National Aeronautics and Space Administration

Subsonic Fixed Wing Project

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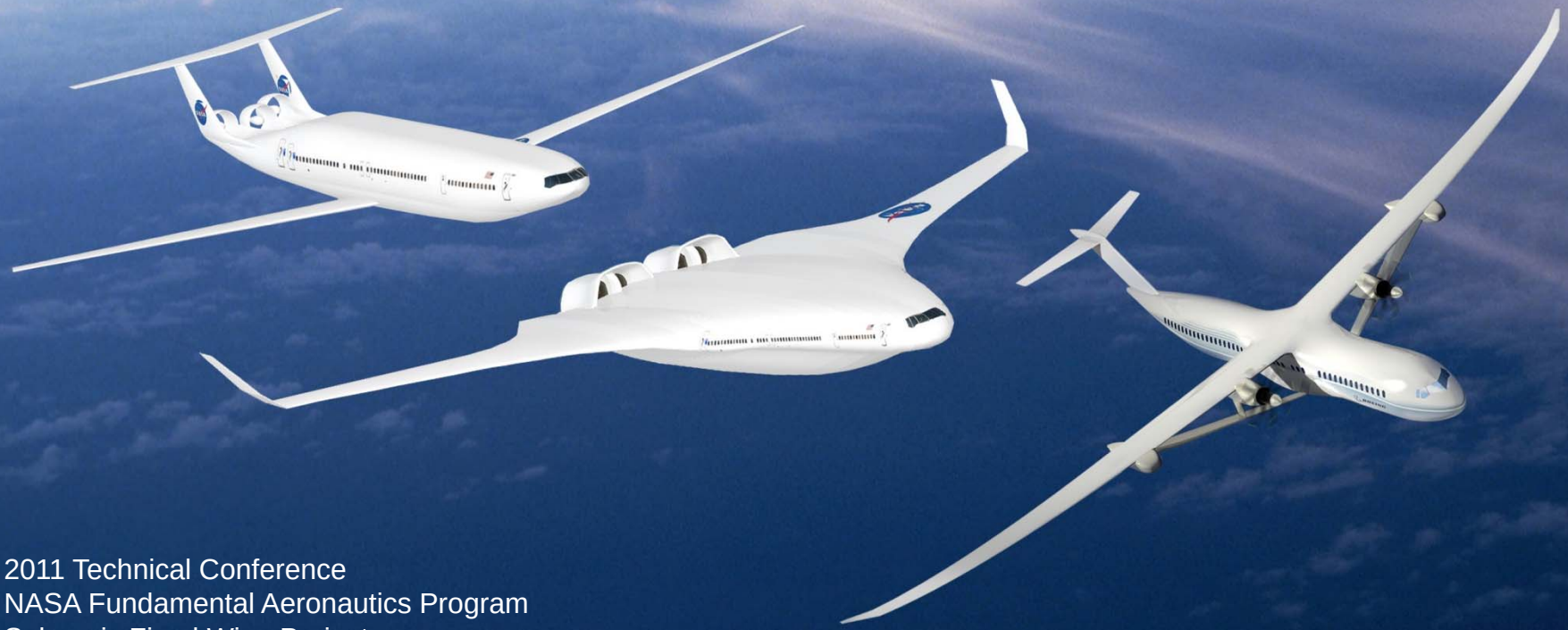


2011 Technical Conference
NASA Fundamental Aeronautics Program
Subsonic Fixed Wing Project
Cleveland, OH, March 15 - 17, 2011

www.nasa.gov

Outline

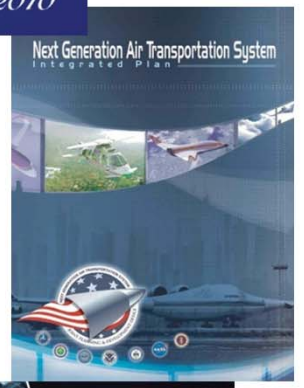
- SFW Project Overview

  National and NASA Context

  Background
- SFW Strategic Framework for the Future
- SFW Technical Content
- Major Ongoing SFW Activities
- Overview of Conference Sessions
- Closing Remarks and Comments

