National Aeronautics and Space Administration

# *An Overview of NASA's Environmentally Responsible Aviation Project*

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**St. Petersburg, Russia**

www.nasa.gov

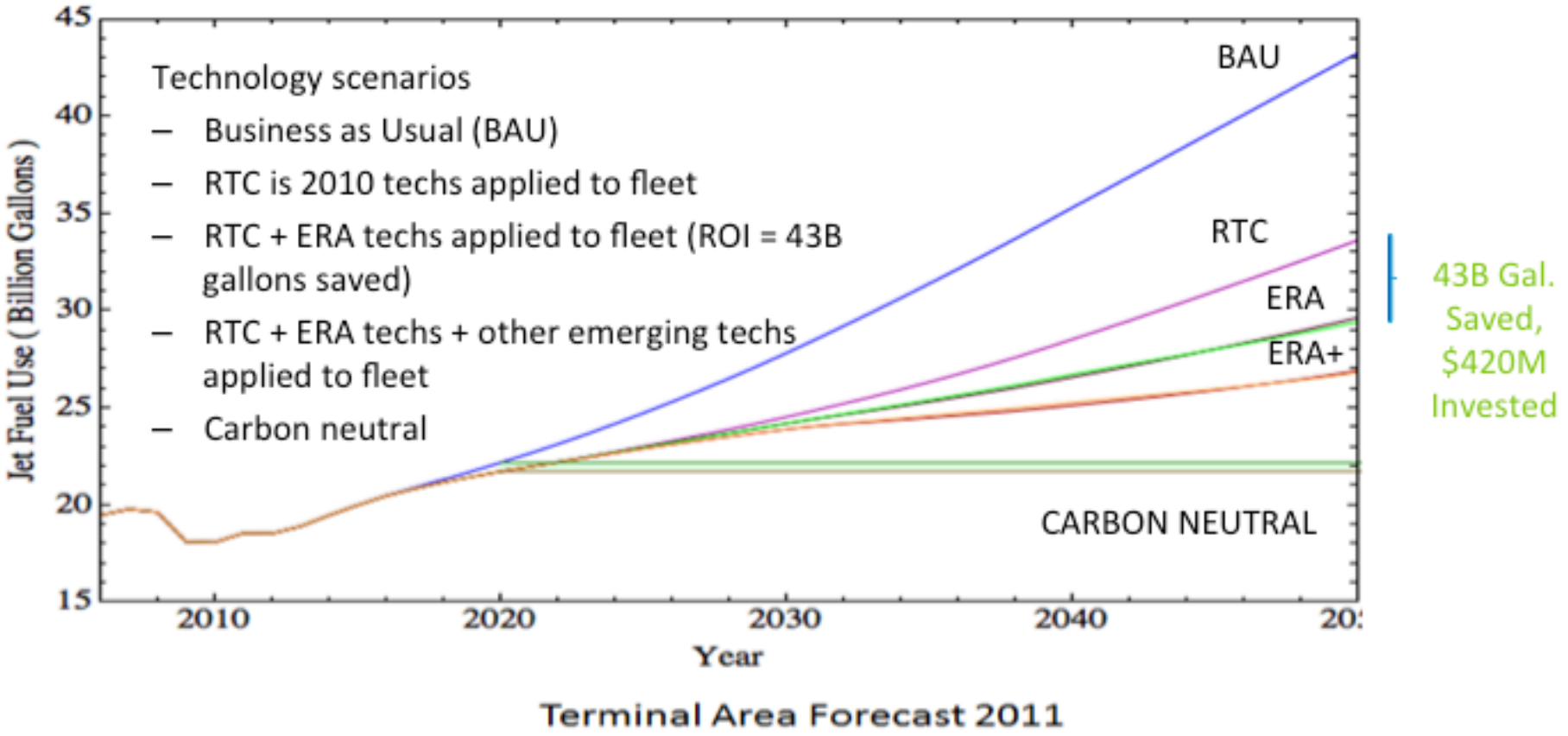
# Outline

- Impact of the Research
- Introduction
- ERA Phase I
- ERA Phase II
  - Integrated Technology Demonstrations
  - Details of ITDs

