sciences
Agency NDE Specialist
Lead for Business Partnership
Senior Project Portfolio Manager
Fac. & Lab Investments Mgr.

Resource Management Team

ATP Business Mgr.
Business Mgr.
Program Analyst (3)
Sr. Adm. Officer
Adm. Officer (3)
TEAMS II Center Mgr.
NIA COR
SMAAART COR
IT Manager
Program Specialist

**D301 Configuration
Aerodynamics Branch**

**D302 Computational
Aero-Sciences Branch**

**D303 Flow Physics
and Control Br**

**D304 Advanced
Sensing & Optical
Measurement Branch**

**D305
Aerothermodynamics
Br**

**D306 Hypersonic
Airbreathing
Propulsion Branch**

**D307 Advanced
Materials &
Processing Branch**

**D308 Aeroelasticity
Branch**

**D309 Durability,
Damage Tolerance, &
Reliability Branch**

**D312 Structural
Mechanics &
Concepts Branch**

**D313 Nondestructive
Evaluation Sciences
Branch**

**D314 Aeroacoustics
Branch**

**D316 Dynamic
Systems & Control
Branch**

**D317 Flight
Dynamics Branch**

**D318 Crew Systems &
Aviation Operations
Branch**

**D319
Electromagnetics &
Sensors Branch**

**D320 Safety-Critical
Avionics Systems
Branch**

**D321 Structural
Acoustics Branch**

**D322 Structural
Dynamics Branch**

**D325 Materials
Experiments Br**

**D326 Structures
Experiments Br**

**D327
Subsonic/Transonic
Testing Branch**

**D328
Supersonic/Hypersoni
c Testing Branch**

**D329 Structures
Testing Branch**

**D330 Technologies
Application Branch**

**D331 Revolutionary
Aviation Technologies
Branch**

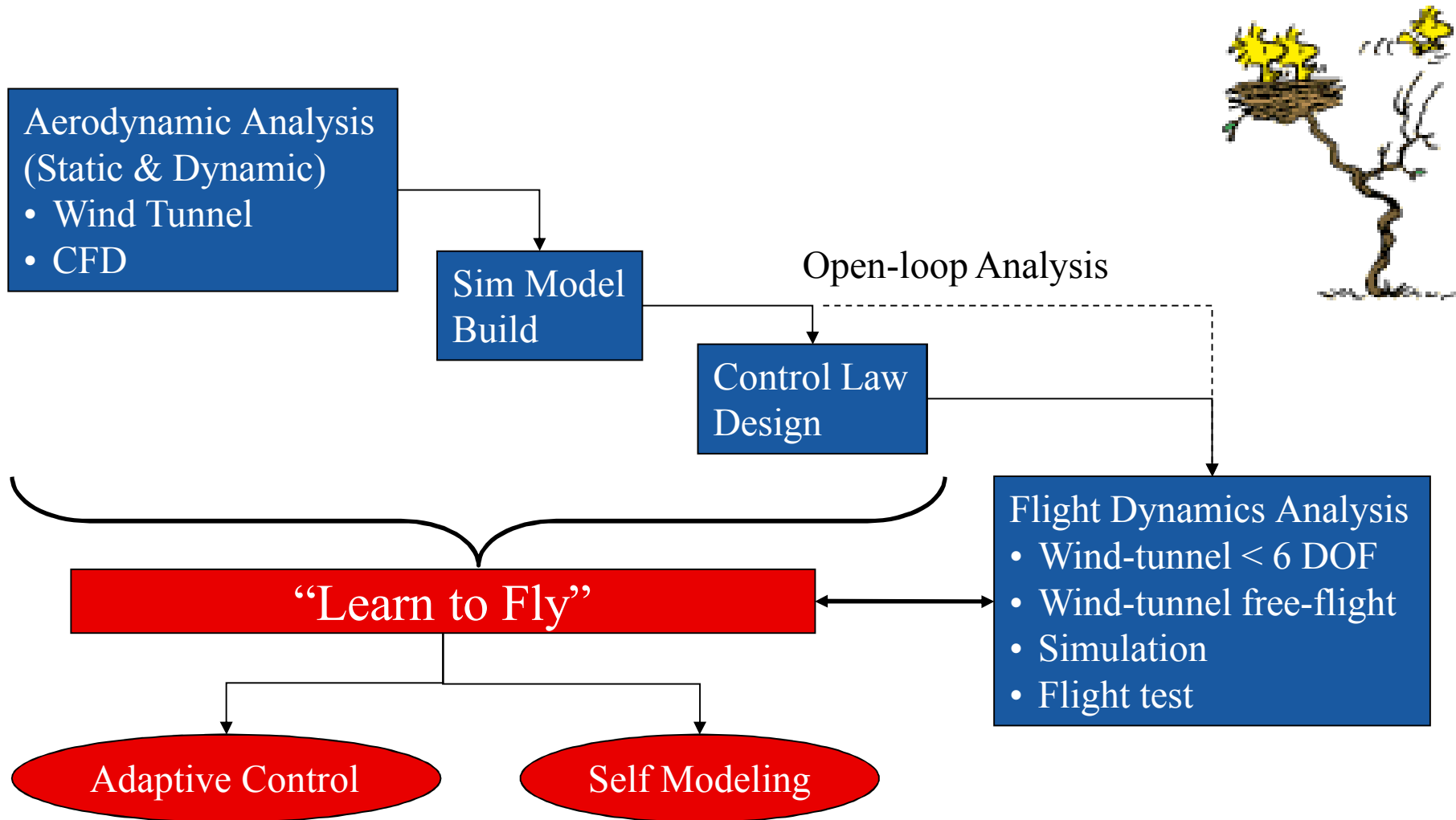


Learn-to-Fly

June 11, 2012

Carey Buttrill
Mike Fremaux

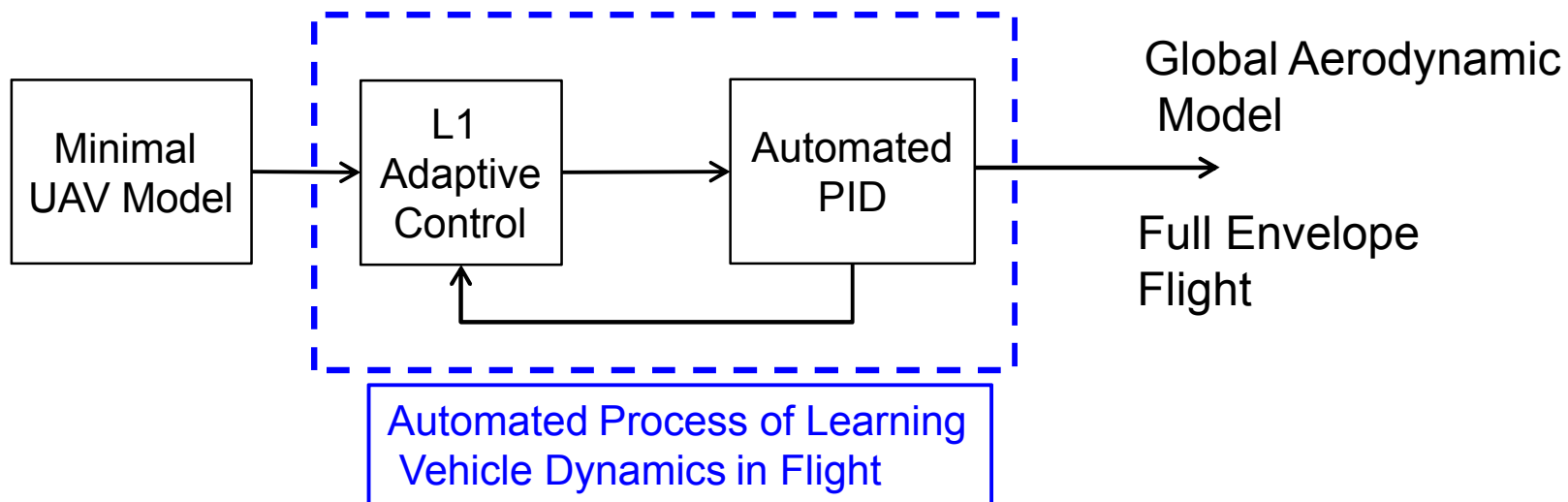
Flight Dynamics Analysis Process



Learn-to-Fly

- Concept that combines the advances in
 - flight control with L1 adaptive control coverage of the flight envelope with a single design
 - parameter identification (PID) with an automated, efficient and accurate method for global aerodynamic modeling

to enable rapid transition to flight with minimal initial knowledge of the vehicle dynamics.



Learn-to-Fly concept particularly appropriate for small, inexpensive UAVs and rapid prototyping.



Commercial Crew Development: Sierra Nevada's Dream Chaser

Bruce Jackson, LaRC

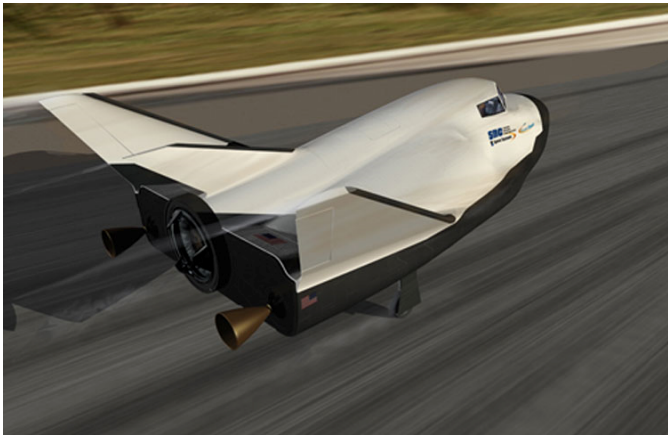
(757) 864-4060

bruce.jackson@nasa.gov

10 September 2012

Problem Description