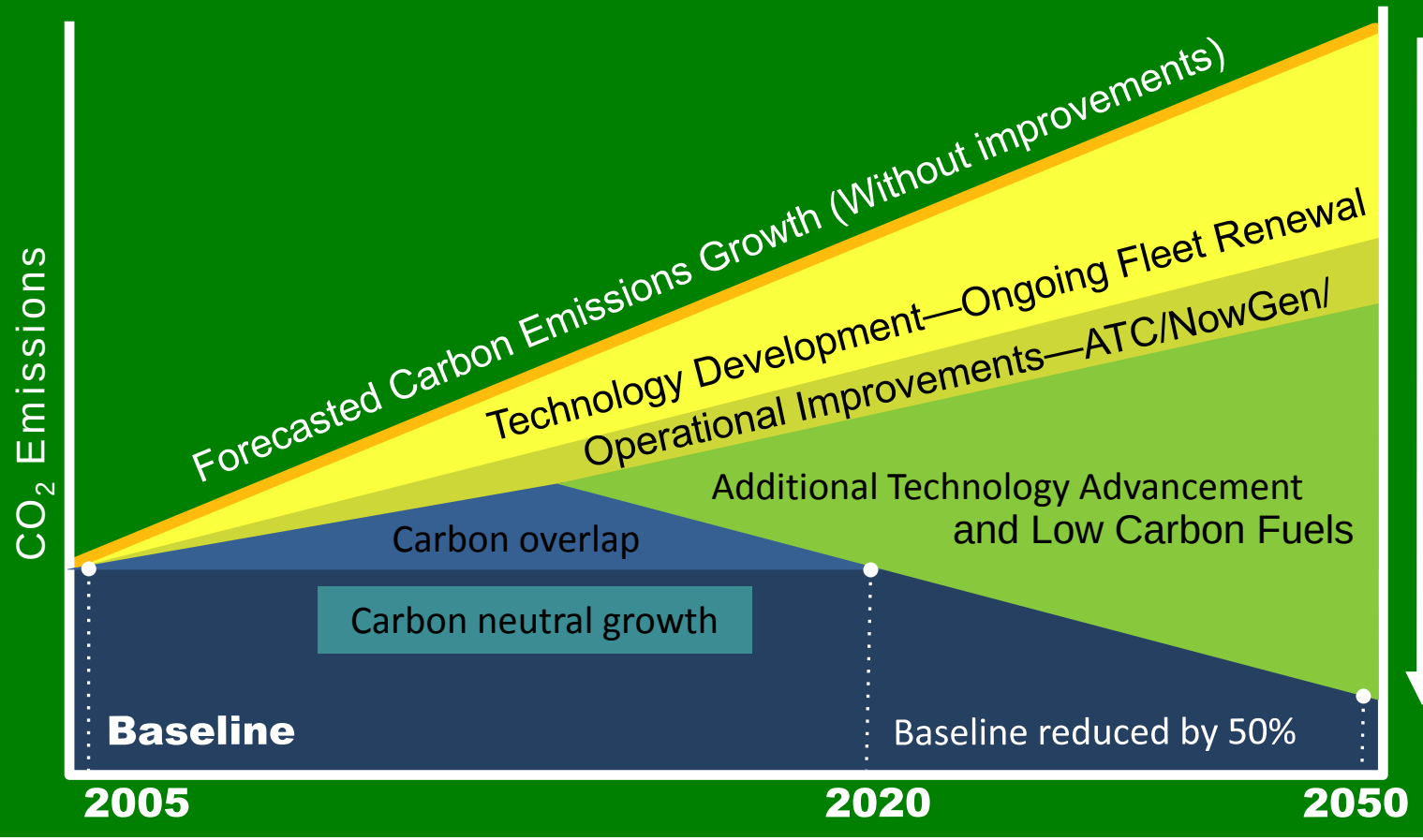
The National and NASA Context

- National Aeronautics R&D Policy (2006) and Plan (2010)
  - Enable growth in Mobility/Aviation/Transportation
  - Civil focus, but dual use with Security and Defense
  - Energy and Environmental goals are central to Energy Diversity, Energy Efficiency, and Environmental Impact
- Revolutionary transformation of the airspace, the vehicles that fly in it, and their operations, safety, and environmental impact
- NASA Strategic Goal 4: Advance aeronautics research for societal benefit.
  - 4.1 Develop innovative solutions and advanced technologies through a balanced research portfolio to improve current and future air transportation



Environmental Challenges for Aviation

By 2050, substantially reduce carbon emissions, while containing objectionable noise within the airport boundary, and significantly reducing emissions of oxides of nitrogen



The Subsonic Fixed Wing Project

Explore and Develop Tools, Technologies, and Concepts for Improved Energy Efficiency and Environmental Compatibility for Sustained Growth of Commercial Aviation

Objectives

- Prediction and analysis tools for reduced uncertainty
- Concepts and technologies for dramatic improvements in noise, emissions and performance

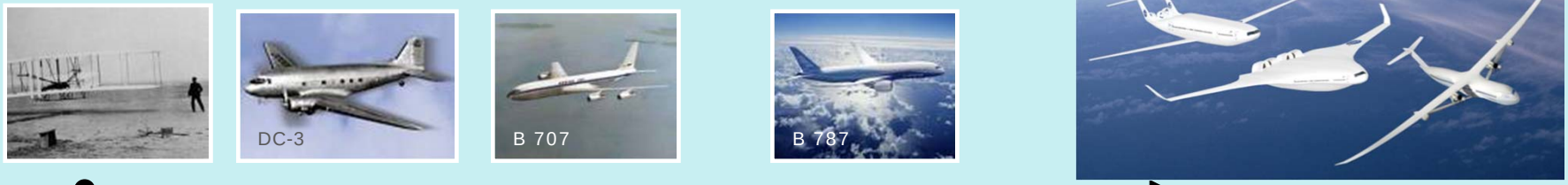
Significance

- Environmental challenges for aviation are daunting
- Demands from NextGen airspace challenges
- Subsonic air transportation vital to our economy and quality of life

Diversified Workforce

- 300+ In-House and Contractor
- 55+ NRAs to Academia and Large and Small Businesses
- Various formal and informal partnerships

Evolution of Subsonic Transports

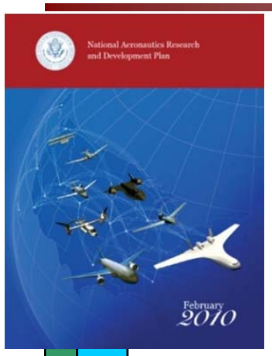


Collaborative Research

Three main components

- NASA in-house research
- Partnerships with Government agencies, industry, universities
- Sponsored research by NASA Research Announcements (NRA)

SFW Strategic Framework for the Future



Strategic Thrusts	Strategic Goals	System Level Metrics
1. Energy Efficiency	1.1 Reduce the energy intensity of air transportation	• Fuel Burn • Energy Efficiency
2. Environmental Compatibility	2.1 Reduce the impact of aircraft on air quality around airports 2.2 Contain objectionable aircraft noise within airport boundaries 2.3 Reduce the impact of aircraft operations on global climate	• LTO NO_X Emissions • Other LTO Emissions • Aircraft Certification Noise • Cruise NO_X Emissions • Life-cycle CO_2e per Unit of Energy Used

NASA Subsonic Transport System Level Metrics

…. technology for dramatically improving noise, emissions, & performance

CORNERS OF THE TRADE SPACE	N+1 (2015)*** Technology Benefits Relative to a Single Aisle Reference Configuration	N+2 (2020)*** Technology Benefits Relative to a Large Twin Aisle Reference Configuration	N+3 (2025)*** Technology Benefits
Noise (cum below Stage 4)	- 32 dB	- 42 dB	- 71 dB
LTO NOx Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance Aircraft Fuel Burn	-33%**	-50%**	better than -70%
Performance Field Length	-33%	-50%	exploit metroplex* concepts

*** Technology Readiness Level for key technologies = 4-6

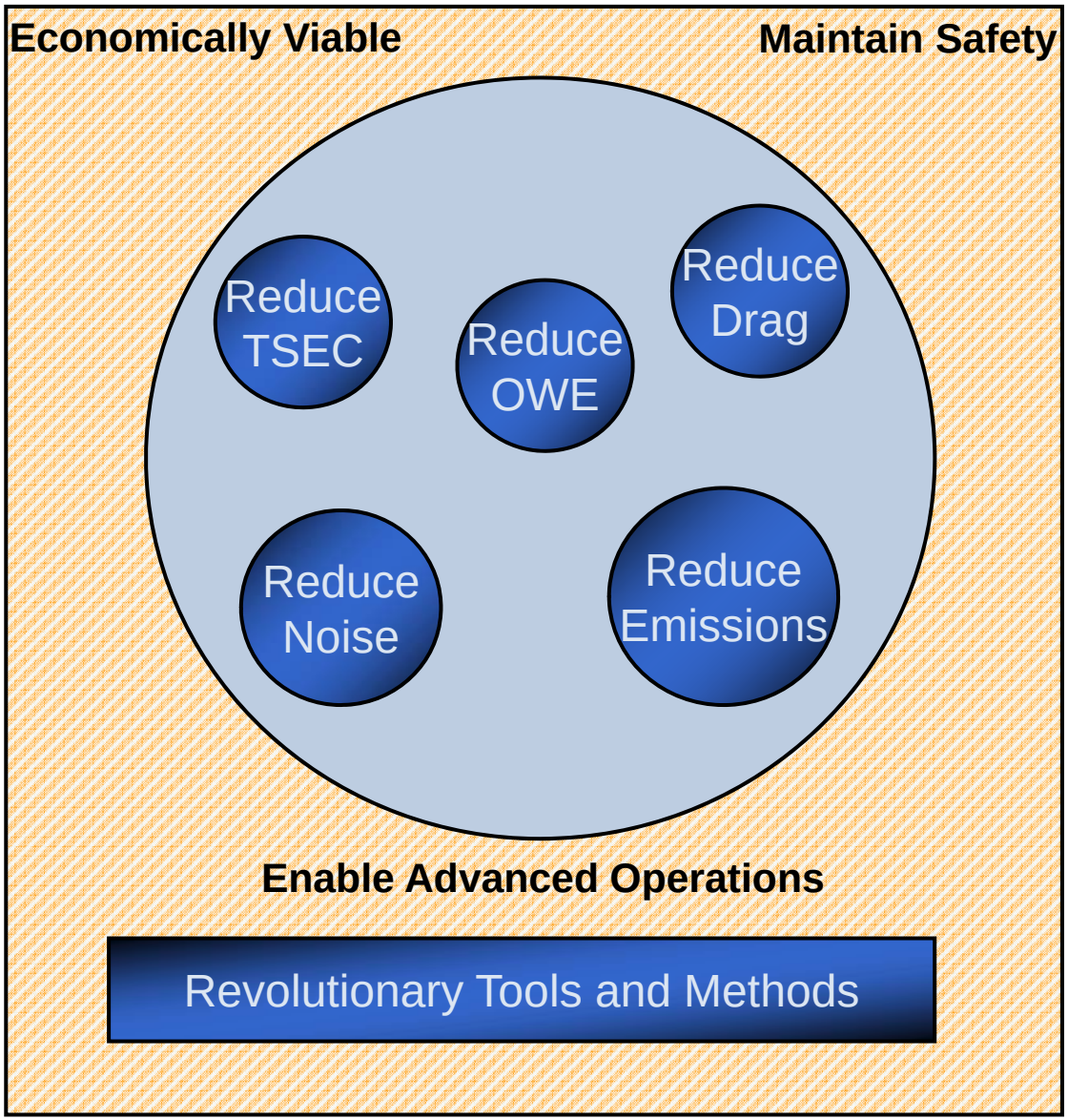
** Additional gains may be possible through operational improvements