757 AFC Enhanced Vertical Tail installed in NFAC
End of day tuft maintenance

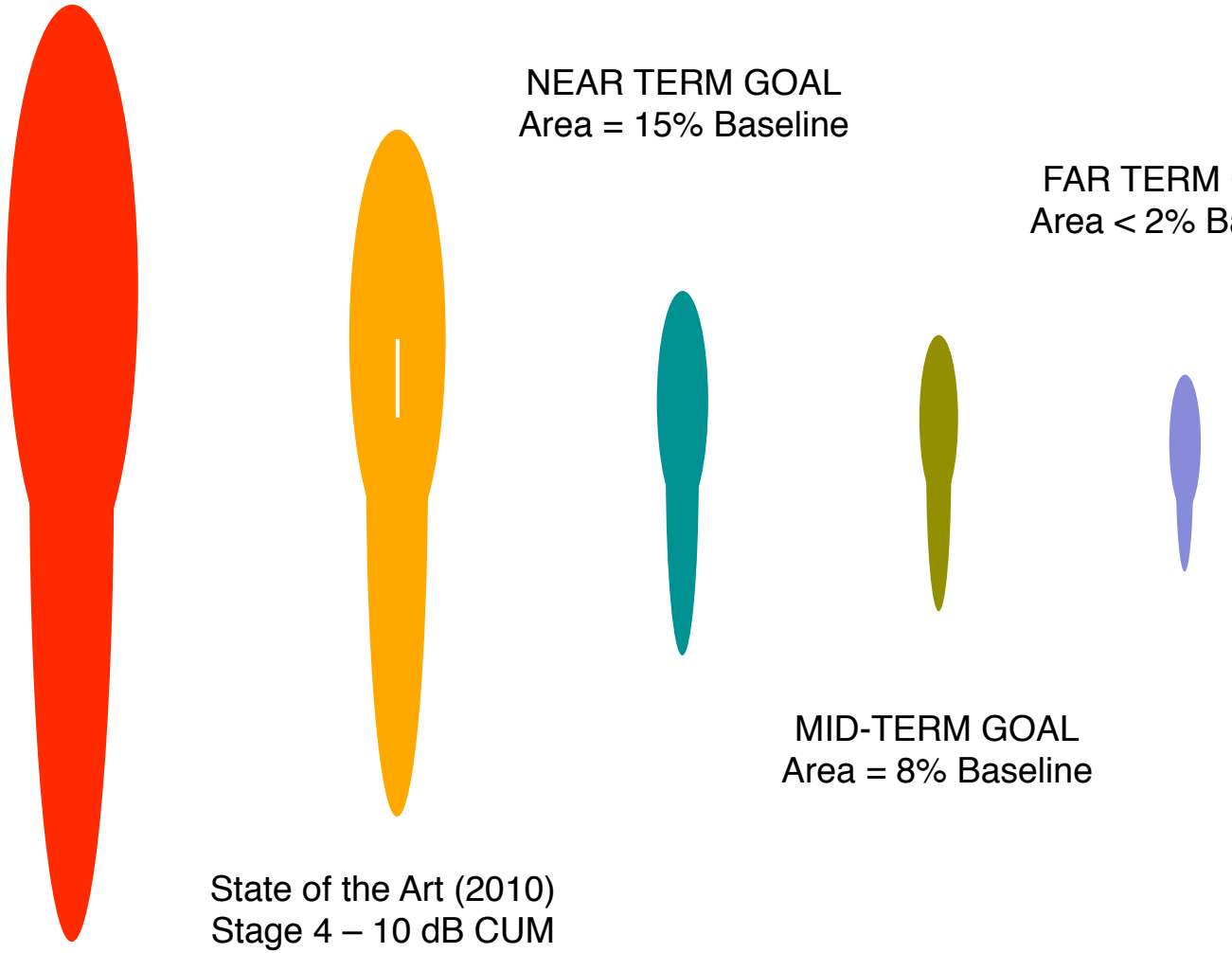
# Impact at the Fleet Level – Carbon Footprint

NASA Aeronautics is delivering technology that is relevant to next generation aircraft designs and will impact the carbon footprint of the fleet



# Impact at the Vehicle Level – Noise Footprint

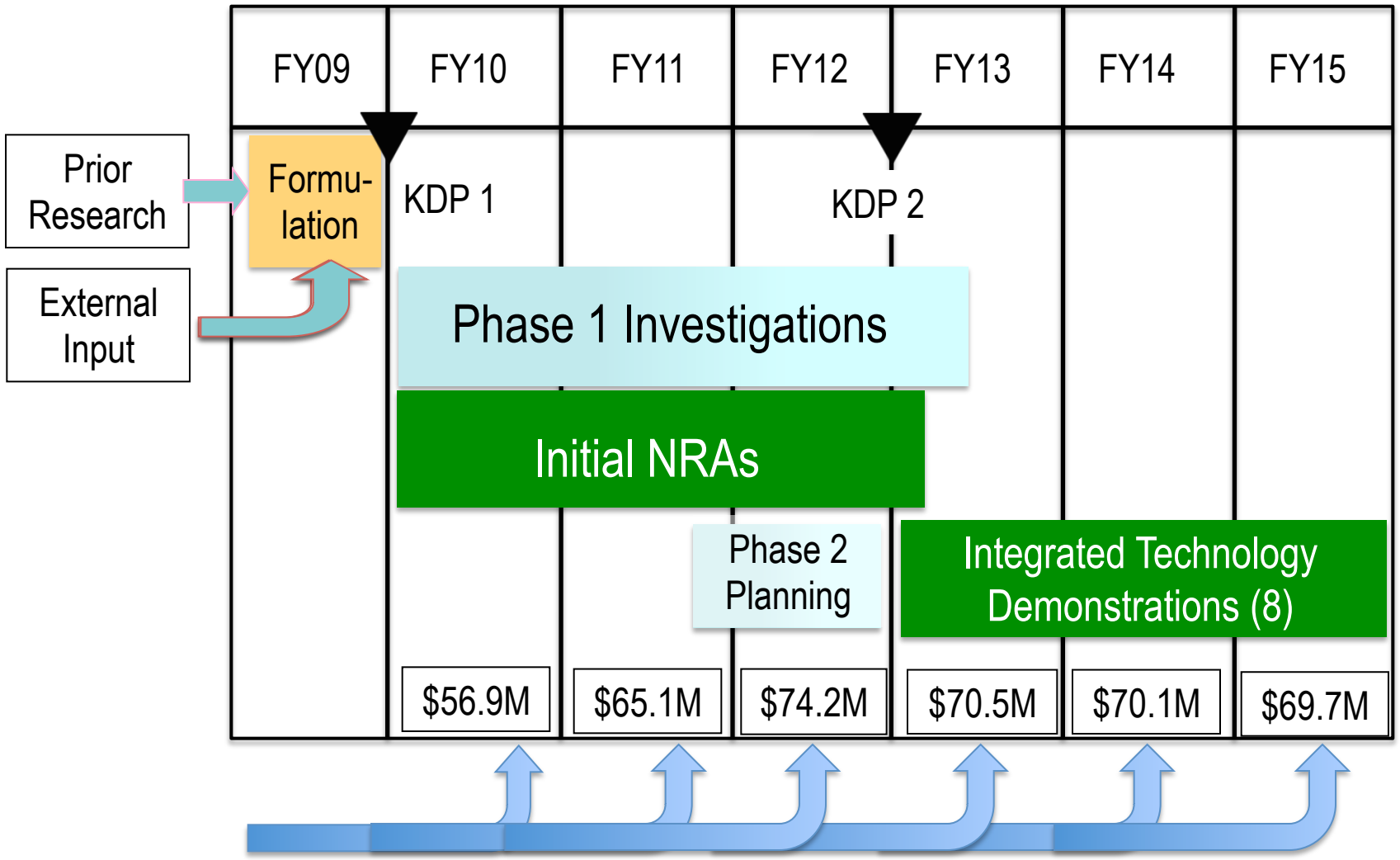
NASA Aeronautics is delivering technology that is relevant to next generation aircraft designs and will impact the noise footprint of the fleet



