Status of ERA Vehicle System Integration Technology Demonstrators

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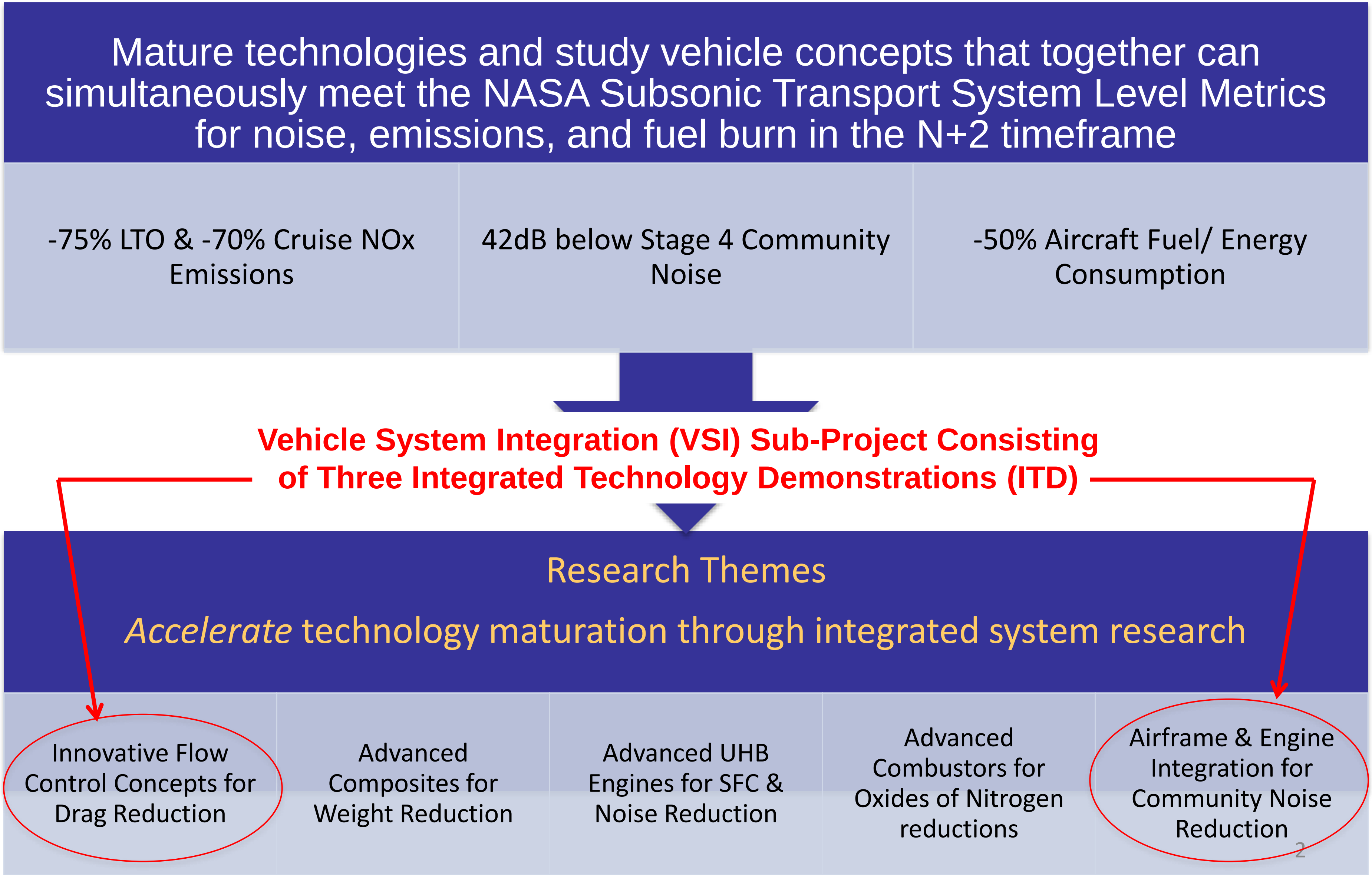
ERA Project Goals and Research Themes



Mature technologies and study vehicle concepts that together can simultaneously meet the NASA Subsonic Transport System Level Metrics for noise, emissions, and fuel burn in the N+2 timeframe

-75% LTO & -70% Cruise NOx Emissions

42dB below Stage 4 Community Noise

-50% Aircraft Fuel/ Energy Consumption

Vehicle System Integration (VSI) Sub-Project Consisting of Three Integrated Technology Demonstrations (ITD)

Research Themes

Accelerate technology maturation through integrated system research

Innovative Flow Control Concepts for Drag Reduction

Advanced Composites for Weight Reduction

Advanced UHB Engines for SFC & Noise Reduction

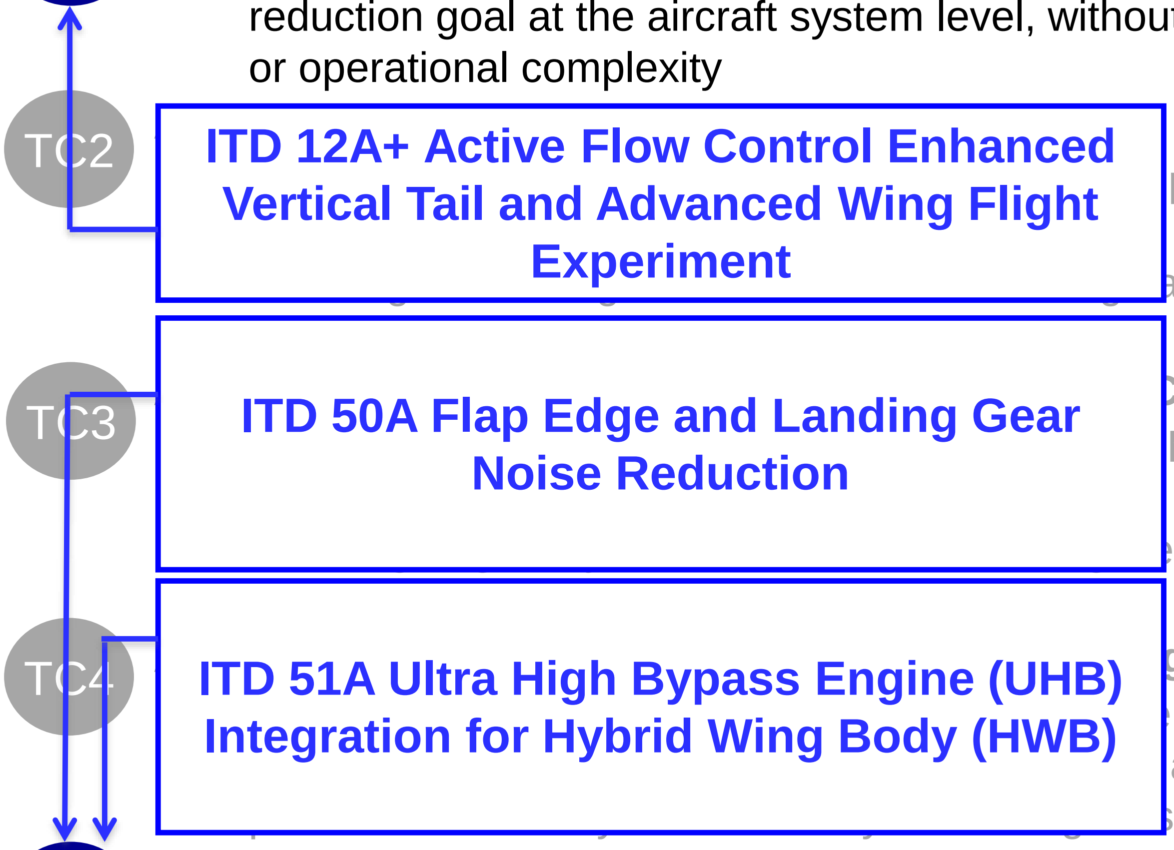
Advanced Combustors for Oxides of Nitrogen reductions