* Concepts that enable optimal use of runways at multiple airports within the metropolitan areas

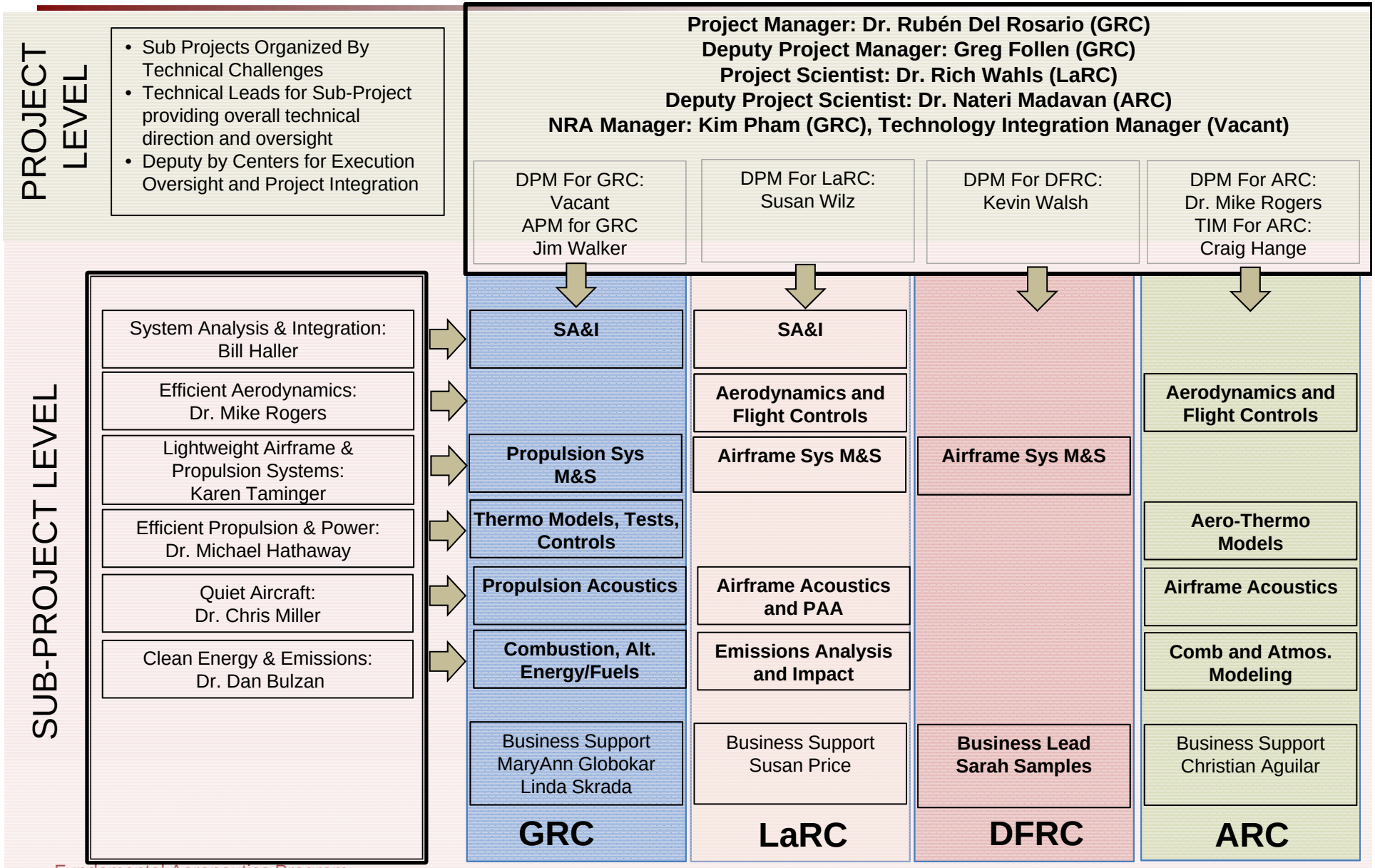
SFW Approach

- Conduct Discipline-based Foundational Research
- Investigate Advanced Multi-Discipline Based Concepts and Technologies
- Reduce Uncertainty in Multi-Disciplinary Design and Analysis Tools and Processes
- Enable Major Changes in Engine Cycle/Airframe Configurations

SFW Technical Challenges



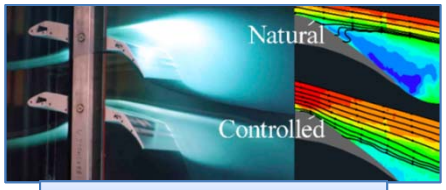
SFW Project Organization



Center Involvement by Sub-project represent current portfolio but any Center could become partner as content is added

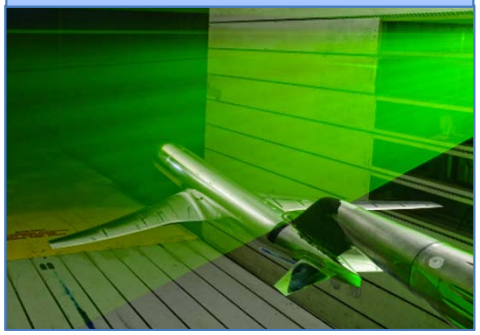
Energy Efficiency: Reduce Drag

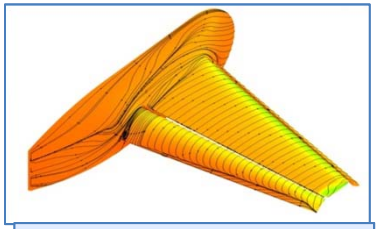
- Reduce aircraft drag with minimal impact on weight (aerodynamic efficiency)
  - Novel configurations/integration
  - Cruise drag reduction
  - Advanced CONOPS



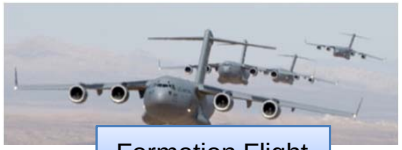
Flow Control Experiments

CRM Model at NTF (top) and PIV tests in 11 ft. tunnel (bottom)