- With the retirement of the Shuttle in 2011, America has no domestic ability to travel to and from the International Space Station (ISS).
- Three commercial firms (SpaceX, Boeing and Sierra Nevada) are bidding to provide a space taxi / space rental car to allow U.S. astronauts access to the ISS.
- Of the three candidates, two are capsules (like Apollo) and one is a lifting body “aircraft” capable of landing horizontally on a runway



Sierra Nevada Dream Chaser

Boeing CST100



SpaceX Dragon

SNC's Dream Chaser is based on HL-20



- In the late 1960s, NASA built and flew three lifting body vehicles that were intended to be space reentry vehicles.
- In mid-to-late 1980s, NASA Langley was asked to study a Soviet re-entry lifting body (now known as the Bor-4)
- Langley proposed a Bor-4 derivative design as a Shuttle replacement in 1990, the HL-20
- Considerable wind-tunnel testing, modeling and simulation of the vehicle's flight characteristics was conducted at Langley with a piloted motion-based simulator
- New NASA administrator canceled program after nine months due to costs
- HL-20 design was well-documented and freely available
- Sierra Nevada used the HL-20 design as the basis for the Dream Chaser
- Intended to manually piloted in final flare and landing

NASA Langley supporting Dream Chaser

- Langley is refining flight control laws for approach and landing of Dream Chaser under a reimbursable Space Act Agreement (SNC is paying for NASA to do development)
- Drop test of early unpiloted Dream Chaser later this year
- First flight of piloted Dream Chaser scheduled for 2015





Airborne Subscale Transport Aircraft Research

David Cox

Dynamic Systems and Control

NASA Langley Research Center

Objective – Flight Testing for Loss of Control



- Loss-of-Control is the leading accident category for aircraft fatalities[‡]
- Flight experiments with transport aircraft are rarely conducted in these conditions:
 - High risk flight conditions
 - Structural load limits constrain maneuverability
 - Little impact on normal performance operation
- AirSTAR was designed to allow modeling and control experiments to be conducted on scaled transport aircraft

[‡] *Worldwide Commercial Jet Fleet, 2002-2011, CAST/ICAO Taxonomy, Boeing Statistical Summary.*

Airborne Subscale Transport Aircraft Research (AirSTAR)