# Introduction
# Vision/Mission/Scope for ISRP/ERA Project


- Vision
  - expand the viable and well-informed trade space for commercial transport design decisions
  - enable simultaneous realization of national noise, emissions, and performance goals by 2025
- Mission
  - Execute integrated technology demonstrations
  - Partner w/Industry and transfer knowledge
- Scope
  - Mature technology for application in the 2020+ time frame
    - Advance the state-of-the-art, reduce risk of application
  - Perform system/subsystem research in relevant environments

# Introduction
# ERA Project Flow with Key Decision Points



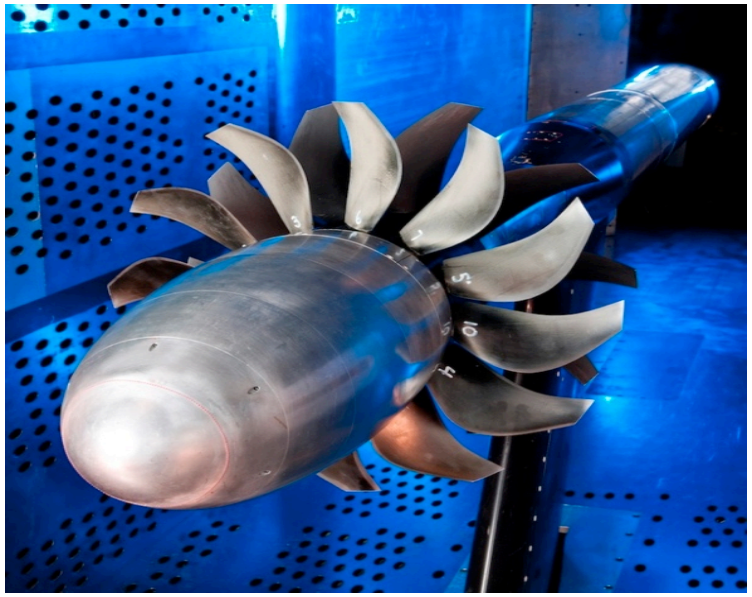

Technical input from Fundamental Programs, NRAs, Industry, Academia, Other Gov't Agencies

FY 10-14 are full cost budgets
FY 15 is projected budget from most recent President's Budget submit

# ERA Phase I
# Concluded Several Multi-Year Campaigns


- Open Rotor Development and WT Test in the GRC 9x15 (w/GE)
- Low NOx Combustor Development in ASCR at GRC (w/GE and P&W)
- X-48B/C Low Speed Flight Controls Test Campaign (w/Boeing)
- HWB Community Noise Reduction Propulsion AeroAcoustics (PAA) Test Campaign in the 14x22 WT (w/Boeing)
- Advanced Vehicle Concept Study (w/Lockheed, NGC, Boeing)

# ERA Phase I
# Open Rotor R&D Test Campaign



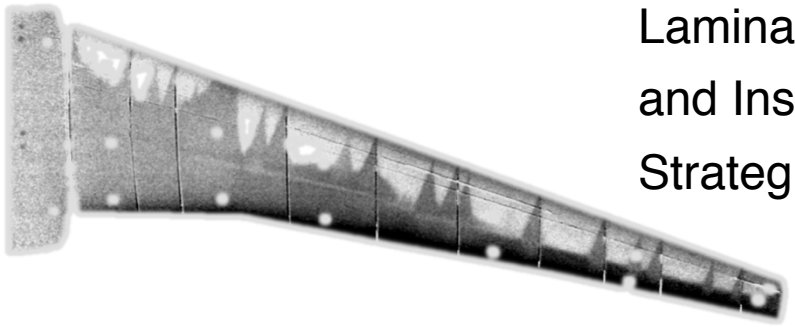
***Open Rotor Propulsion Rig installed in GRC's 8x6 and 9x15 Wind Tunnels***

This technology applied to advanced 2025 EIS single aisle A/C showed 36 percent block fuel reduction & 15 EPNdB cum. noise margin below Stage 4 (compared to 1998)