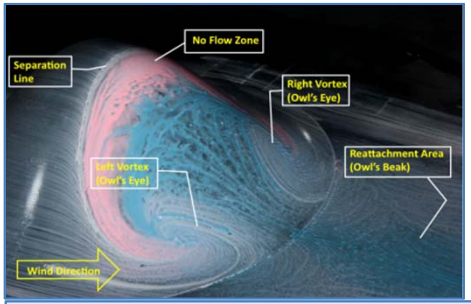




Trap Wing Flap Separation Experiment and CFD

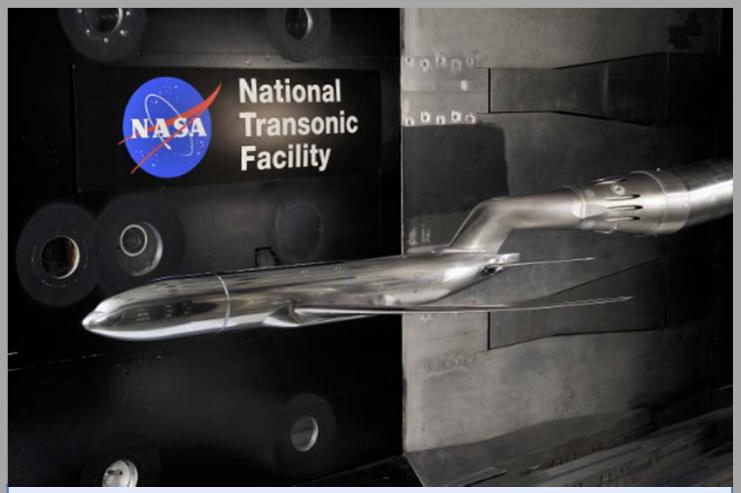


Formation Flight

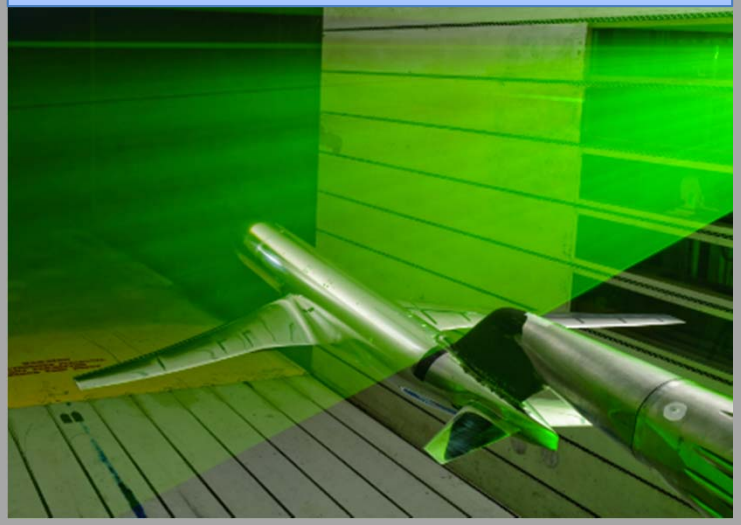


FAITH Experiment Flow Visualization

Energy Efficiency: Reduce Drag

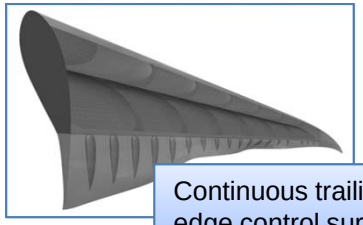


CRM Model at NTF (top) and PIV tests in 11 ft. tunnel (bottom)

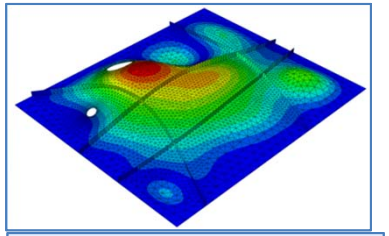


Energy Efficiency: Reduce Weight

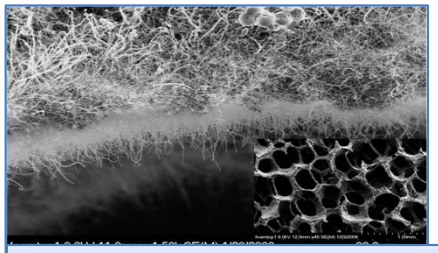
- Reduce aircraft operating empty weight with minimal impact on drag (structural efficiency)
  - Advanced fuselage structures
  - Lightweight wing structures
  - Lightweight propulsion materials and structures



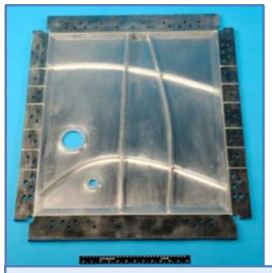
Continuous trailing edge control surfaces



Mode 1 buckling analysis for compression-shear panel

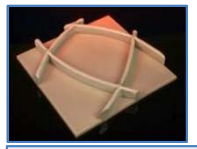


BNNT reinforced porous metals

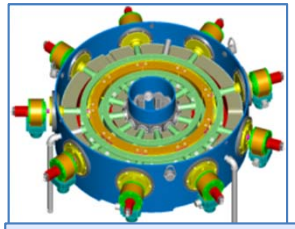


Machined Aluminum test baseline panel

Disk concept

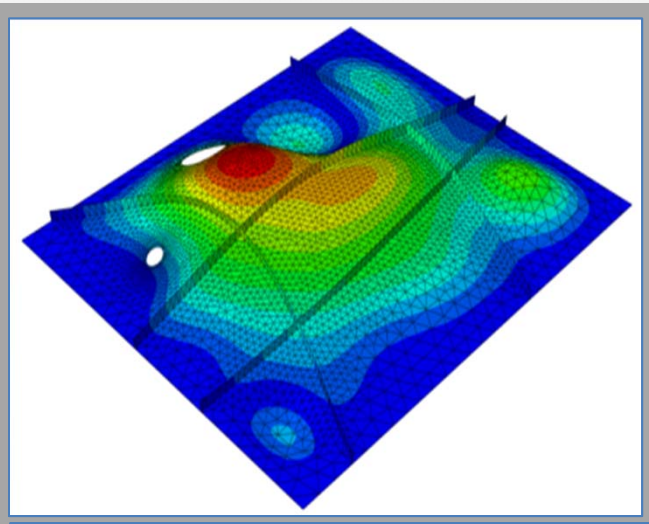


EBF^3 panel with curvilinear stiffeners



Non-contacting seals

Energy Efficiency: Reduce Weight



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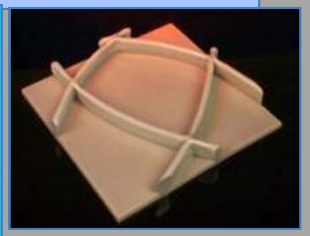
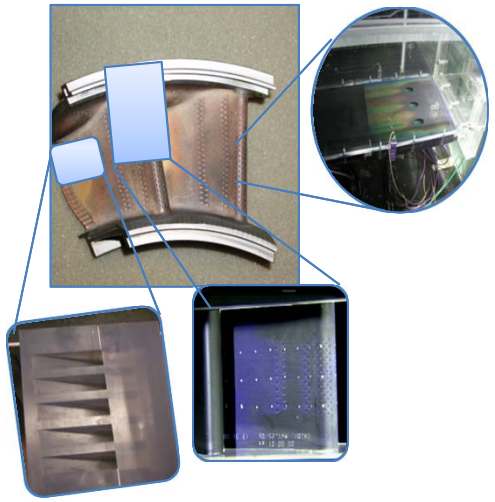