Airframe & Engine Integration for Community Noise Reduction

ERA Project
Research Themes and Technical Challenges

TC1 **Innovative Flow Control Concepts for Drag Reduction**

– Demonstrate drag reduction of 8 percent, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, without significant penalties in weight, noise, or operational complexity



TC2

ITD 12A+ Active Flow Control Enhanced Vertical Tail and Advanced Wing Flight Experiment

pared to SOA composites,

goal at the aircraft system level, while

afety margins at the aircraft system

TC3

ITD 50A Flap Edge and Landing Gear Noise Reduction

Consumption and Noise Reduction

hieve 15% TSFC reduction,

goal at the aircraft system level, while

eight, drag, NOx, and integration

TC4

ITD 51A Ultra High Bypass Engine (UHB) Integration for Hybrid Wing Body (HWB)

gen Reduction

nt from CAEP6 and cruise NOx by 70

at the aircraft system level, without

system

TC5 **Airframe and Engine Integration Concepts for Community Noise and Fuel Burn Reduction**

– Demonstrate reduced component noise signatures leading to 42 EPNdB to Stage 4 noise margin for the aircraft system while minimizing weight and integration penalties to enable 50 percent fuel burn reduction at the aircraft system level

ITD 12A+ Active Flow Control Enhanced Vertical Tail and Advanced Wing Flight Experiment

Brian F. Beaton, NASA 12A+ ITD Lead
Michael Alexander, NASA 12A+ ITD System Engineer

Ed Whalen, Boeing Project Manager

Active Flow Control (AFC)

Insect Accretion Mitigation (IAM)

John C. Lin, NASA
Principal Investigator

Emilie J. Siochi, NASA
Principal Investigator

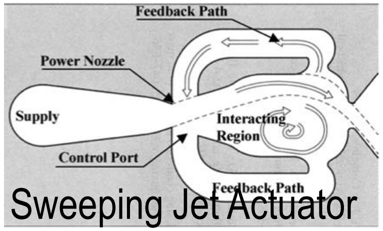
12A+ AFC Enhanced Vertical Tail and Advanced Wing Technology Flight Experiments - Technology Maturation

Weight | Drag | TSFC | Noise | NOx

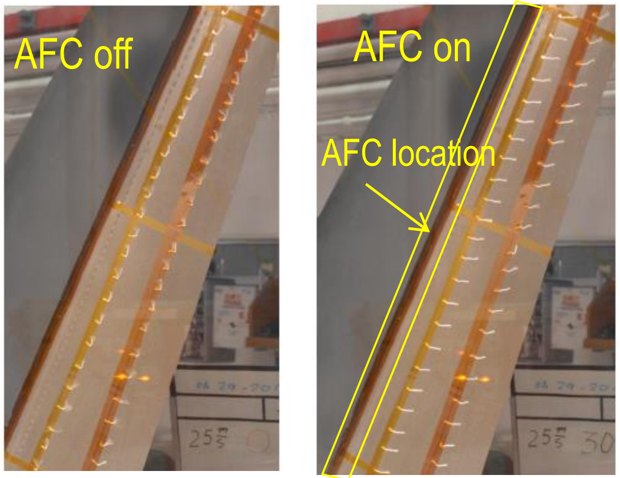
End TRL: 6

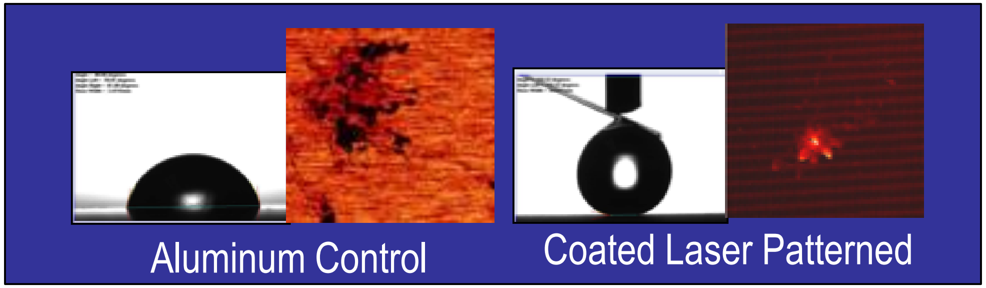
Technology Insertion Challenges Addressed

- Full-scale AFC demonstration in flight system
  - Actuator scaling, location, and operability
- Integration of AFC power source
- Effect of flight profile on insect accumulation
- Durable insect accretion mitigation surfaces