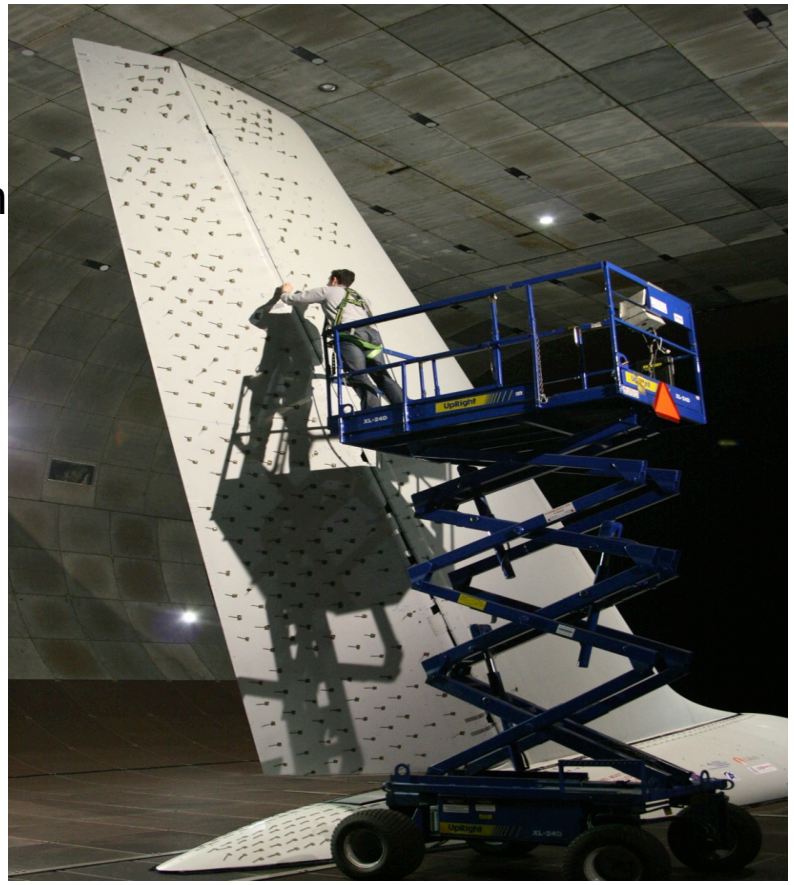
# ERA Phase II
# Integrated Technology Demonstrators – In progress


| | ITD Finish |
|---|---|
| **Drag Reduction of 8 percent** | |
| - ITD 12A+ - Active Flow Control Enhanced Vertical Tail and Advanced Wing Flight Experiment | 7/2015 |
| **Weight Reduction of 10 percent** | |
| - ITD 21A - Damage Arresting Composites Demonstration | 7/2015 |
| - ITD 21C - Adaptive Compliant Trailing Edge Flight Experiment | 4/2015 |
| **SFC and Noise Reduction of 15 percent and 15 EPNdB** | |
| - ITD 30A – Highly Loaded Front Block Compressor Demo | 9/2015 |
| - ITD 35A – 2nd Generation UHB Propulsor Integration | 6/2015 |
| **NOX Reduction of 75 percent below CAEP 6** | |
| - ITD 40A – Low NOX Fuel Flexible Combustor Integration | 7/2015 |
| **Noise and Fuel Burn Reduction of 42 EPNdB and 50 percent** | |
| - ITD 50A – Flap Edge and Landing Gear Noise Reduction Experiment | 8/2015 |
| - ITD 51A – UHB Integration for Hybrid Wing Body Aircraft | 7/2015 |

# ERA Phase II
# AFC Enhanced Vertical Tail and Advanced Wing



Laminar Flow
and Insect Abhesion
Strategies

Active Flow Control on B757 Tail


**Thank you for your attention!**

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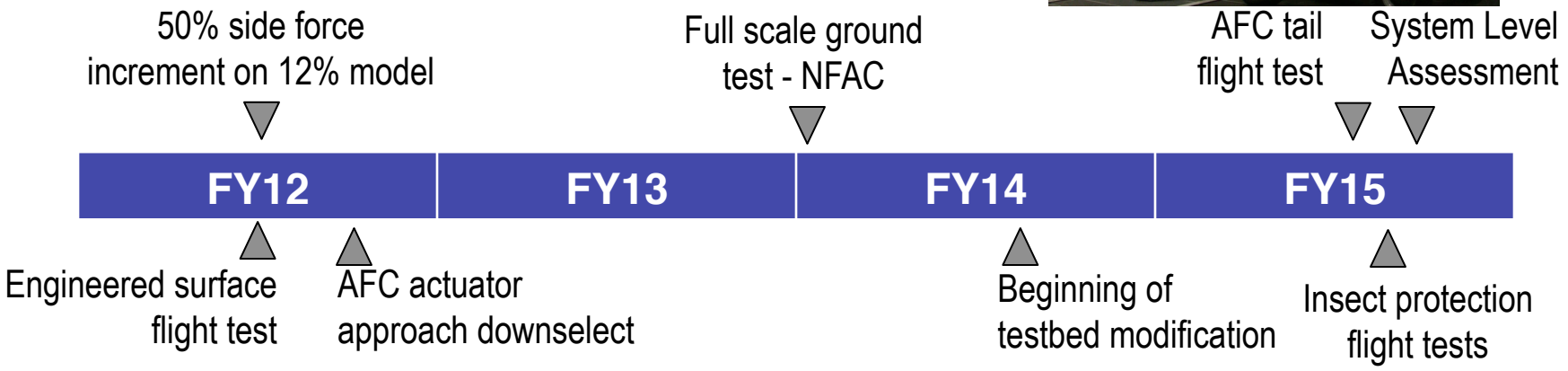
# Integrated Technology Demonstrator
# AFC Vertical Tail and Advanced Wing Flight Test


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, repairable insect abhesion surfaces