EBF^3 panel with curvilinear stiffeners

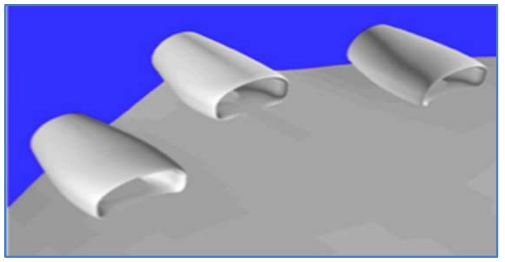
Machined Aluminum test baseline panel

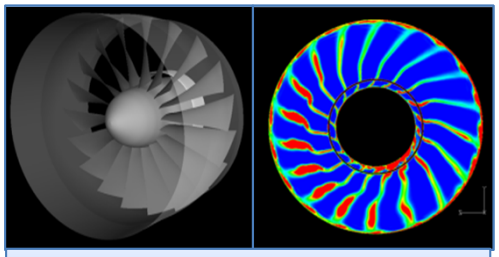
Energy Efficiency: Reduce TSEC

- Reduce TSEC while minimizing cross-disciplinary impacts (propulsion efficiency)
  - Innovative power and propulsion architectures
  - Propulsion components
  - Hot section materials
  - Efficient electric systems
  - Propulsion controls and sensors

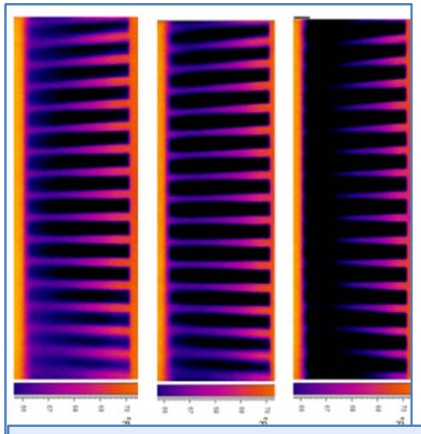


Turbine film-cooling effectiveness studies

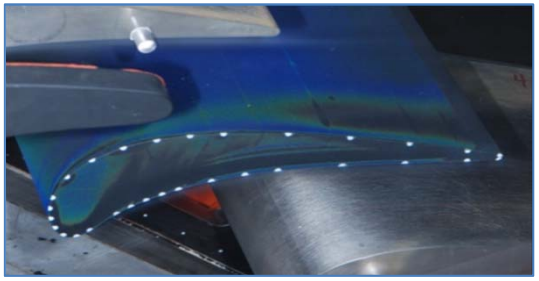




Distortion-tolerant fan development for embedded propulsion

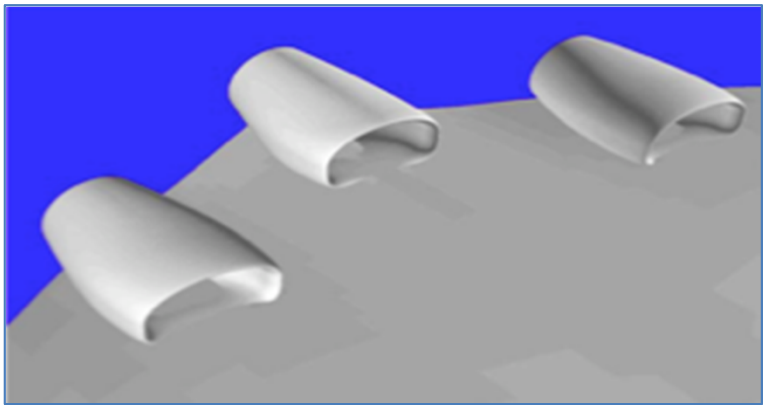


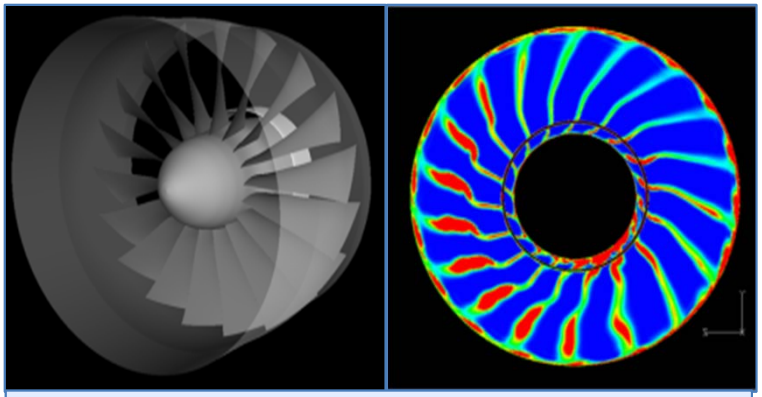
IR images of turbine TE film ejection showing cooler TE land with increasing blowing ratio



Detailed aerodynamic and heat transfer measurements of EEE tip clearance region

Energy Efficiency: Reduce TSEC

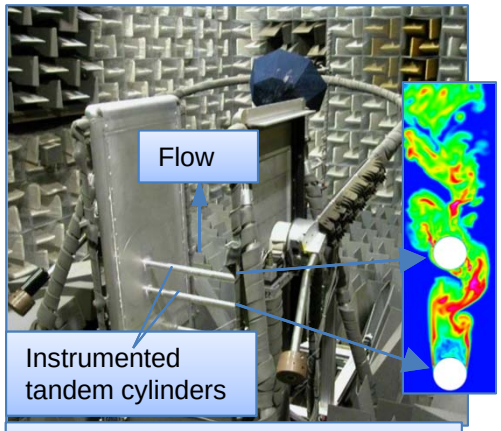




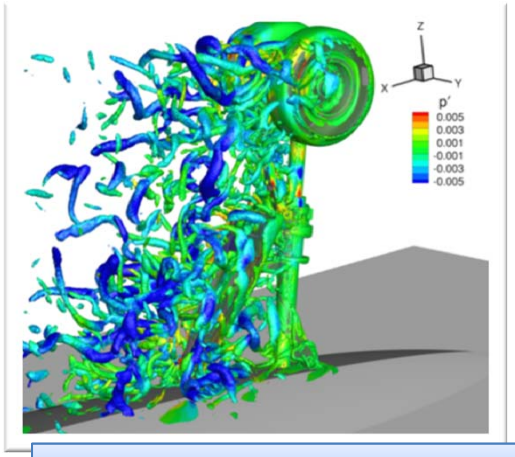
Distortion-tolerant fan development for embedded propulsion

Environmental Compatibility: Reduce Noise

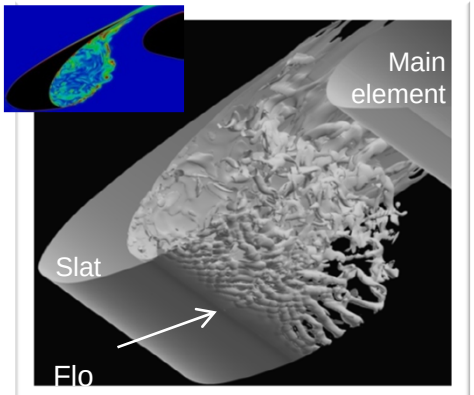
- Reduce perceived aircraft noise with minimal impact on weight and performance
  - Novel configurations/shielding
  - Clean airframe noise
  - Core noise
  - Propulsor noise
  - Liner technology