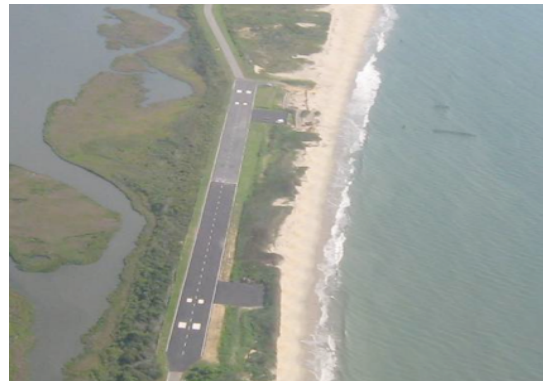
Ground Support Systems



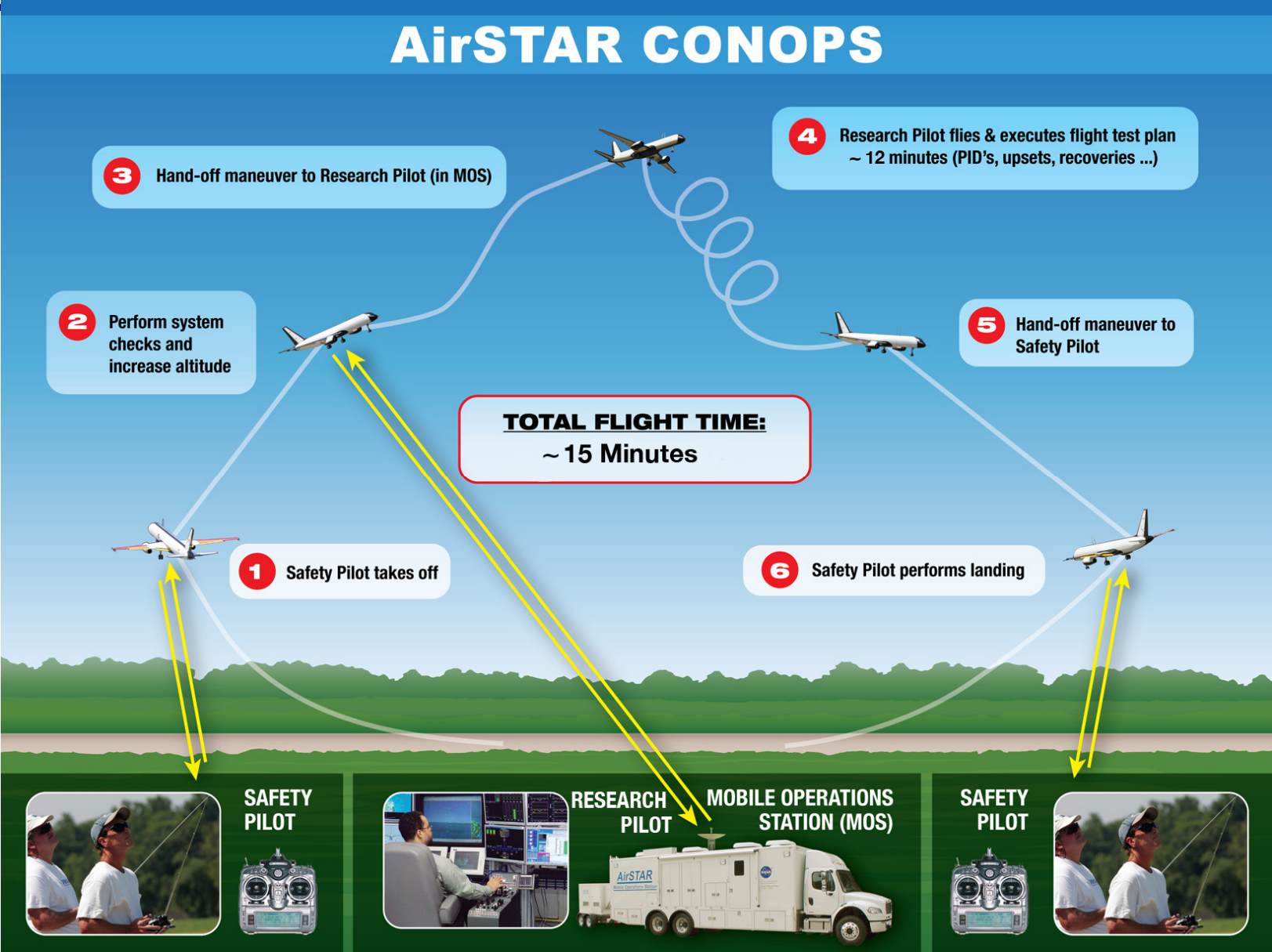