# Integrated Technology Demonstrator
# Damage Arresting Composites Demonstration

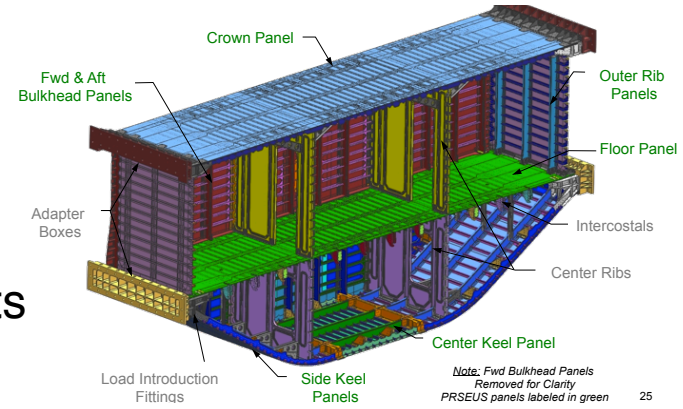
Weight | Drag | TSFC | Noise | NOx

**End TRL: 5**

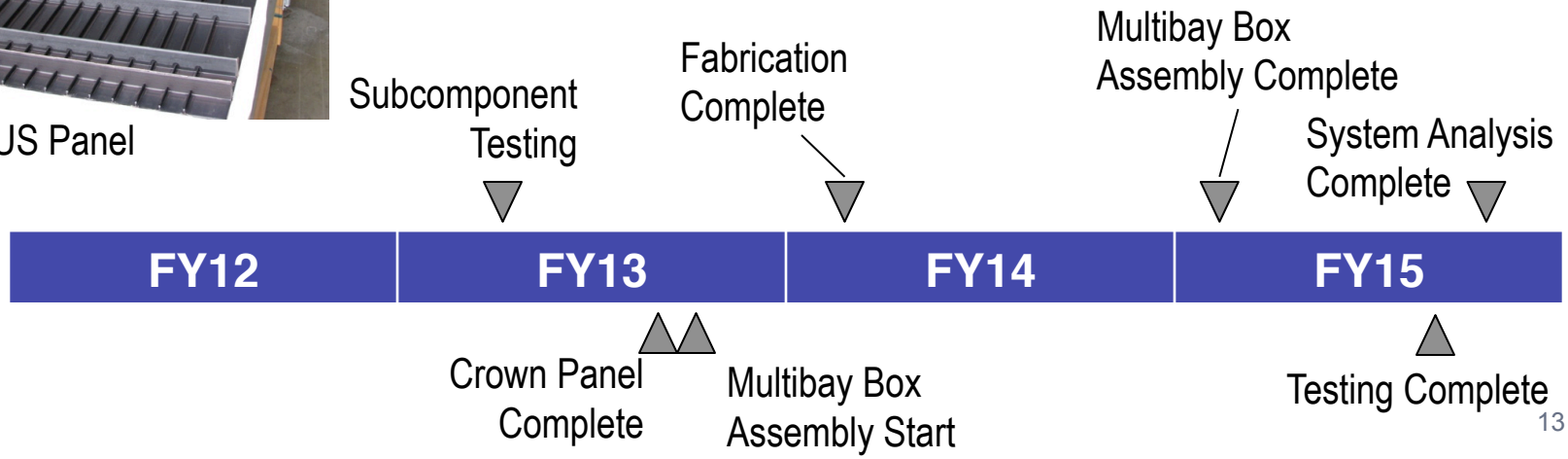
## Technology Insertion Challenges Addressed

- Damage Tolerance
- Postbuckled composite structure
- Integrated System Weight
- Large scale flight weight infused composite parts

PRSEUS Panel




30 foot Multibay Box



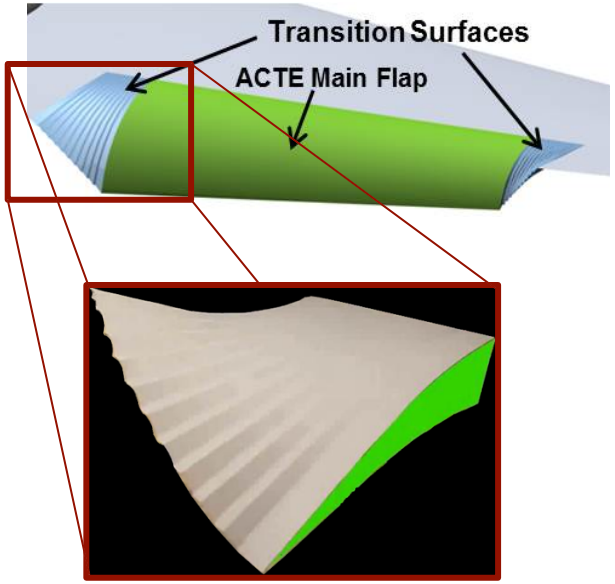
# Integrated Technology Demonstrator
# Adaptive Compliant Trailing Edge Flight Demonstration