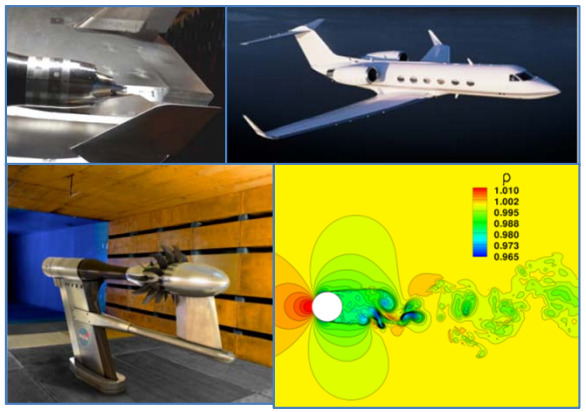
Tandem cylinder QFF experiment vs FUN3D computation



Landing gear noise simulations

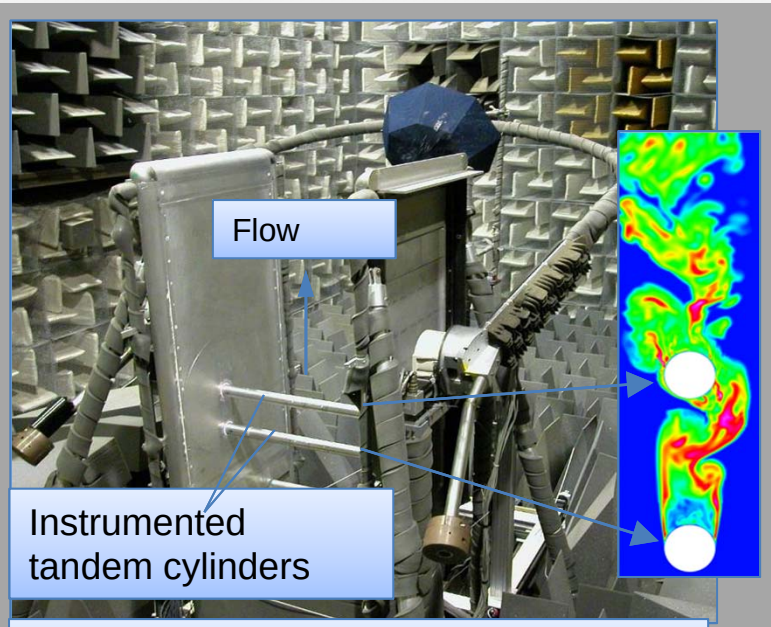


Vorticity magnitude isosurfaces showing complexity of turbulent flow in slat cove region

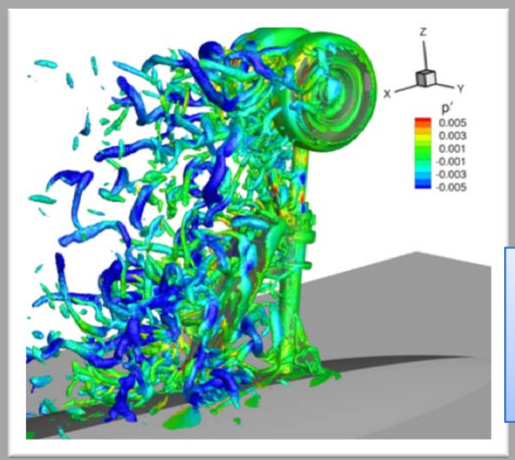


Open rotor experimental data analysis

Environmental Compatibility: Reduce Noise



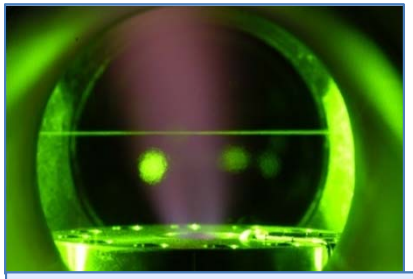
Tandem cylinder QFF experiment vs FUN3D computation



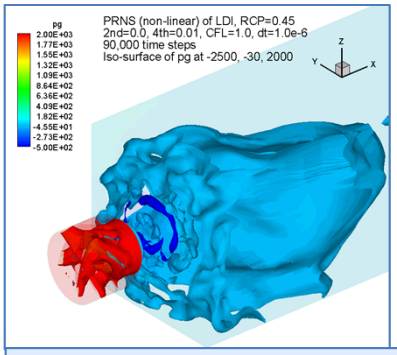
Landing gear noise simulations

Environmental Compatibility: Reduce Emissions

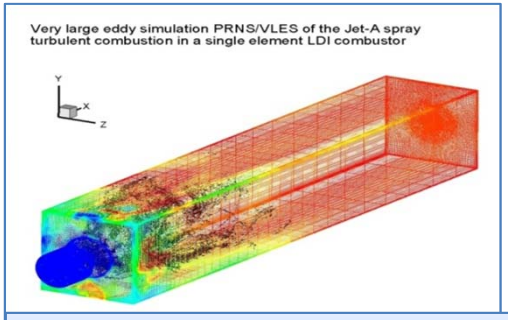
- Reduce harmful emissions attributable to aircraft energy consumption
  - Fuel flexible combustors
  - Alternative fuel characterization



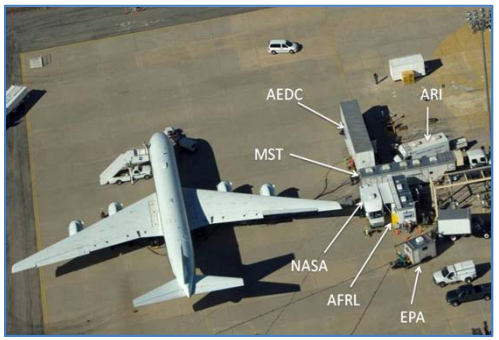
Single LDI element validation experiment

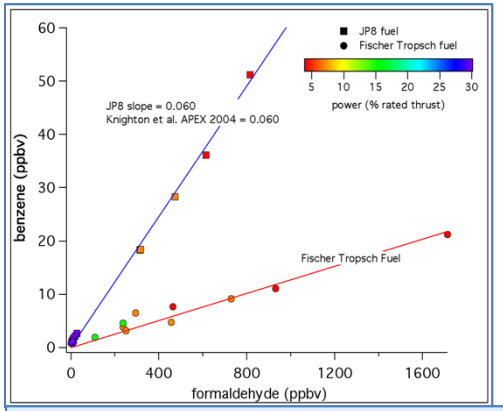


Large eddy modeling of single-element LDI (non-reacting)