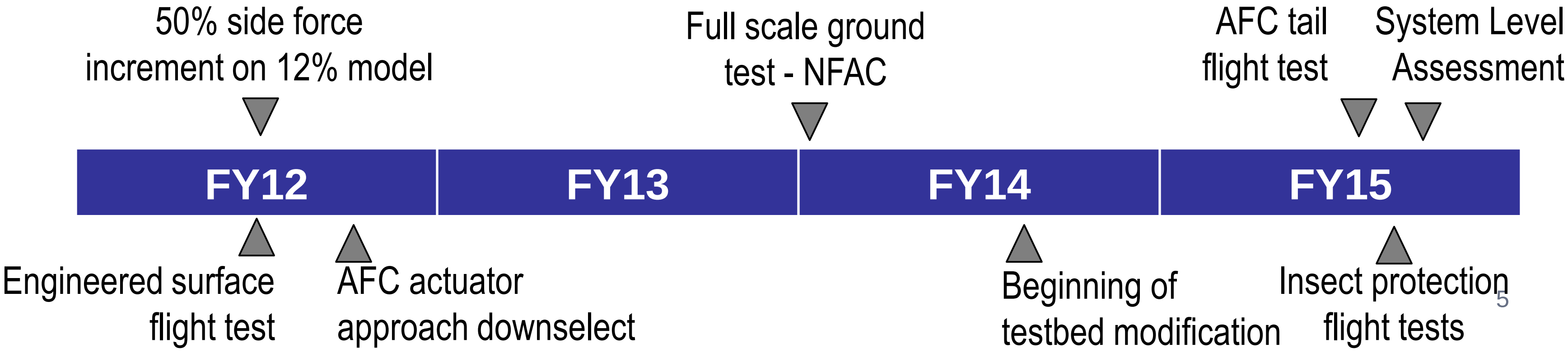
Sweeping Jet Actuator





Aluminum Control

Coated Laser Patterned



FY12 | FY13 | FY14 | FY15

50% side force increment on 12% model

Full scale ground test - NFAC

AFC tail flight test

System Level Assessment

Engineered surface flight test

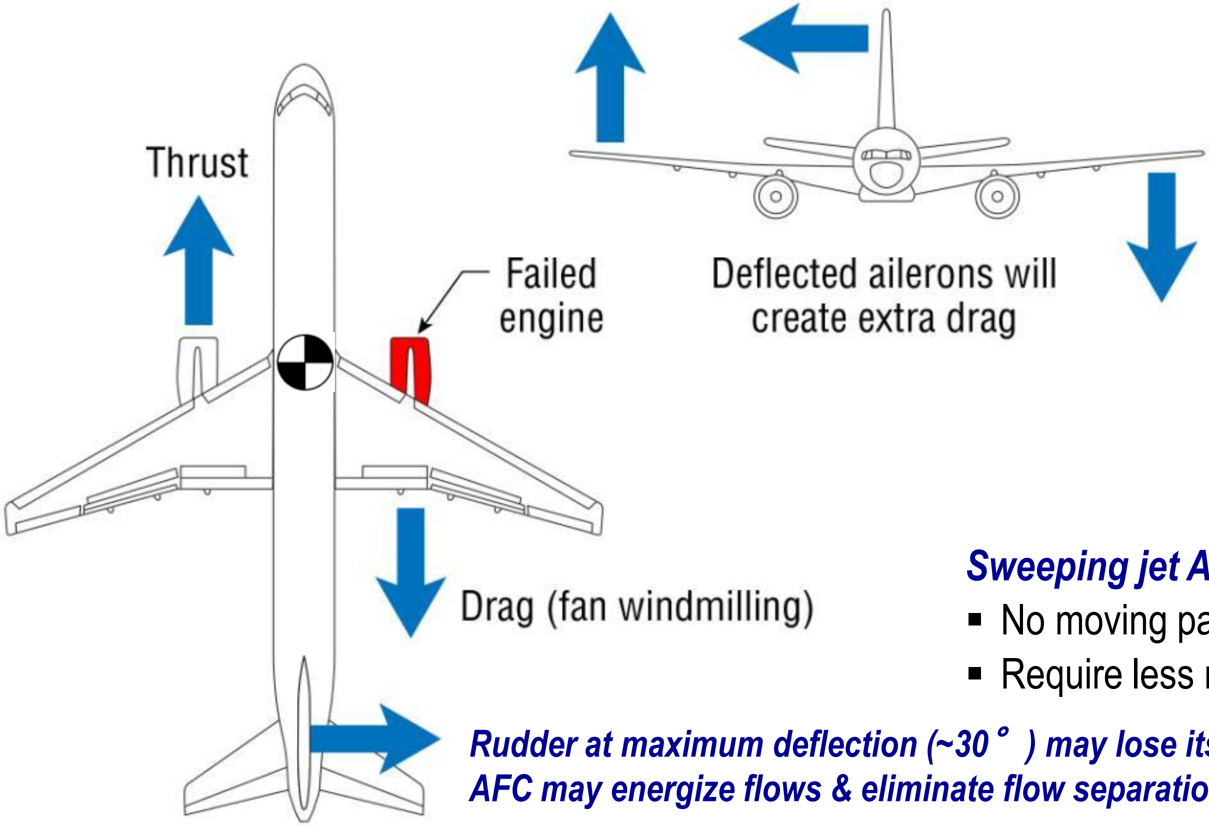
AFC actuator approach downselect

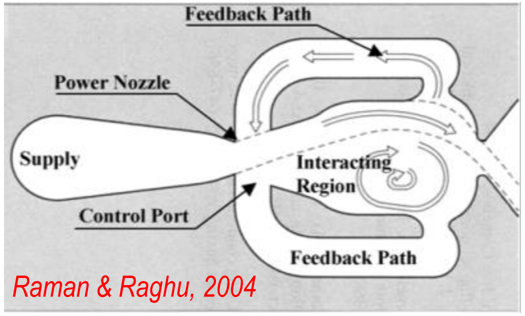
Beginning of testbed modification

Insect protection flight tests

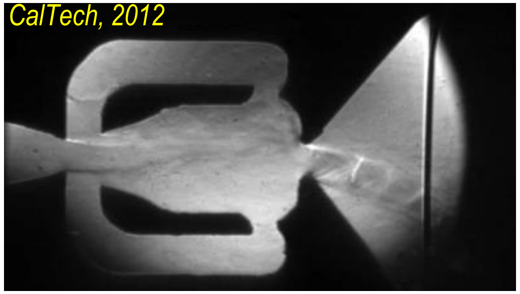
12A+ AFC Enhanced Vertical Tail Flight Demonstration

Motivation: Vertical Tail Size Reduction





Raman & Raghu, 2004



CalTech, 2012

Sweeping jet AFC

- No moving parts
- Require less mass flow than steady blowing

Rudder at maximum deflection (~30°) may lose its effectiveness due to flow separation

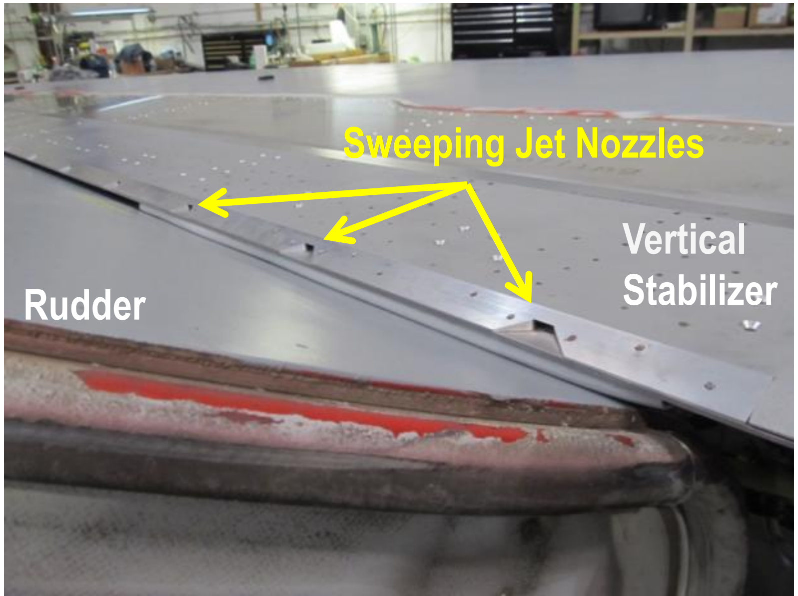
AFC may energize flows & eliminate flow separation and thereby increase rudder effectiveness

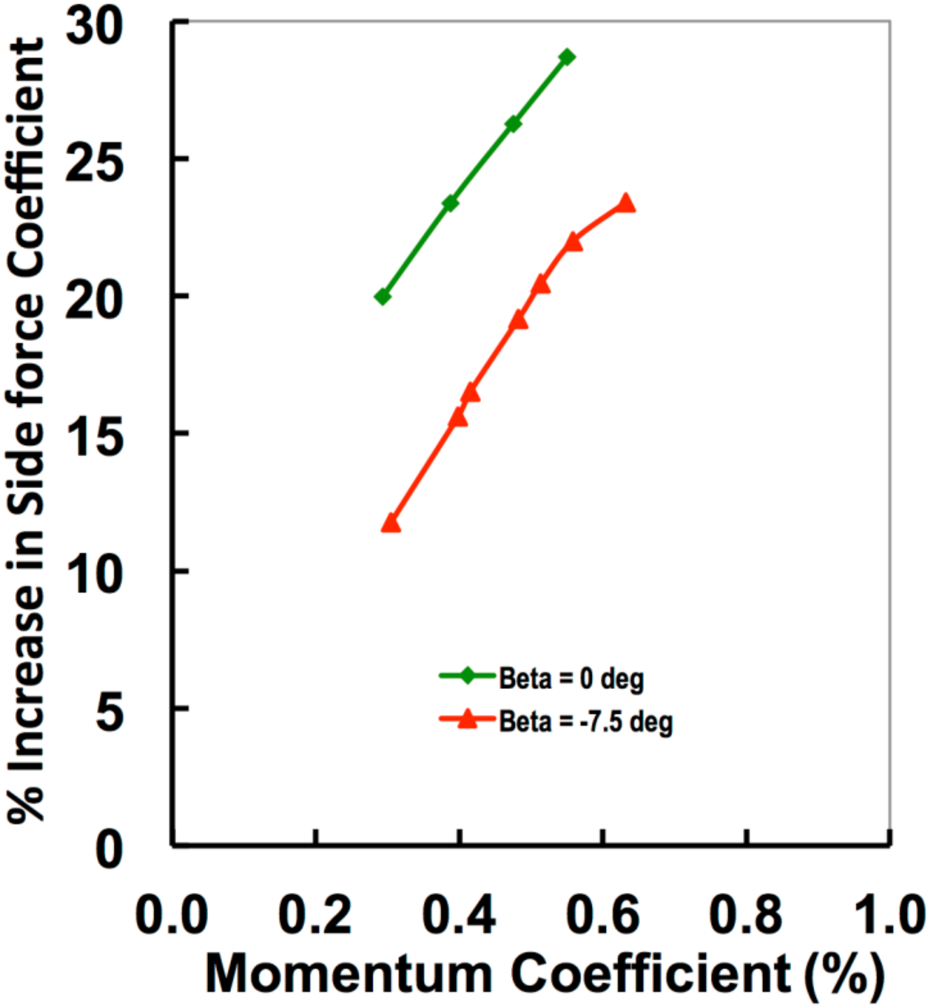
- **Planform size is determined by critical engine out situation at low speeds**
- **Sizing by shortest version make shared tail oversized for rest of the family → extra drag & weight**
- **Active Flow Control (AFC) may provide extra side force & enable size reduction → fuel savings**