Weight | Drag | TSFC | Noise | NOx

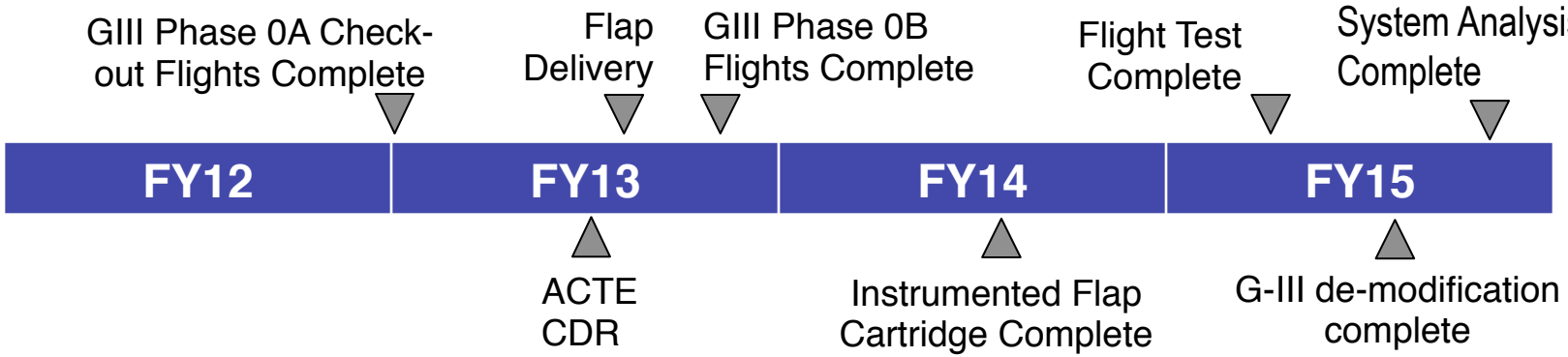
**End TRL: 6**

## Technology Insertion Challenges Addressed

- Airworthy, compliant trailing edge
- Transition region
- Analytical and ground test flutter predictions validated through high speed flight




AFRL & FLEXSYS Flap



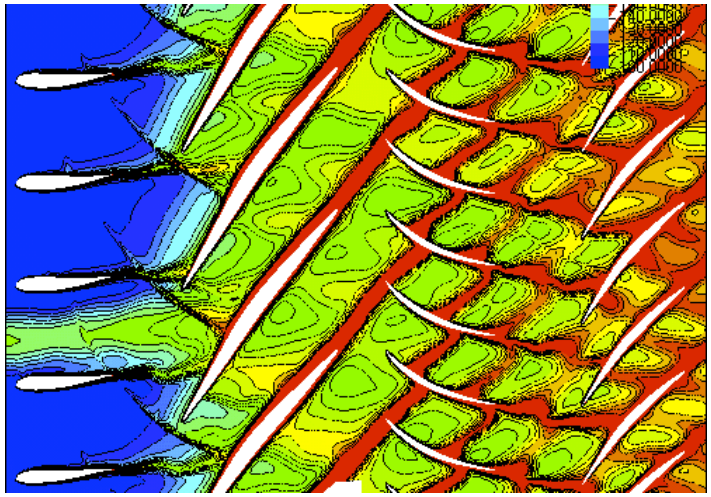
# Integrated Technology Demonstrator
# Highly Loaded Front Block Compressor Deomonstration

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

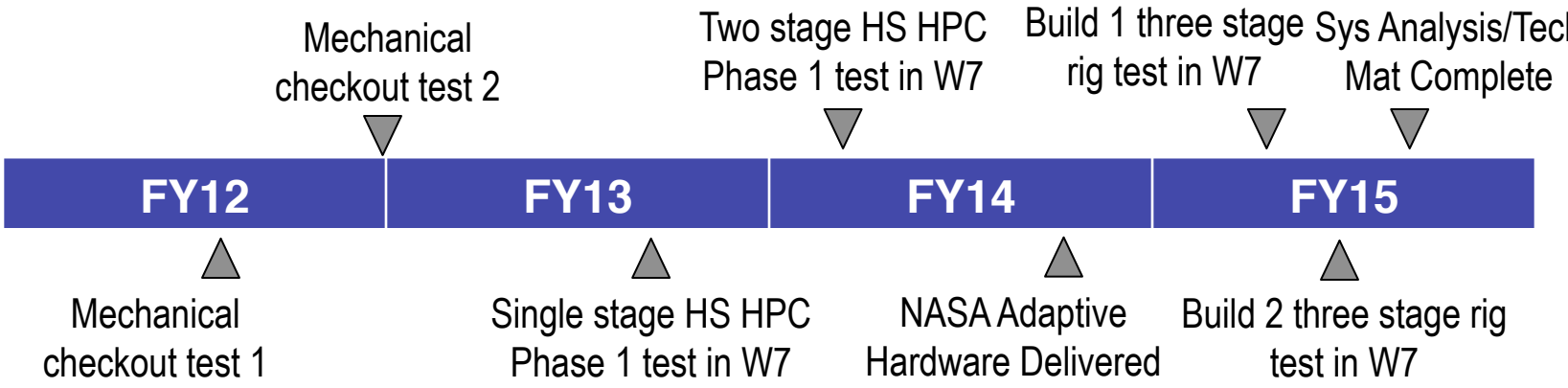
**End TRL: 5**

## Technology Insertion Challenges Addressed

- Identify loss mechanisms and interaction effects of highly-loaded compressor stages
- Trade-off between OPR, Efficiency, and operability to optimize fuel burn
- Establish part-speed operability margin
- Integrated 1st 3 stages of HPC with engine bleed and inlet flowpath