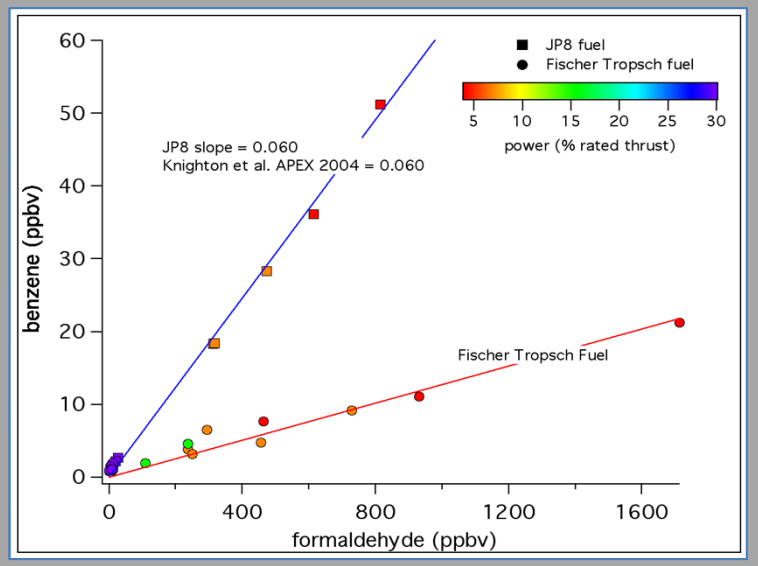
VLES of JetA spray turbulent combustion in a single-element LDI combustor (instantaneous temperatures)





Aviation alternative fuel experiment (AAFEX)

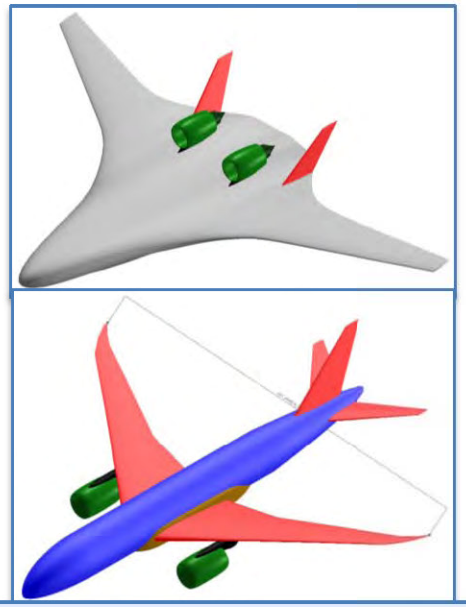
Environmental Compatibility: Reduce Emissions



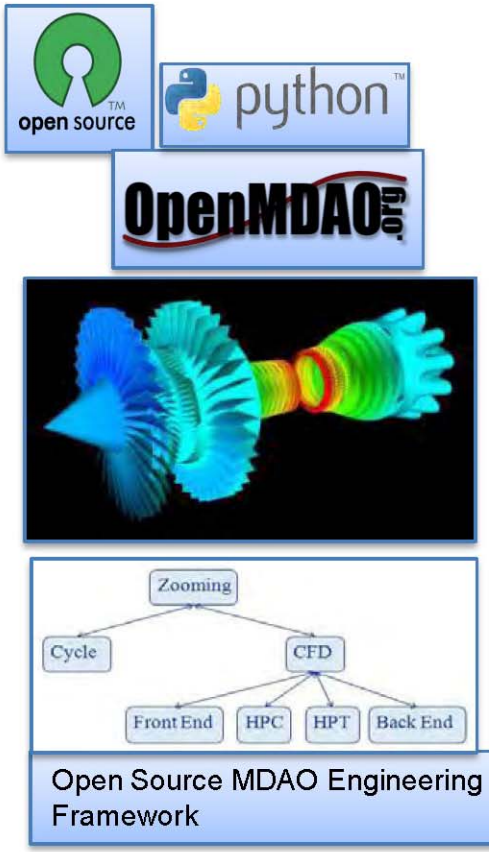
Aviation alternative fuel experiment (AAFEX)

SFW Tools and Methods Challenge

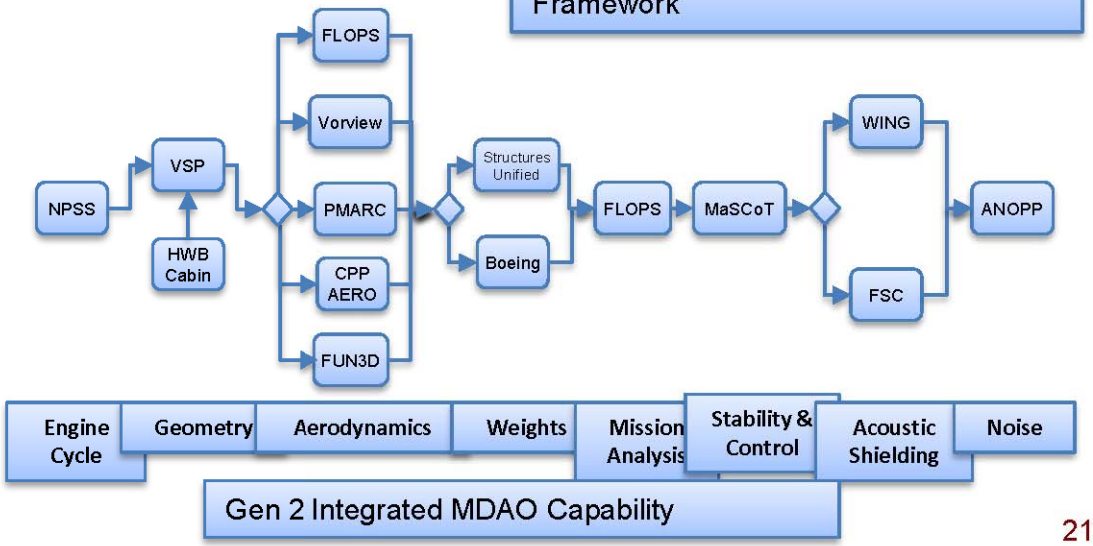
- Robust, cost-effective experimental capabilities and variable fidelity computational tools that increase accuracy and reduce uncertainty and/or enable faster turnaround
  - Multidisciplinary design, analysis, and optimization
  - Disciplinary Tools
  - Conceptual design and assessment