12A+ AFC Enhanced Vertical Tail Flight Demonstration

- NFAC full-scale test cleared the way for flight demonstration
  - Achieves > 20% side force increase at 30° rudder deflection and sideslip angles (β) of 0° and -7.5°
  - Using mass flow and pressure within the aircraft system capability

- AFC configuration for flight test
  - 31 sweeping jet actuators
  - Same size and spacing as the NFAC model

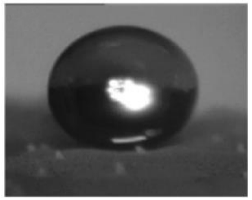




NFAC full-scale test results (Whalen el al., 2015)

12A+ IAM Objective and Approach

Objective: **To design an engineered surface that prevents insect residue adhesion under take-off and landing conditions.**

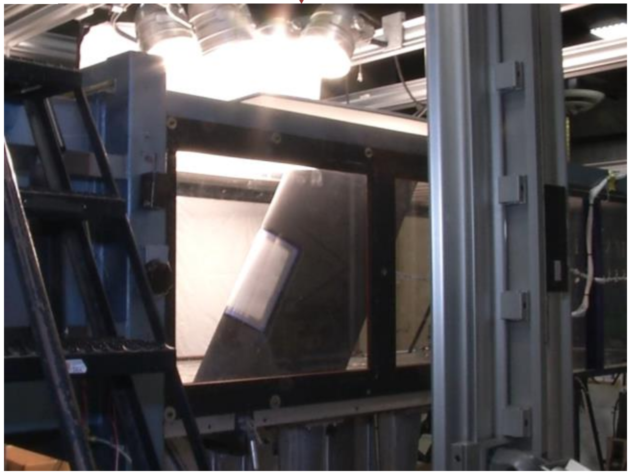


1) Start by screening commercial and experimental materials using contact angle goniometry

5) Promising coatings downselected for Boeing EcoDemonstrator flight test

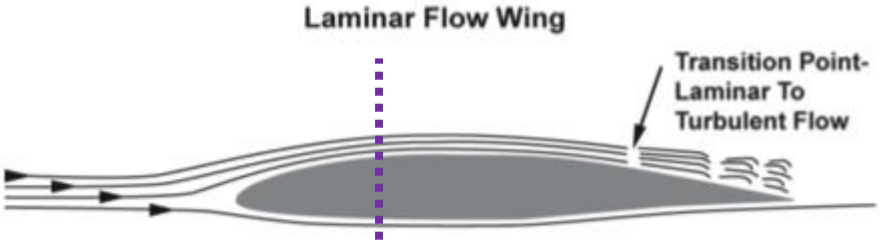
2) Lab scale bug gun tests of engineered surfaces

4) Candidate coatings down-selected from wind tunnel tests and flight tested on HU-25 Falcon aircraft for risk mitigation

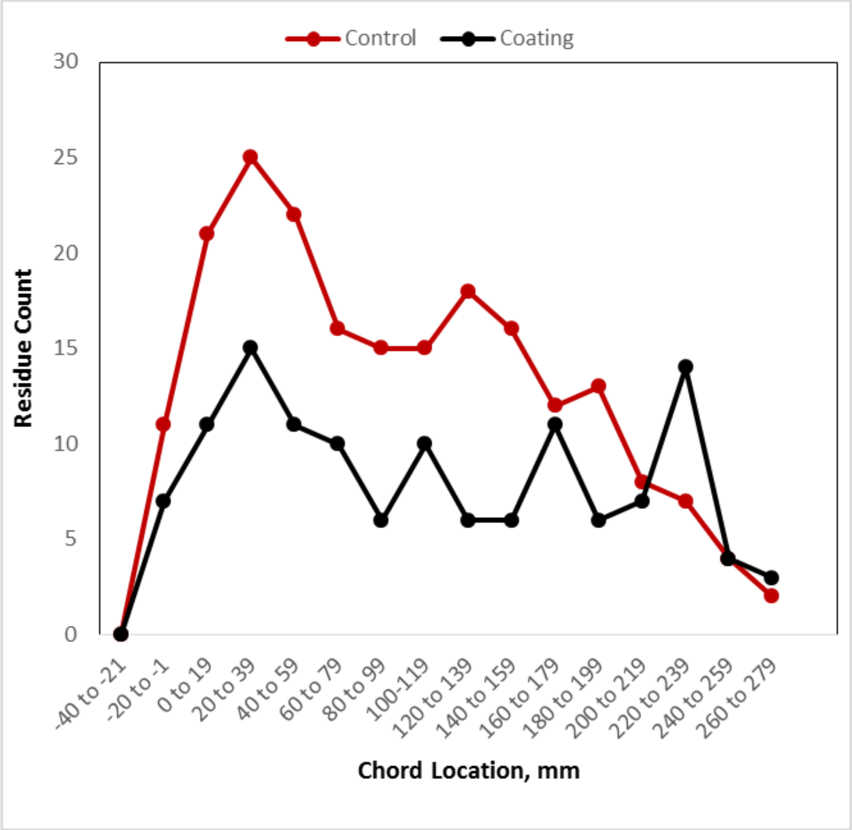


3) Downselect promising coatings for wind tunnel testing

12A+ IAM Falcon Flight Test Results
Residue Position and Count



Insect Residue vs Chord Position



Insect Residue Count

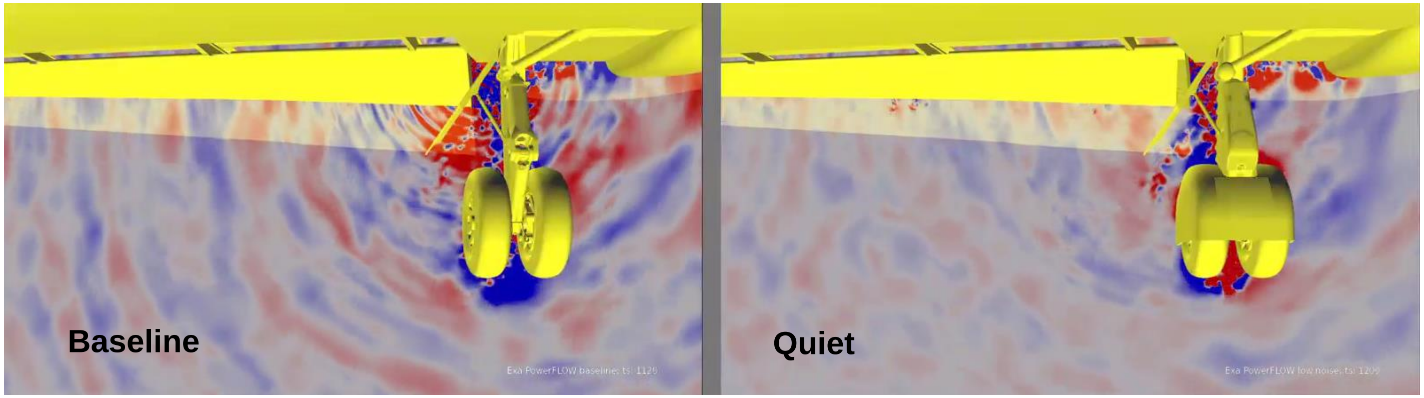
Surface	# of Residues
Control	207
Coating	128
Total	335

38% Reduction of insect residues on the epoxy particulate composite surface!!!