Unsteady Interactions Predicted by CFD: Entropy Plot



# Integrated Technology Demonstrator
# 2nd Generation UHB Propulsor Integration

Weight | Drag | TSFC | Noise | NOx

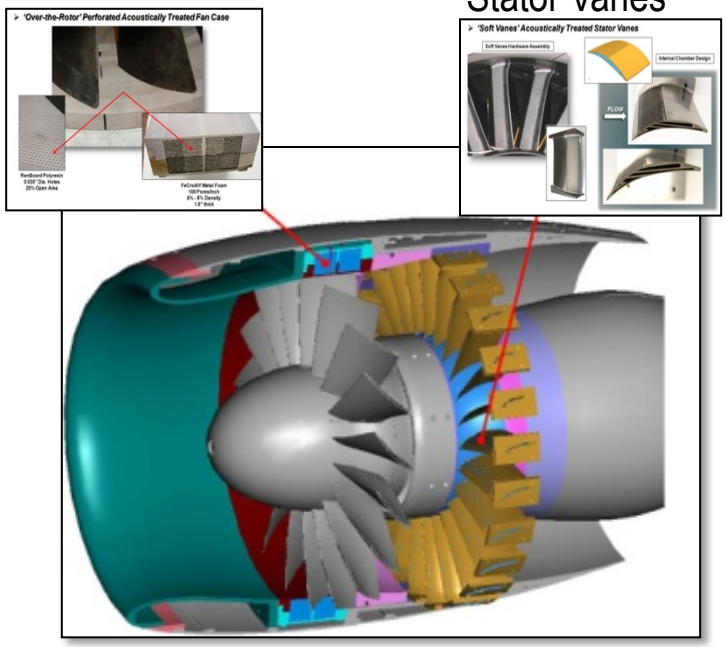
**End TRL: 5**

## Technology Insertion Challenges Addressed

- Noise reduction & aero performance of advanced liners validated
- Comprehensive, modern database of propulsor multi-discipline performance characteristics
- Integrated performance of modern fan + advanced FEGVs + short inlet verified

Over-the-Rotor Treated Fan Case

"Soft Vanes" Treated Stator Vanes




SMA VAN Prototype Demo

UHB OTR Perf. Risk Mitigation Test

UHB OTR/SV Noise Reduction Validation Test

Integrated System LS Test

**FY12** | **FY13** | **FY14** | **FY15**

UHB Gen 2 Test

Integrated Systems Design Task Start

UHB Integ. System DDR

UHB Low Loss FEGVs Test

Sys Analysis/Tech Mat Complete

# Integrated Technology Demonstrator
# Fuel Flexible, Low NOX Combustor Integration

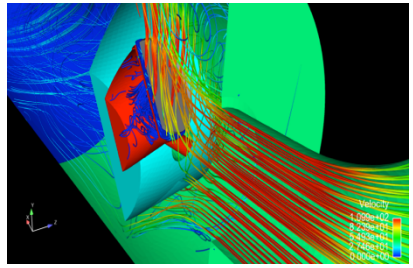
Weight | Drag | TSFC | Noise | NOx

End TRL: 5

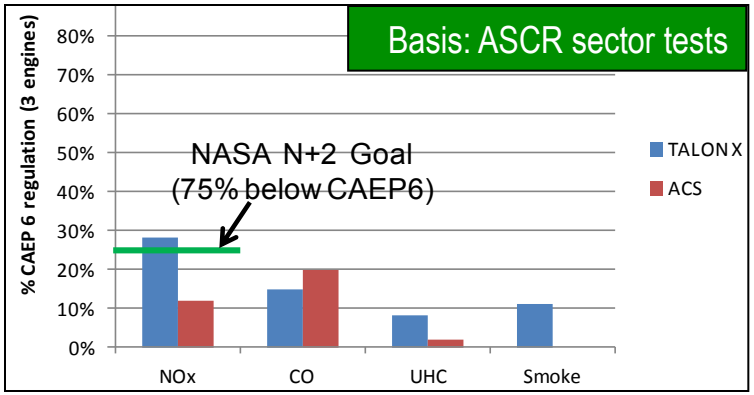
## Technology Insertion Challenges Addressed

- The lean burn system operability concerns
  - auto-ignition
  - flame stability
  - acoustic resonance
- Durability with reduced cooling flow
- 50/50 jet/alt fuel mixture