Subscale Flight Vehicles



Operations Expertise

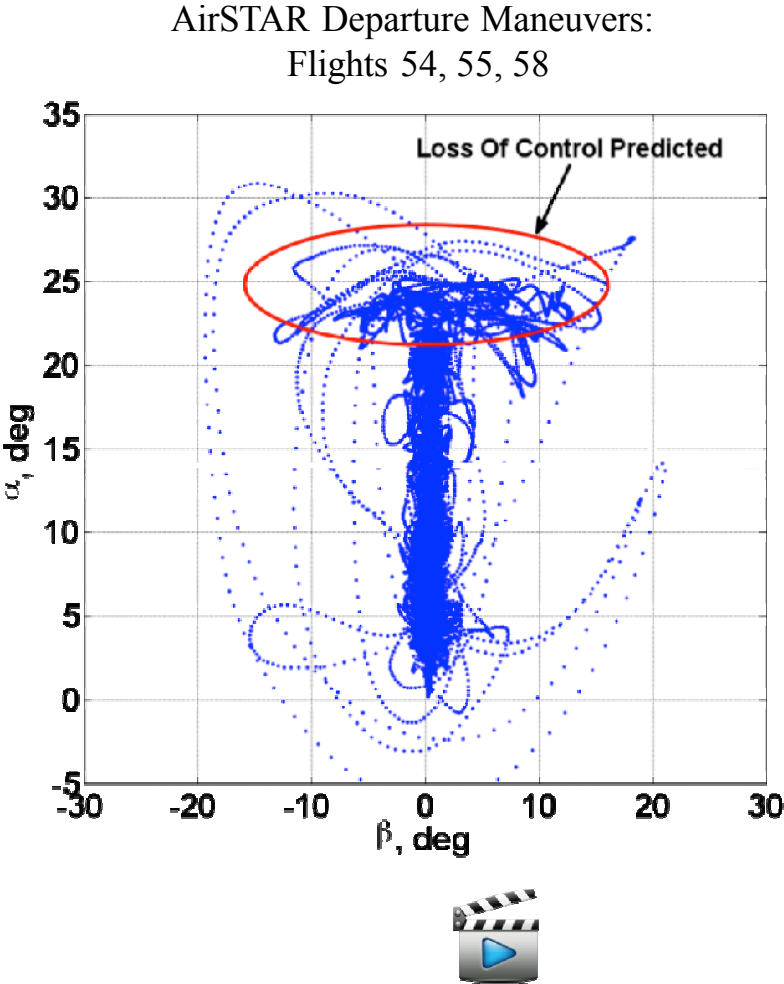
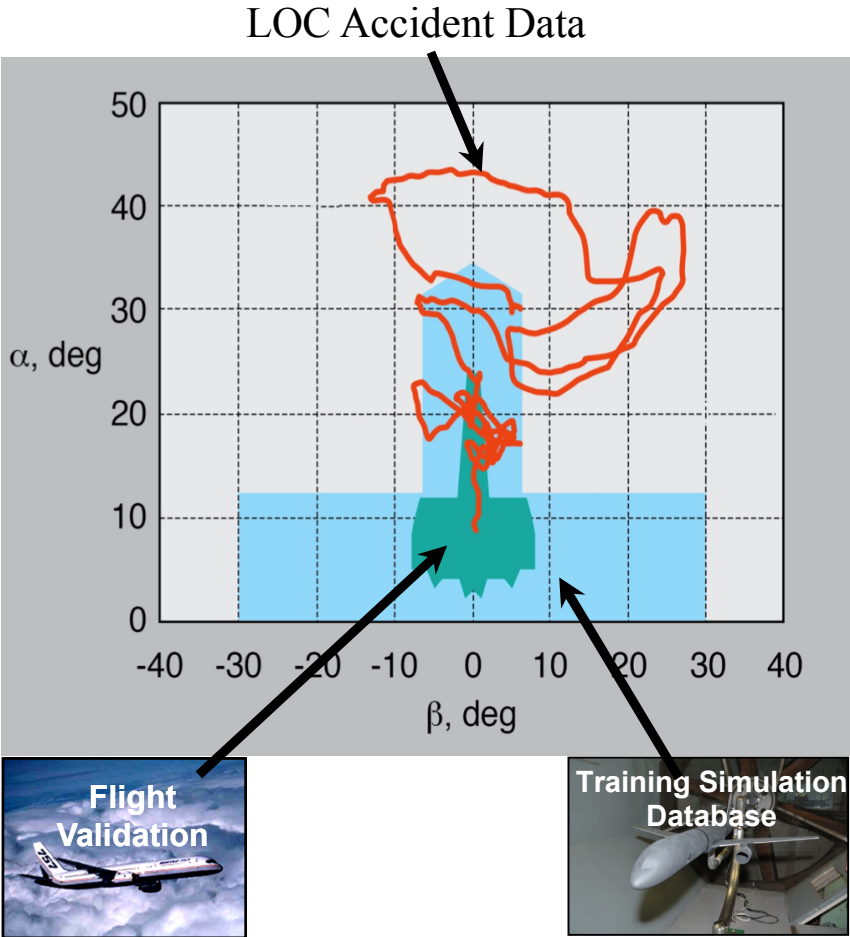