ITD 50A Flap Edge and Landing Gear Noise Reduction

Mehdi Khorrami, NASA ITD 50A Lead

Thomas Van de Ven, Gulfstream Aerospace Principal Investigator



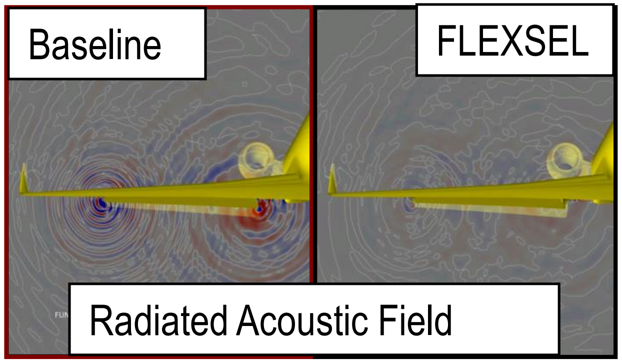
50A: Flap Edge and Landing Gear Noise Reduction Overall Approach – Technology Maturation

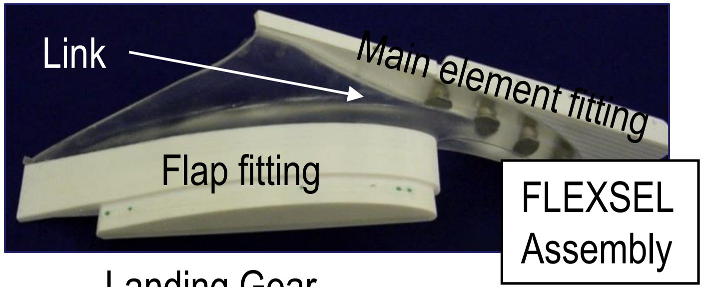
Weight | Drag | TSFC | **Noise** | NOx

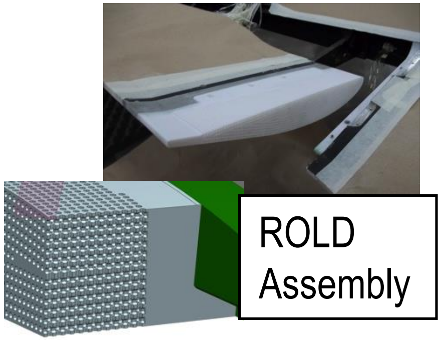
End TRL: Was 6 now 5

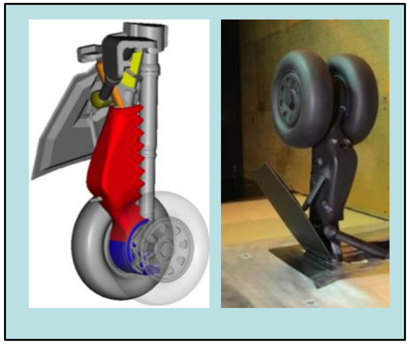
Technology Insertion Challenges Addressed

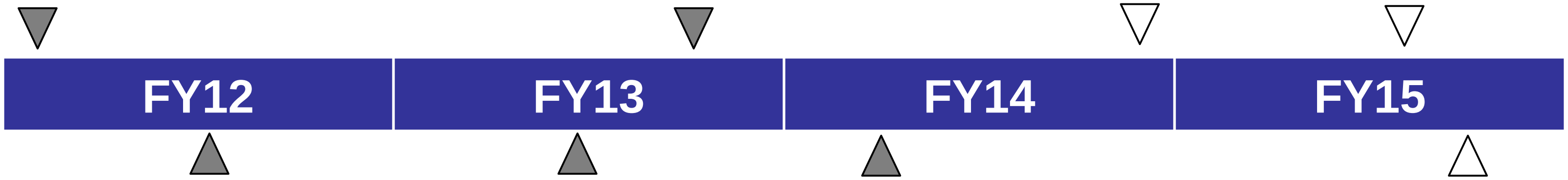
- Minimize weight penalty and performance degradation
  - Component flap noise – 4.0 EPNdB reduction with < 0.5% degradation in C_L and < 6% of flap system weight
  - Component landing gear noise reduction of greater than 2.0 EPNdB with < 2.0% of main landing gear subsystem weight
- Identify/Address Integration and Operability challenges
- Determine Ground to Flight Scaling











Landing Gear Ground Test

Flap and Landing Gear Concept Downselect

~~Flight Test Demonstration~~

Full-scale Prediction via CFD

FY12 | FY13 | FY14 | FY15

Flap Edge Concepts Design/Fabrication

18% Semispan Model Acoustic/Flowfield Test

CDR for Downselected Concepts for Flight Test

System Level Assessment

50A – Technical Highlight
Aero-acoustic predictions

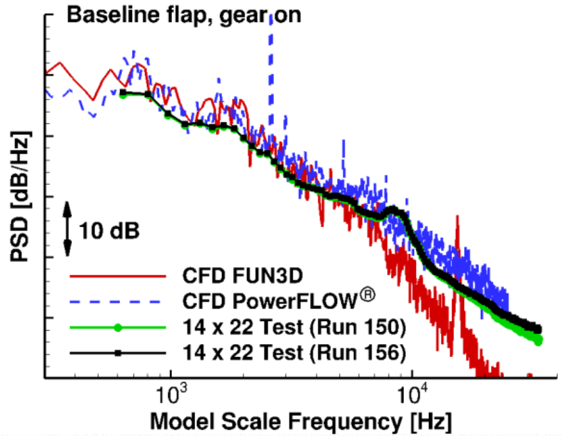
Simulation-based airframe noise predictions:

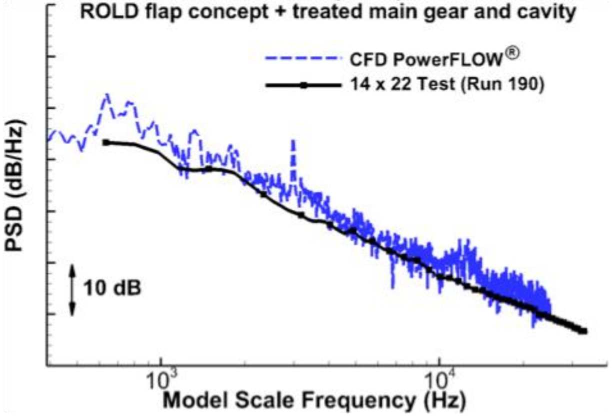
- Simulated geometry: As–built 18% scale Gulfstream model
- Baseline configurations:
  - 39º flap deflection, main gear removed
  - 39º flap deflection, main gear deployed
- Quietest configurations:
  - Reactive Orthotropic Lattice Diffuser (ROLD) concept applied to flap tips with main gear off
  - ROLD plus fully treated main gear

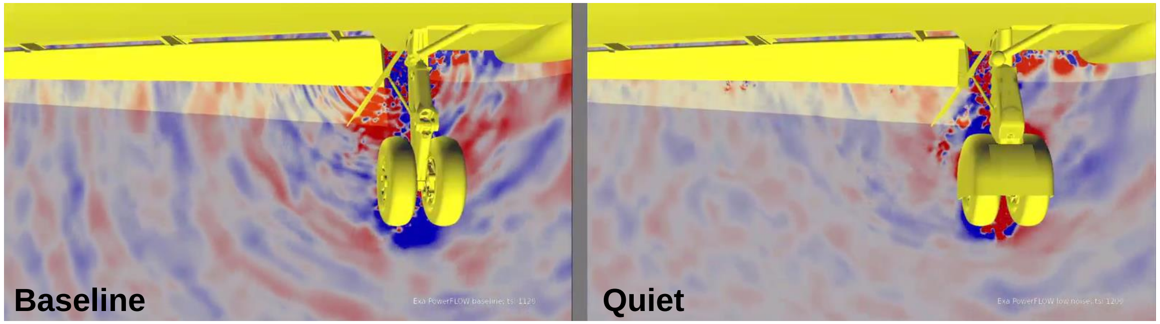
Accomplishments:

- Core objectives met—predicted farfield noise for baseline and quiet configurations in good agreement with14x22 measurements
  - Established computational simulations as an accurate predictive tool
  - Paved the way for application to full-scale
- Evaluation of full-scale noise reduction concepts via simulations has commenced


Flap 39º, main gear on configuration





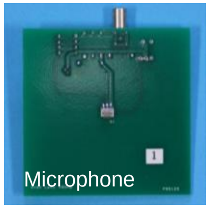


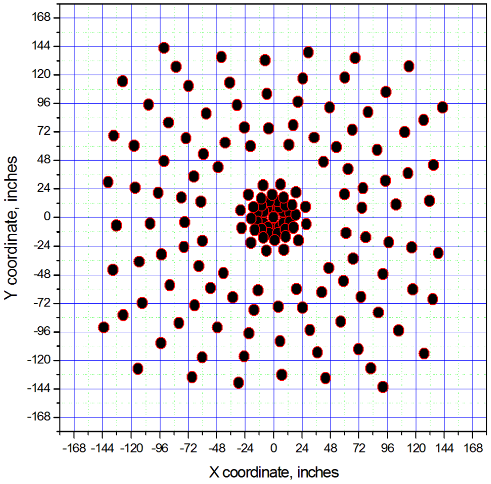
Simulated instantaneous pressure field for baseline and quiet configurations

50A – Technical Highlights for 2014
Conduct Full-up Test of Microphone Array

Mockup of Array in Langley Acoustic Development Lab (ADL):

- ADL entry started on 04/03/14
- Mockup successfully completed on 05/20/14
- Complete exercise of 185 sensors along with cabling, acquisition, data reduction, and weather subsystems:
  - ➢ Compressed array pattern utilized to fit in ADL test cell
  - ➢ Acquired data using broadband point source located 13.5’ above array

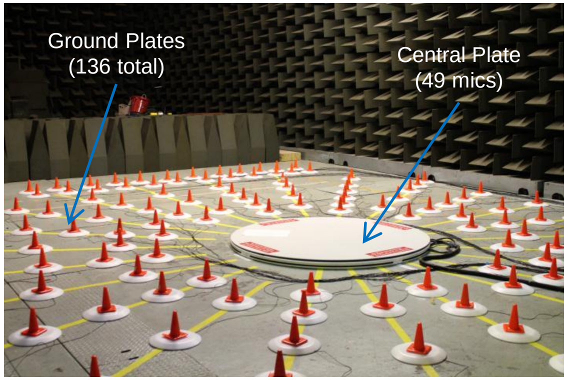




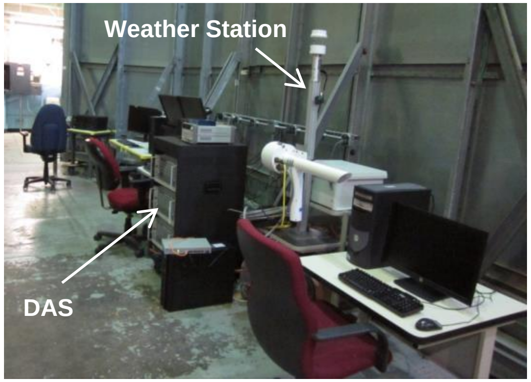
Array Pattern for Mockup

Accomplishments:

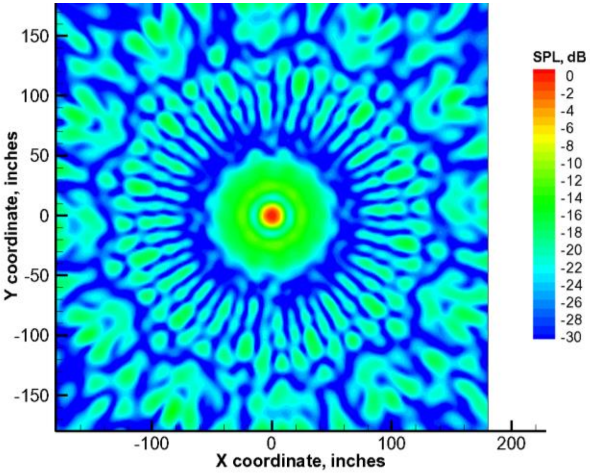
- All objectives met—hardware thoroughly exercised with following observations noted:
  - ➢ Data acquisition issues identified for resolution prior to field deployment
  - ➢ Moisture protection issues for microphones identified (resolved through application of conformal acrylic coating to sensor modules)
  - ➢ Microphone sensitivities and frequency responses were acceptable (refinement of microphone calibration process continuing)
  - ➢ Overall operation of array was acceptable for field deployment