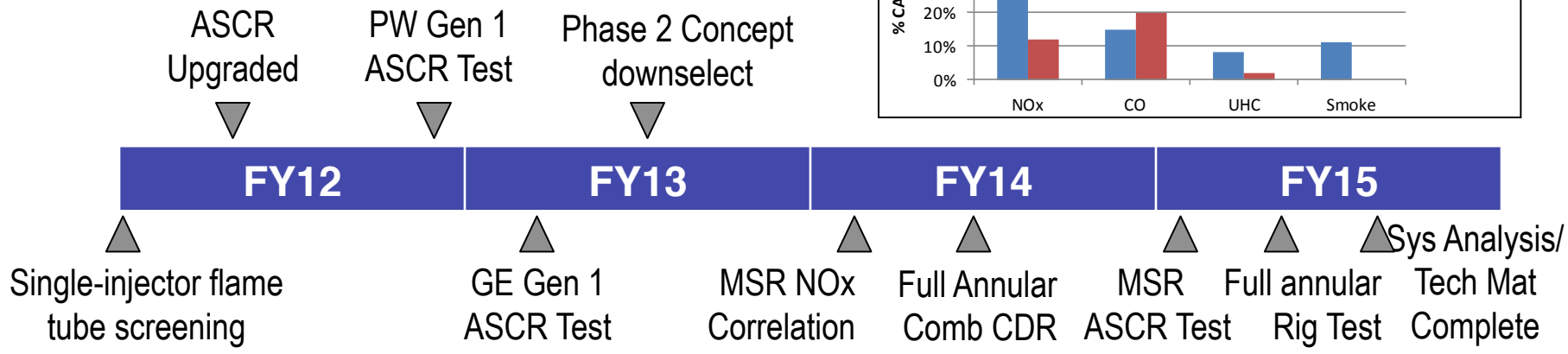
CFD of film cooling and CMC liners



% CAEP6 LTO Emissions in a N+2 Cycle




**ASCR Sector Rig test results indicated as much as -88% LTO NOx reduction achieved**



# Integrated Technology Demonstrator
# Landing Gear and Flap Edge Noise Reduction Flight T

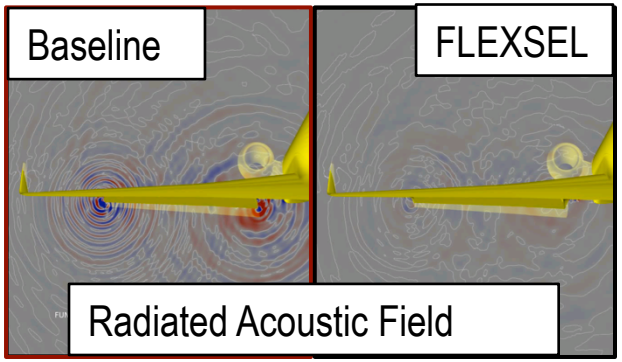
TC5

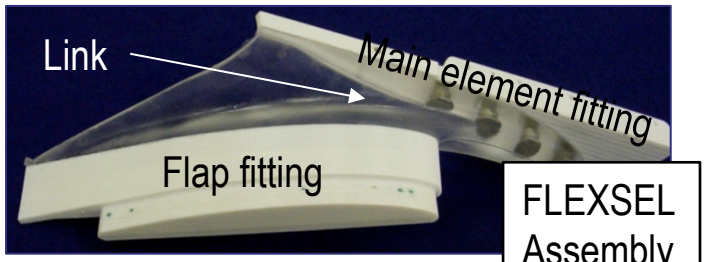
Weight | Drag | TSFC | **Noise** | NOx

**End TRL: 6**

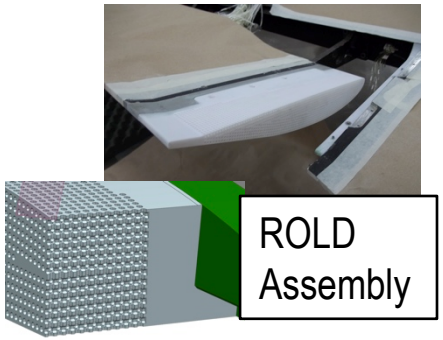
## Technology Insertion Challenges Addressed

- Minimize weight penalty and performance degradation
- Identify/Address Integration and Operability challenges
- Determine Ground to Flight Scaling

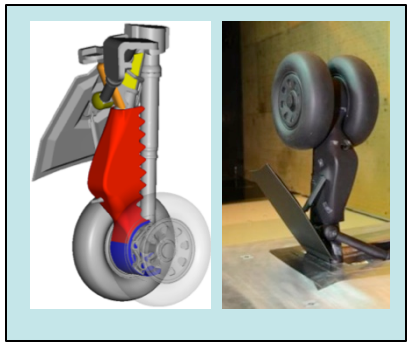



Landing Gear Ground Test




Flap and Landing Gear Concept Downselect



~~Flight Test Demonstration~~

| 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 |

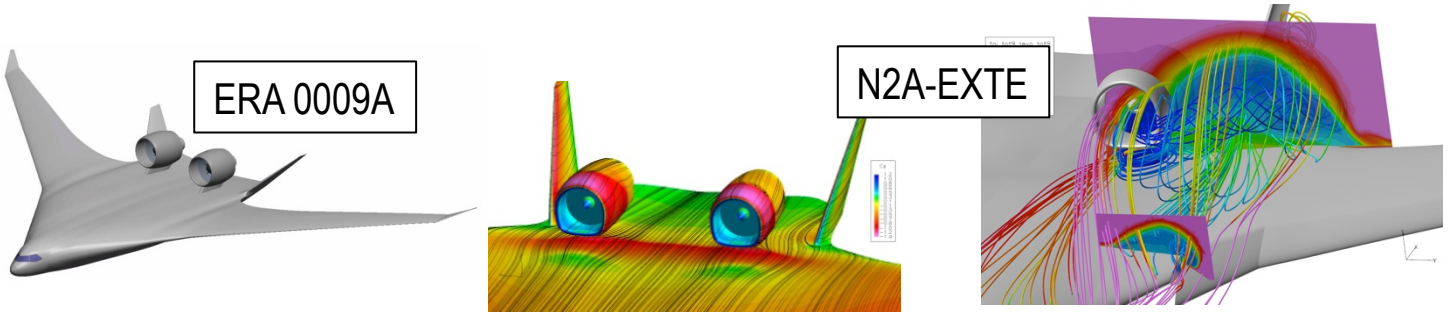
# Integrated Technology Demonstrator
# UHB Integration on a Hybrid Wing Body

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

**End TRL: 5**

## Technology Insertion Challenges Addressed

- Optimization of engine Integration for all envelope performance
- UHB engine operability at low speed, high $\alpha$ and $\beta$
- Balance solution for low drag with low noise
- Hi-fidelity simulation for cruise drag of HWB/UHB integration




HWB Aerodynamic Test in 14 x 22

HWB Redesign Complete

Low Speed Operability Test (Ejectors)

System Level Assessments

**FY12** | **FY13** | **FY14** | **FY15**

AVC NRA N+2 Design

HWB Model CDR

Low Speed Performance Test (TPS)