AirSTAR Operations Model



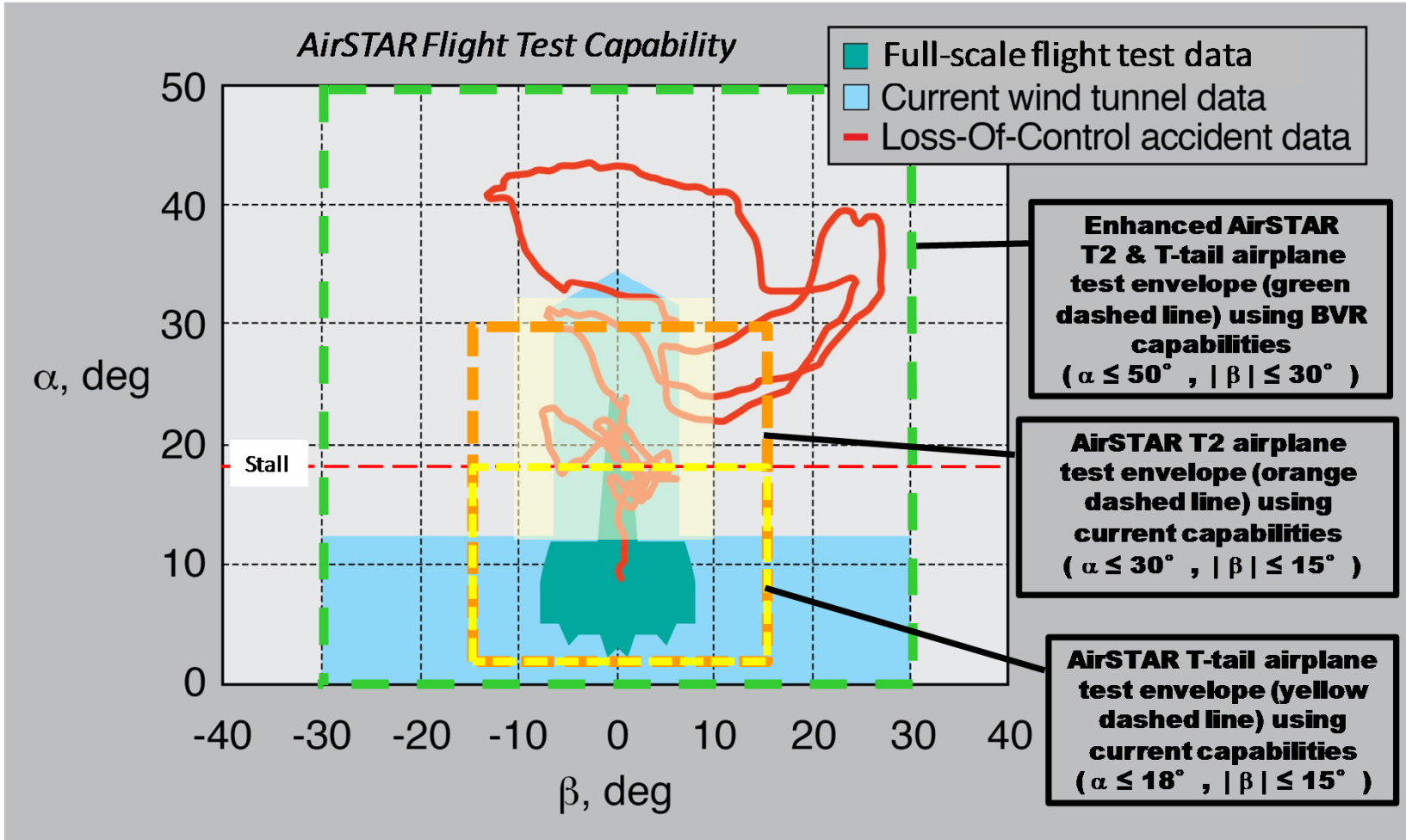
Post-Stall Flight Testing

Conducted testing to obtain parameter identification data and evaluate control law performance in an envelope relevant to LOC conditions.



AirSTAR Current/Future Directions

- Beyond Visual Range (BVR) Operations
 - Larger Test Range
 - Longer Test Segments
- Larger Modular Research Aircraft (16%)
 - Conventional & T-Tail Configurations
 - Higher Payload for Onboard Computing





Infrastructure Upgrades for Beyond-Visual Range

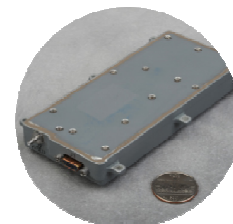
➤ Upgraded flight computer system

- Allows for on-board for control and guidance
- Multi-processor for partitioning of flight critical code
- Increase flexibility in instrumentation selection, high channel count



➤ Next generation RF telemetry system selected, L3's Bandit Transceiver

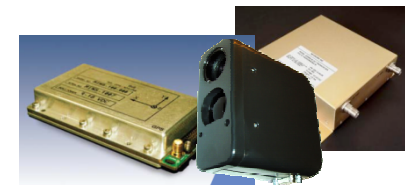
- Lightweight and compact, IP data + digital video
- Software defined, configurable encoding options



Telemetry

➤ Upgraded Instrumentation

- Higher bandwidth INS/GPS, Rockwell Collins GuS
- Above ground sensing with laser altimeter, Latitude AGL-M
- ADS-B for range safety and guidance, NavWorks-ADS600
- Industry Standard Flight Termination System



Airborne Instrumentation

➤ Beyond Visual Range Checkout Vehicle

- 130 lbs max weight, 30lbs payload, 13ft wingspan
- 300 ft runway, grass strip capable
- Long endurance (6 hours), 40-75 knots



Surrogate Vehicle

Upcoming Tests, FY13Q1



MOS/SR22 Telemetry Systems Test

Objective:

- Determine range/sensitivity of critical RF links
 - Data Transceivers
 - Flight Termination System
- Determine effects of ground clutter
 - Minimum operational altitude
 - RF issues for main runway ops at Wallops



Parameters:

- Equip SR22 with AirSTAR data telemetry transmitter and FTS receiver
- Integrate position and attitude information from existing instrumentation
- MOS positioned at Wallops, in likely field position for future BVR operations
- Dual ground receivers, test both directional and omnidirectional antennas
- Target Date – Week of Nov 26th

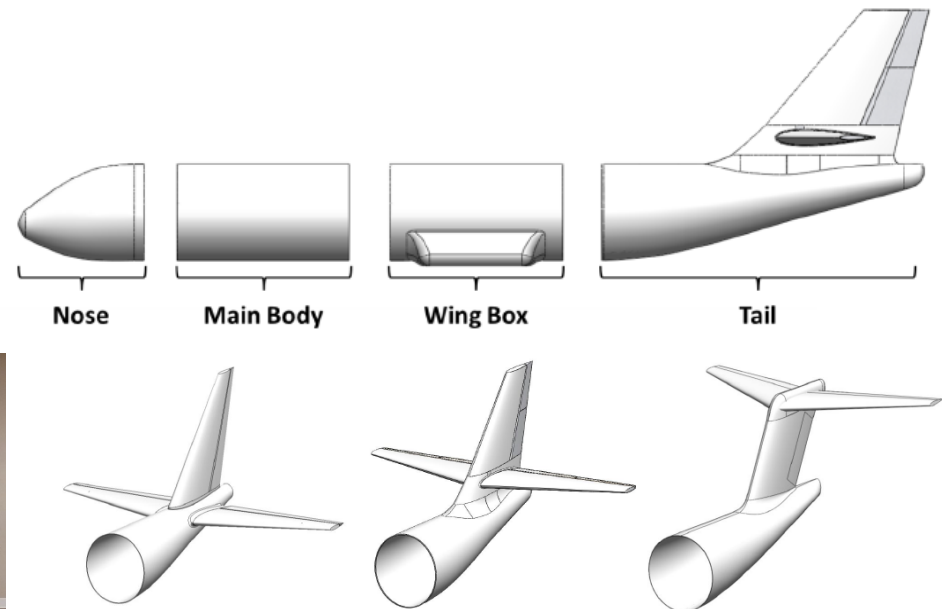
Next Generation Test Vehicle

Modular Vehicle for Class-Representative LoC Flight Testing

- Initiated Spring 2012.
- Modular fabrication technique will allow multiple targets for class representative models
- Larger size: 150 inch span, (~16% for Regional Jet), vs. 5.5% for T-series models
 - Eases mass requirements to hit dynamic scaling target (requires ballast)
 - More room for avionics, instrumentation, telemetry equipment and fuel
 - Better approximation to Reynolds number effects