Deployment of Array in ADL



Array Support Hardware at ADL



Response of Array to Point Source Excitation, 1 kHz Tone

ITD 51A UHB Integration for Hybrid Wing Body

Jeff Flamm & Kevin James, NASA ITD 51A Co-Leads

John Bonet, Boeing Project Manager

51A – UHB Engine Integration for Hybrid Wing Body - Technology Maturation

Weight

Drag

TSFC

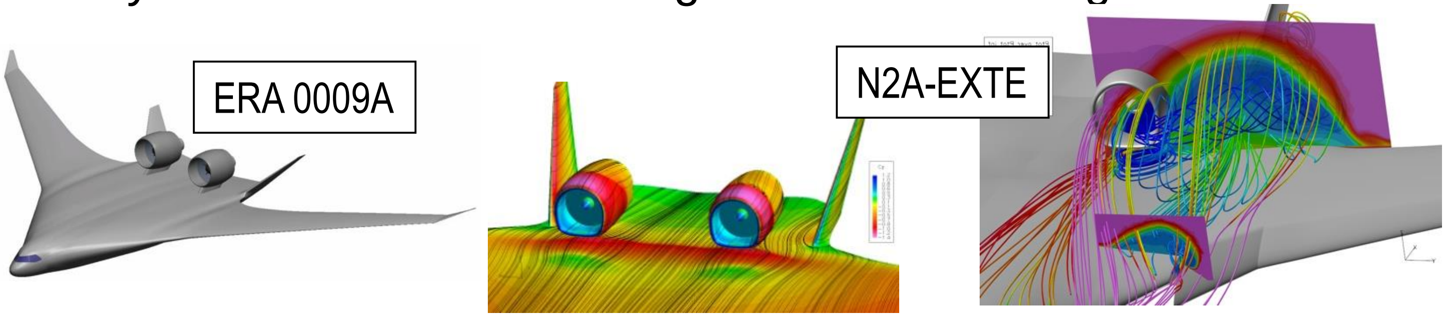
Noise

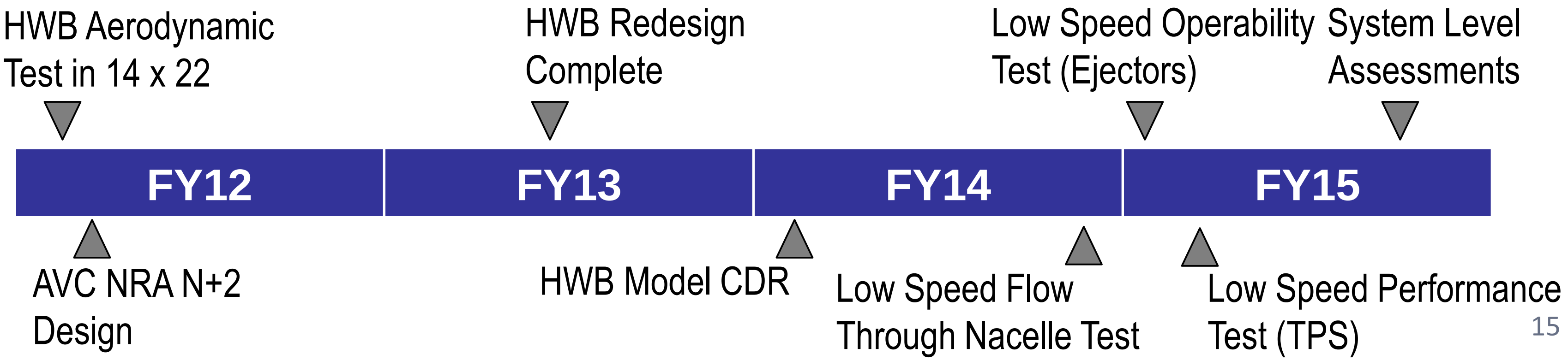
NOx

End TRL: 4

Technology Insertion Challenges Addressed

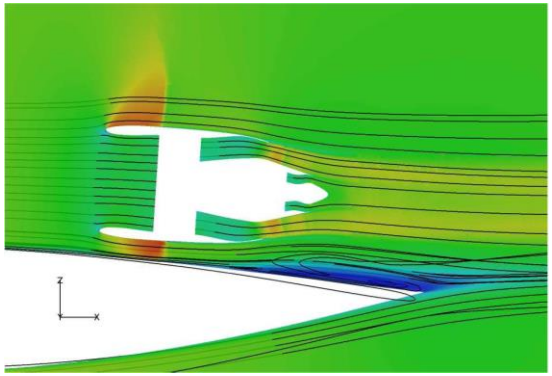
- Optimization of engine integration for all envelope performance
- UHB engine operability (pressure recovery, distortion, flow angularity) at low speed, high 〈 and β
- Balance solution for low drag with low noise
- Hi-fidelity simulation for cruise drag of HWB/UHB integration



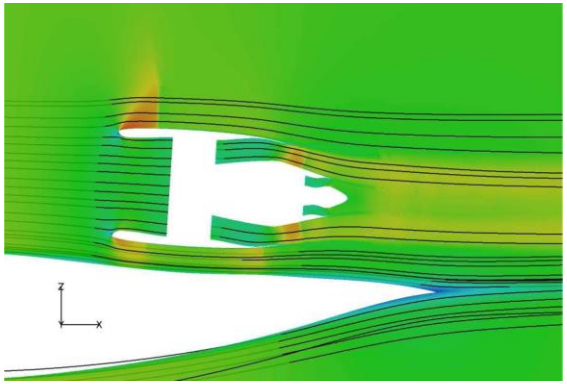


51A – Technical Highlight
Installed Drag Penalty

High speed predictions of 0009H configuration cruise (Mach 0.85 and 43,000 ft)

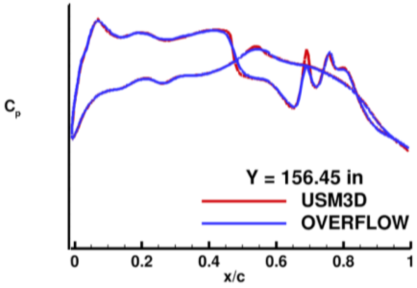


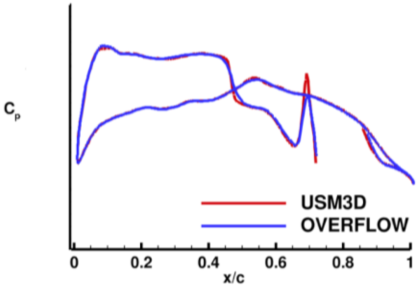
Nacelle shaping, positioning, and fuselage carving minimize flow separation resulting in reducing installed drag penalty to 1.4%

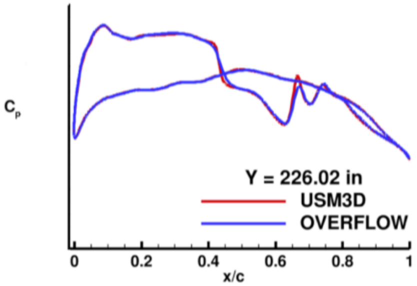


Independent NASA review of predictions agree to within one drag count

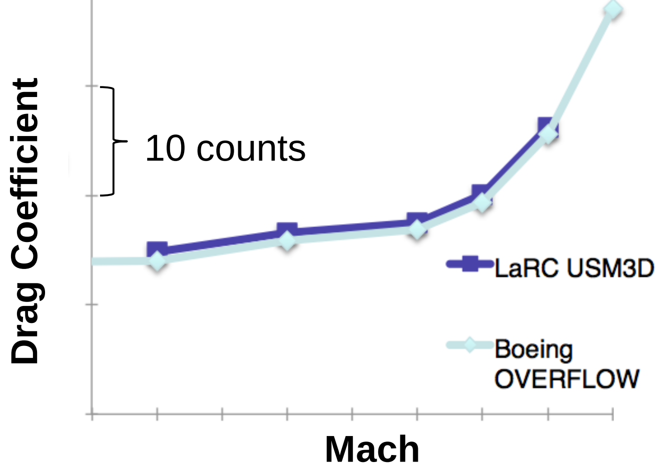
Hybrid Wing Body 0009H Body Pressures







Wing-Body-Tail Drag Polar at $C_{L,des}$



51A – Technical Highlight
Flow Through Nacelle Test in 14x22

Test Objectives:

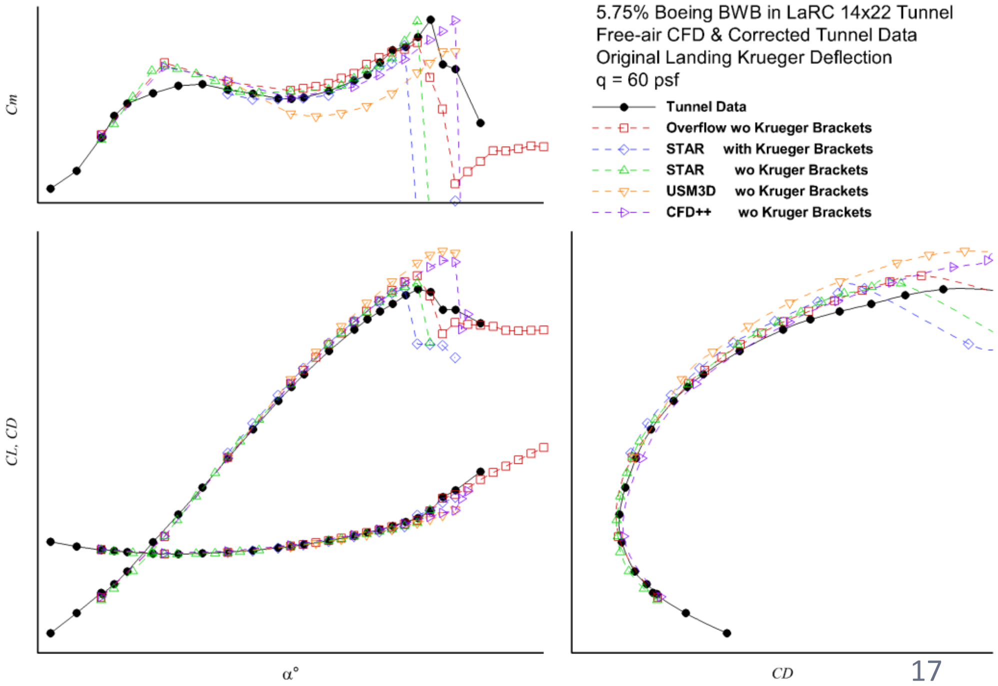
Primary – Optimize leading edge Krueger to maximize lift and increase stall angle of attack, also:

- Obtain force and moment and pressure data for comparison to powered test data
- Evaluate control effectiveness
- Use data for CFD validation

Results:

Test conducted 7/11/14 to 7/28/14. Completed 91 runs including repeat runs to meet primary objective.

- 18 Krueger flap settings for landing and take-off optimization/characterization of high-lift system
- Elevon effectiveness
- Data correction runs with Q probe (walls-up/walls down)
- CFD Krueger configuration
- Clean wing



POC (Dan Vicroy dan.d.vicroy@nasa.gov)

51A – Technical Highlight
Ejector Test in LaRC 14x22

Test objective: Collect flow surveys useful for characterizing engine operability.

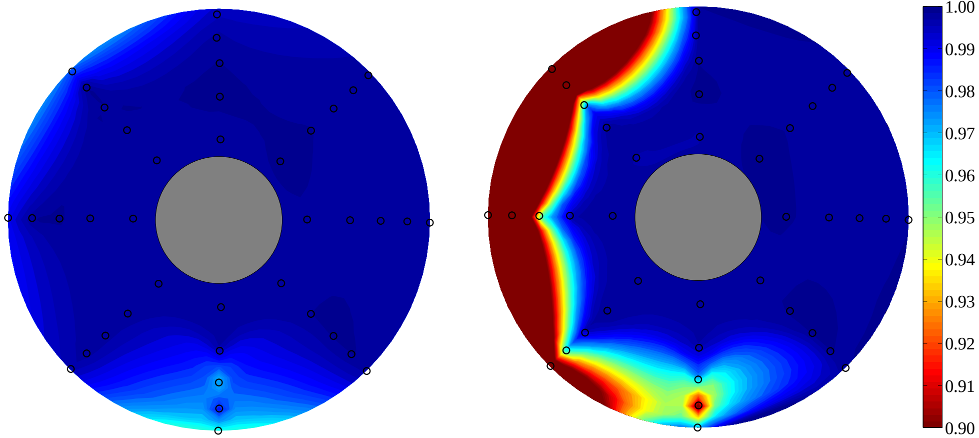
Motivation: For aft body, upper surface engine location, the inlets may be susceptible to vortex ingestion from the wing leading edge at high angles of attack and sideslip, and separated wing/body flow.

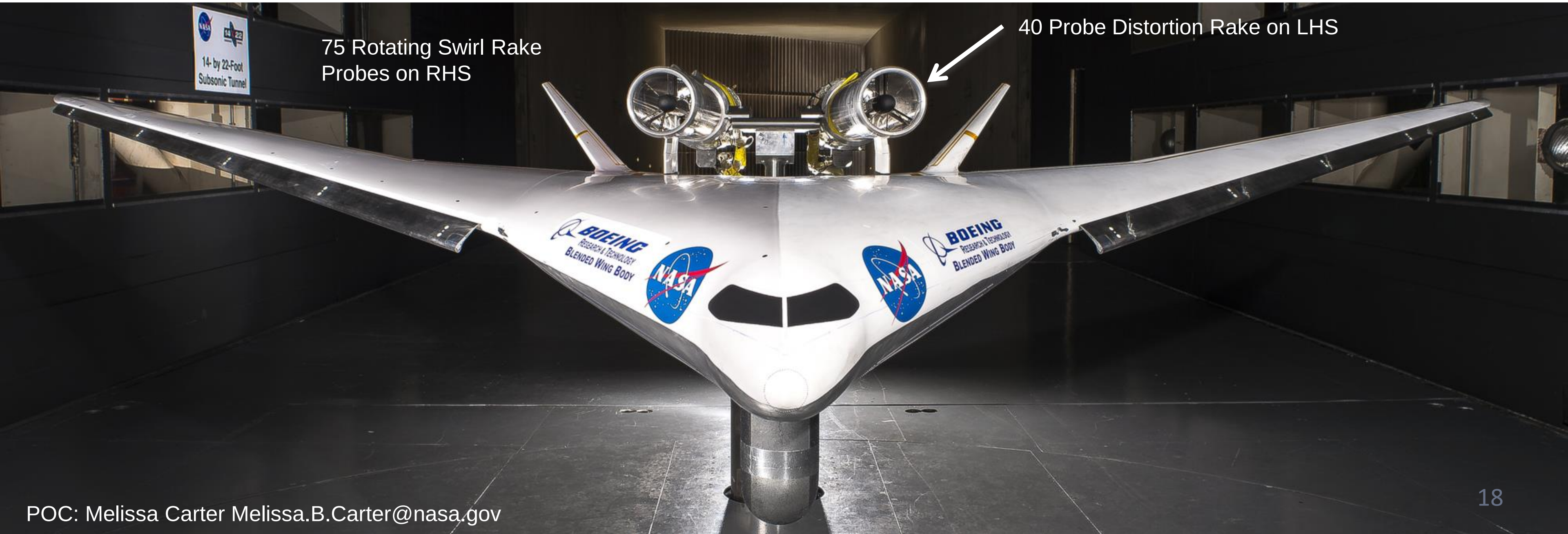
Results:

- Just over 1 week of running, Sept 2014
- 14 x 22 drive motor failed before completion of test
- 226 Runs,   2,965 data points
- 3 different ejector location data sprints completed
- Uncertainty of pressure recovery at a fan face = 0.04%
- Uncertainty of DPCPavg of fan face = 0.06%

Total Pressure Ratio, LHS Nacelle, Rear Looking Forward

0.0058	**DPCPavg**	0.0475
0.9968	**Pressure Recovery**	0.9652
-10 degrees	**Beta**	-40 degrees





75 Rotating Swirl Rake Probes on RHS

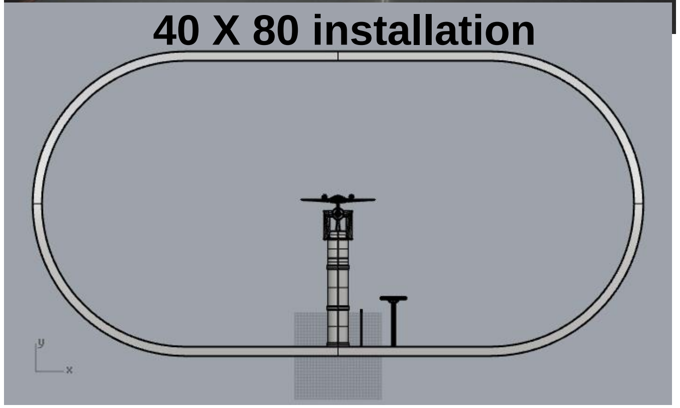
40 Probe Distortion Rake on LHS

POC: Melissa Carter Melissa.B.Carter@nasa.gov

51A – Testing Recovery Plan

- Main drive of the NASA LaRC 14x22 failed – testing suspended 10/22/2014. Tunnel down until summer 2015.
- Moved testing to AEDC NFAC 40 x 80 tunnel to maintain data delivery within ERA timeline.
- Initial plan was to resume testing 12/1/2014.
- NFAC suffered a motor generator failure. Currently scheduled to be back in service by 12/31/2014.
- Revised Testing Schedule:
  - Conduct TPS calibrations 12/1-11/2014 at ARC 9x7
  - Begin HWB Ejector installation in 40 x 80 12/8/2014.
  - Resume HWB Ejector testing 1/5/2015 (or when tunnel comes back online)
  - Conduct FTN testing 2/3/2015
  - Conduct TPS testing 2/20/2015


HWB – in 14x22
~13 ft span model


40 X 80 installation


Ejector Mount Prelim Design

Status Summary of Vehicle System Integration ITDs

- All three VSI ITDs have major events in the remainder of FY15:
  - 12A+: Boeing 757 EcoDemonstrator Flight Test
  - 50A: Full Aircraft, Full Scale Simulations of Flap and Landing Gear Noise Reduction Concepts
  - 51A: Additional HWB Flow Through Nacelle and Complete Ejector and Turbine Powered Simulator Wind Tunnel Tests
- All three VSI ITDs are on track to meet success criteria