Prior fabrication in transport scale-models
Area-I, PTERA vehicle

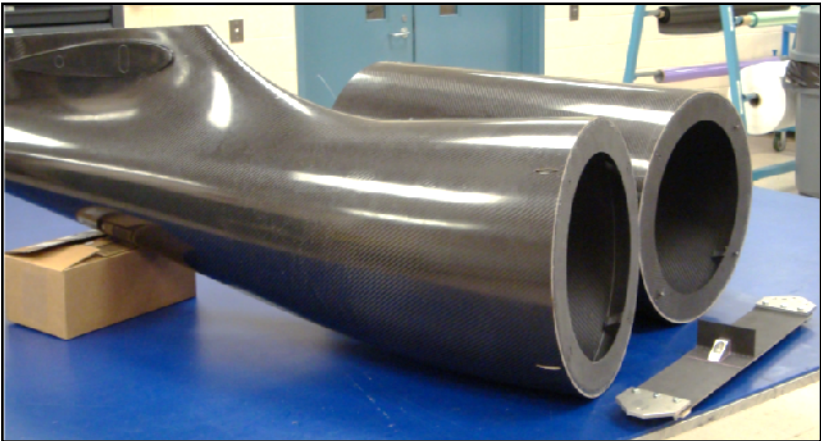
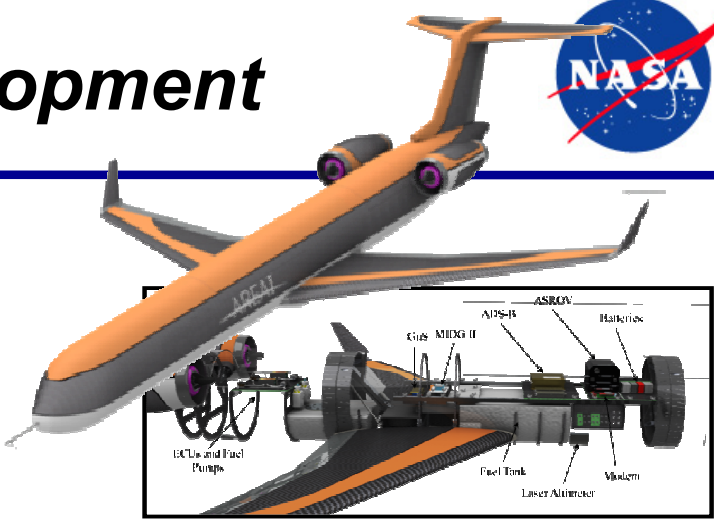


Modular design for variability in
fuselage and empennage.

Modular Research Vehicle Development



- SBIR Phase-I Complete
 - Debrief at LaRC, Sept 5th.
- Preliminary Vehicle Design – Regional Jet Model
 - Sizing, Engines, Actuators
 - Aerodynamic Analysis and Structural Loads
- Modular Fuselage Design
 - Replaceable Tail and Body Sections
 - Under wing and Rear Engine Mounts
- Prototype Hardware Constructed
 - Joining/Alignment mechanics



Property	Full-scale	Model	Units
Aircraft Scale	100	15.8	%
Wingspan	915	147	inches
Total Length	1280	204	inches
Maximum Takeoff Weight	75,250	287	pounds
Airspeed	270	107	knots
Takeoff Thrust (per engine)	12,670	50	pounds

Parameter	Value
Stall Speed (Clean,MGW)	51.5 knots
Maximum Speed	116 knots
Takeoff Distance	742 ft
Landing Distance	487 ft
Endurance @ 60knots	56 min
Fuel Capacity (Jet-A)	13.4 gal/90 lbs



Aviation Safety

Christine Belcastro

Dynamic Systems and Control

NASA Langley Research Center

Representative Upset Modeling Collaboration with NAVAIR



Problem

- Upset models and simulations are needed for upset prevention & recovery training
- Extensive wind tunnel testing is infeasible / impractical for every aircraft configuration

Objectives

- Develop & validate representative upset simulation models for U.S. Navy P-8 (B737-800)
- Support P-8 stall training research & development

Accomplishments

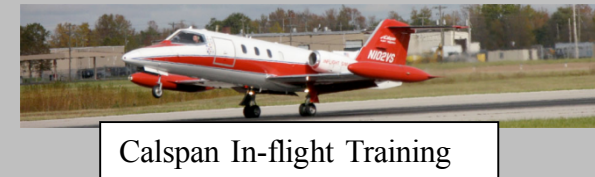
- Simulator Development for Joint Calspan/Navy/NASA stall training research (testing Oct 24 – Nov 4, 2011)
 - Development of representative P-8 upset simulation based on GTM data
 - Stall buffet model for motion base facility
 - Development of prototype training maneuvers
 - Simulator evaluation by 20 U.S. Navy pilots
- Simulator motion cueing research for upsets

Next Steps

- Validate representative models with Navy-supplied aerodynamic data

Significance

- Directly supports VSST representative modeling and real-time simulation development for extension of GTM upset models to other aircraft
- Enhances visibility of VSST upset modeling research to other government agencies and industry



Representative Upset Modeling Collaboration with NAVAIR

Background

- Loss-of-control (LOC) is leading cause of commercial transport accidents
- LaRC wind tunnel testing demonstrated unprecedented simulator fidelity for a selected large transport (2001-2006)
- NASA Aviation Safety Program representative modeling research enabling Congressionally-mandated airline upset/stall training for classes of aircraft



Integrated Academic/Simulator/Flight Training Syllabus

Accomplishments

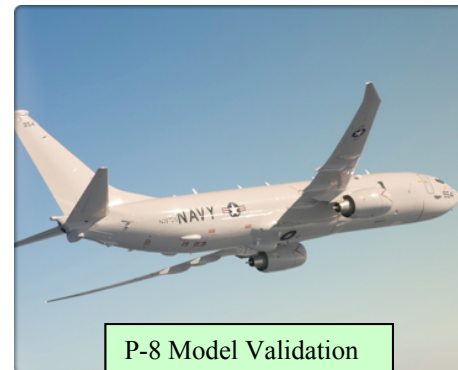
- Representative P-8 aerodynamic stall model developed from NASA aircraft upset database
- Operational Evaluation (OpEval) completed for 30+ U.S. Navy pilots of proposed P-8 upset training syllabus (Nov 2011)
- Model validation using P-8 flight test data

Significance

- Partnership addresses a critical safety issue for loss-of-control susceptibility
- Both U.S. Navy and airlines benefit from advancements in state-of-the-art of simulator fidelity and pilot training
- Supports national need for cost-effective transport stall training using representative modeling



NASA P-8 Upset Simulator

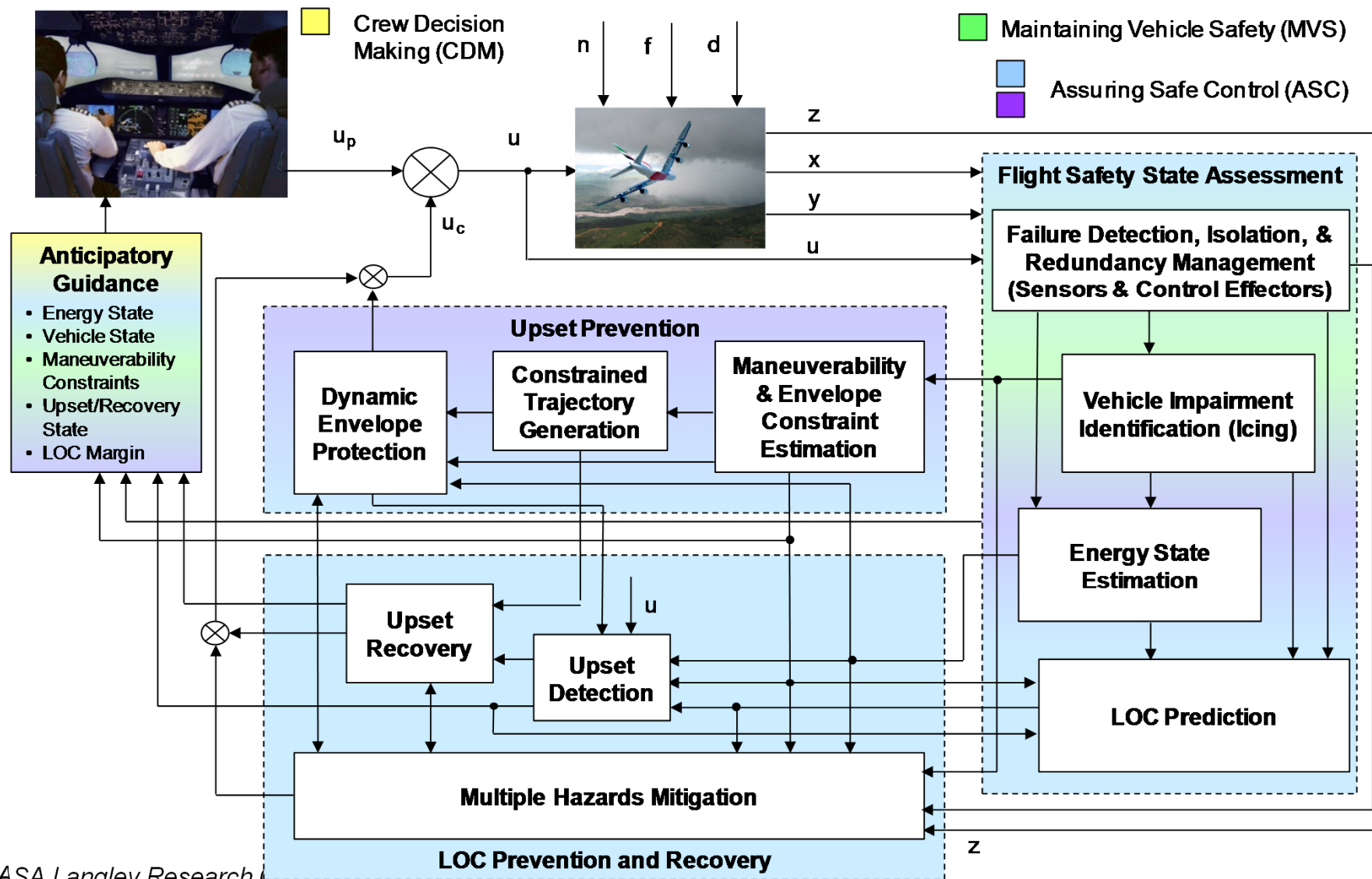


P-8 Model Validation

VSST Project – Guidance, Control, and Systems Technologies



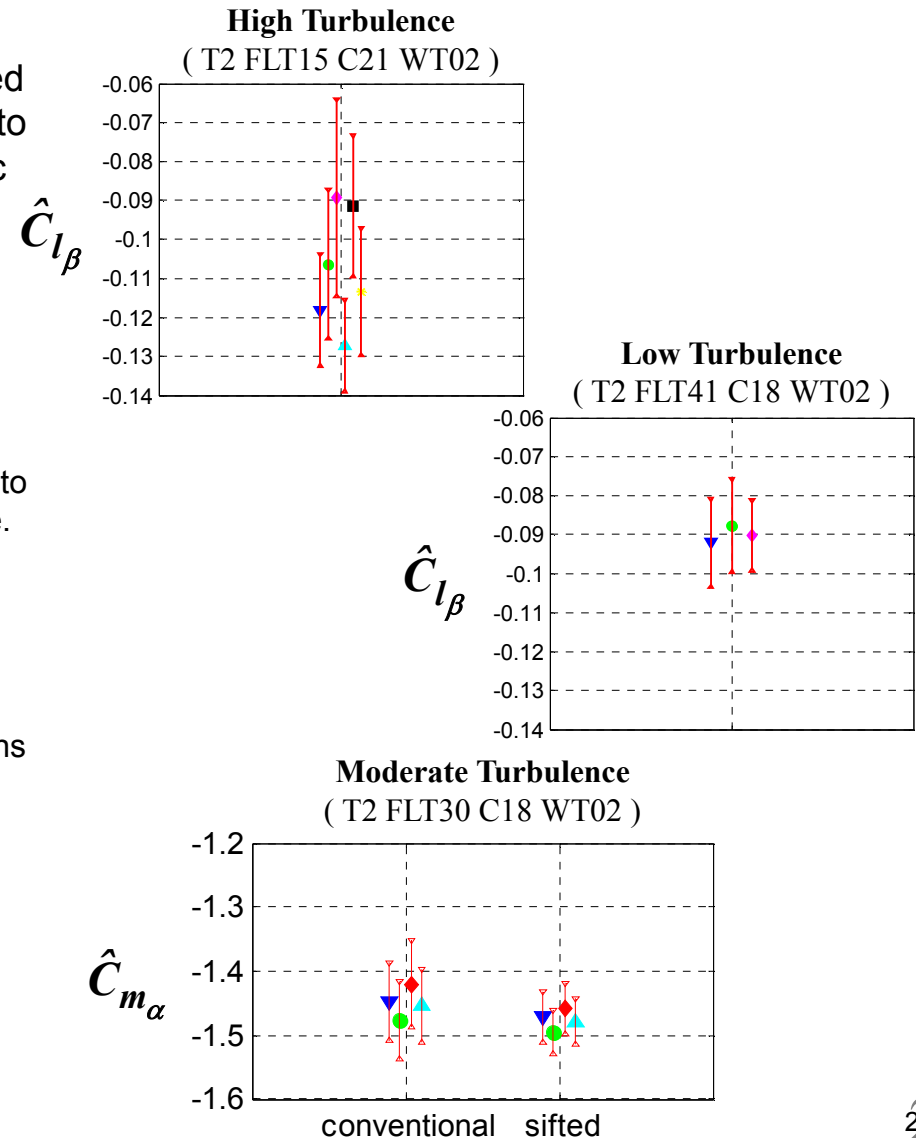
Preliminary GCST System Architecture



Vehicle Impairment Detection – Airframe Icing

Real-Time Parameter Identification under Turbulence

- **Problem:** In-flight icing conditions are often associated with turbulence. Turbulence is an unmeasured input to the aircraft, and therefore degrades real-time dynamic modeling results.
- **Objective:** Develop a real-time dynamic modeling approach that works in turbulence.
- **Accomplishments:**
 - Studies using T-2 flight test data show that turbulence can be dominated by excitation inputs with sufficient amplitude to achieve accurate real-time dynamic modeling in turbulence. An analytical approach that sifts out turbulence from the modeling data has also been successfully demonstrated.
- **Impact:** Accurate real-time dynamic modeling in turbulence is necessary for:
 - Real-time flight envelope estimation in all weather conditions
 - Quantifying in-flight icing effects on aircraft stability and control

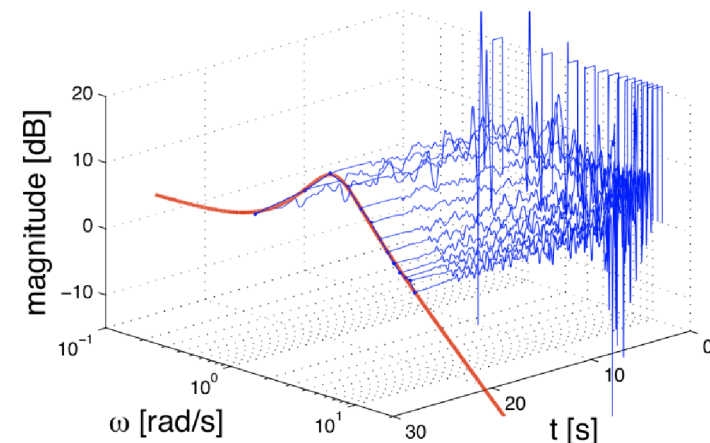
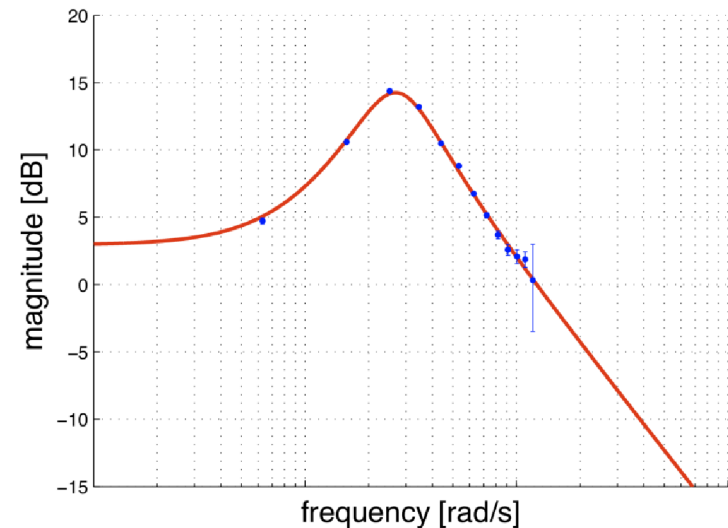


Morelli, E.A. and Cunningham, K. "Aircraft Dynamic Modeling in Turbulence," AIAA-2012-4650, *AIAA Atmospheric Flight Mechanics Conference*, Minneapolis, MN, August 2012

Vehicle Impairment Detection – Airframe Icing

Real-Time System Structure Identification

- **Problem:** Changes in aircraft dynamic models due to structural damage, icing, and actuator failure are difficult to predict but are vital for aircraft safety.
- **Objective:** Develop a dynamic modeling approach using frequency responses that can capture changing aircraft models for control in real time with no prior information.
- **Accomplishments:**
 - Developed theory using orthogonal phase-optimized multi-sine inputs and a recursive Fourier transform to estimate frequency responses and their uncertainties in real time.
 - Investigations using nonlinear F-16 simulations and T-2 flight test data indicates the method performs well and is statistically accurate.
 - Results indicate that time-varying dynamics and their stability margins can be tracked in real time.
- **Impact:** Accurate real-time dynamic modeling using frequency responses
 - Tracking time varying frequency responses
 - Online monitoring of stability margins
 - Quantification of uncertainty



End / Back-up