Vehicle sketchpad (VSP) models of N2A BWB (top) and SoA Tube and Wing



Open Source MDAO Engineering Framework



Gen 2 Integrated MDAO Capability

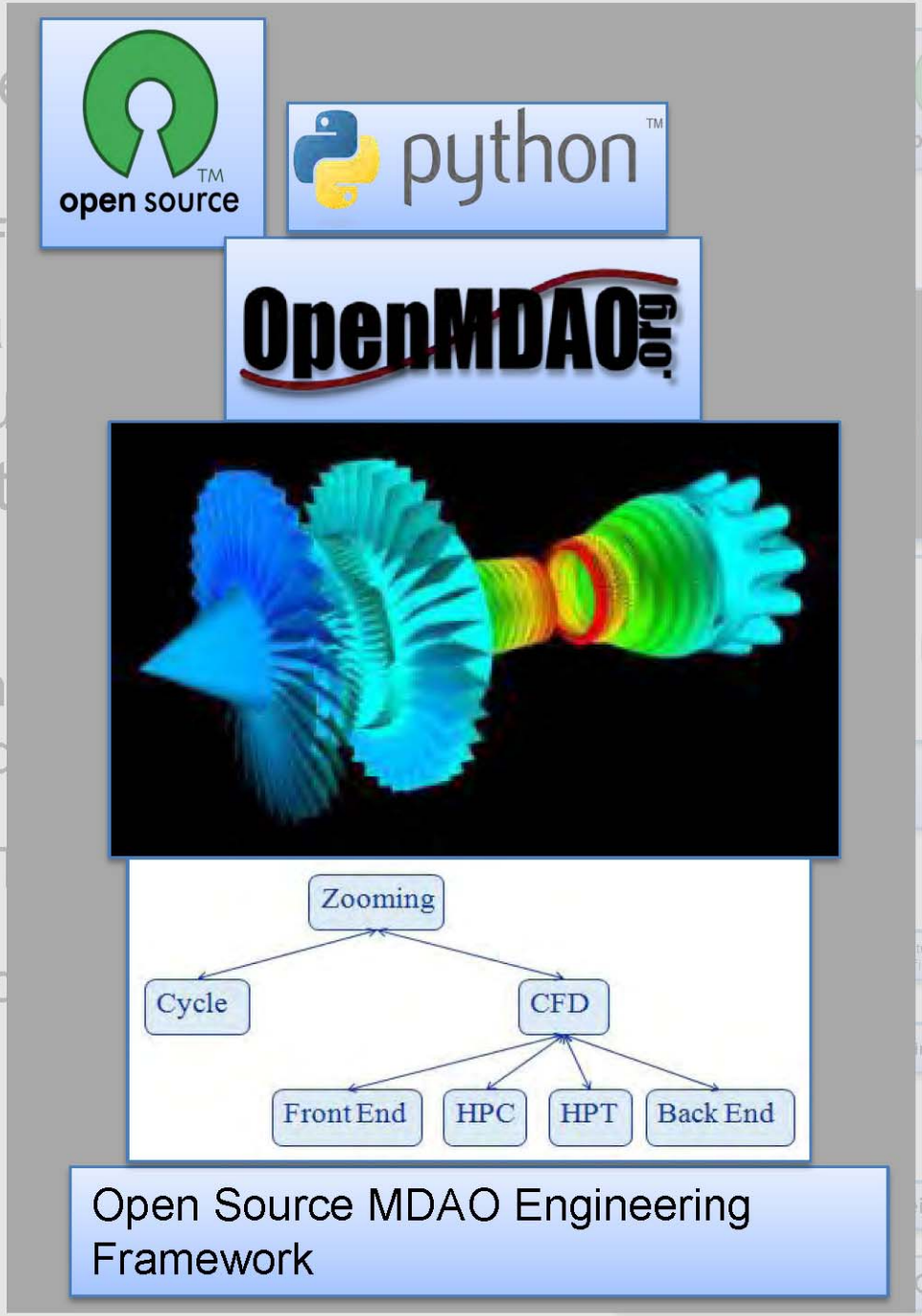
SFW Tools and Methods Challenge

- Robust, cost-e
  experimental
  and variable f
  computationa
  increase accu
  reduce uncert
  enable faster

  – Multidisciplin
    analysis, and

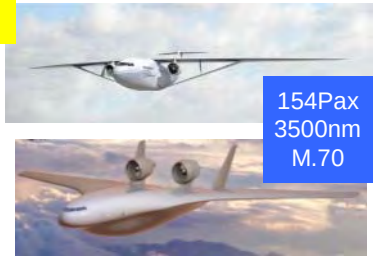
  – Disciplinary T

  – Conceptual d
    assessment



N+3 Advanced Vehicle Concepts

Boeing, GE, GaTech



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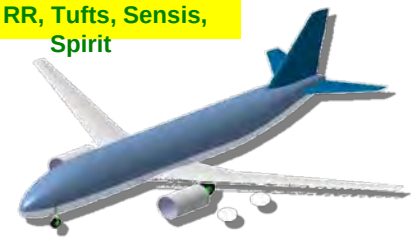
Advanced concept studies for commercial subsonic transport aircraft for 2030-35 EIS

NG, RR, Tufts, Sensis, Spirit



120Pax
1600nm
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Intended to stimulate far-term thinking towards future aircraft needs and identify key technologies needed.

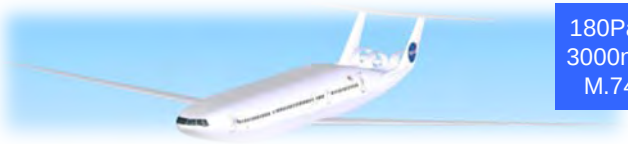
Aviation Week cover picture and story (May 17, 2010)

GE, Cessna, GaTech

20Pax
800nm
M.55

MIT, Aurora, P&W, Aerodyne

354Pax
7600nm
M.83



180Pax
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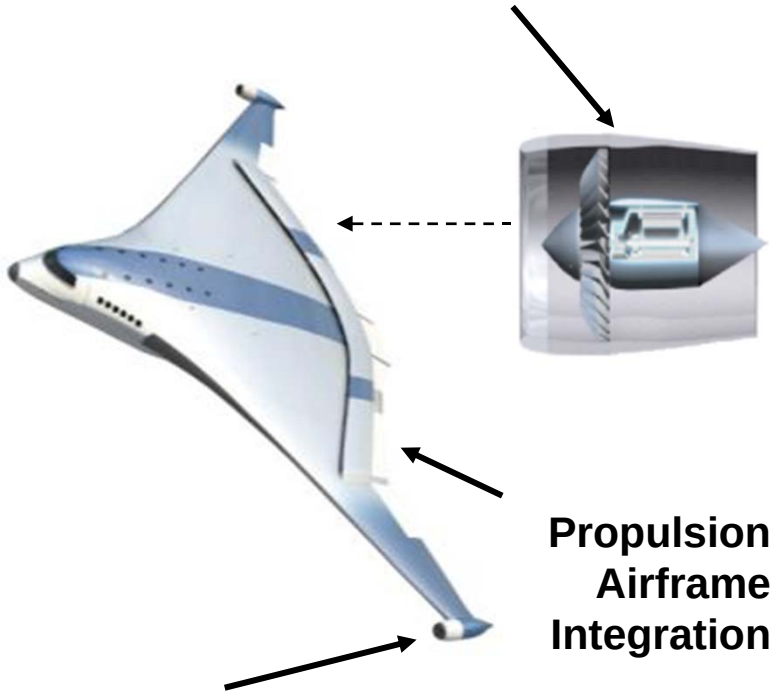
Gen N+3 In-House Vehicle Concepts

Distributed Turboelectric Propulsion

NASA In-house, SBIRs

Lightweight High Temperature Superconducting Components



Propulsion Airframe Integration

Turboelectric Engine Cycle

Truss-Braced Wing (TBW) Research

NASA In-house, NIA, Virginia Tech, Georgia Tech

High Span Truss-Braced Wing with Fold

Goldschmied Propulsor

Laminar Flow

Major Ongoing SFW Activities

- Complete strategic planning of SFW portfolio with emphasis on concepts, tools and technologies needed for enabling N+3 vision
- Assess and improve fan and rotor noise prediction codes (including Open Rotor)
- Start work on Phase 2 of N+3 Advanced Concepts Studies NRA
- Validate GEN 2 integrated multidisciplinary analysis tools for Noise, NOx, and Performance of a Hybrid Wing Body Configuration (APG)
- Test FAST-MAC at NTF to understand benefit of circulation control to low-speed high-lift and high-speed aerodynamic efficiency at high Reynolds numbers
- Conduct Aviation Alternative Fuel EXperiment 2 (AAFEX-2) using biofuels
- Complete construction of W-6 single-spool turbine facility
- Complete planning of cross-project turbulence modeling focused-research effort
- Complete design and fabrication of distortion-tolerant fan for embedded engines
- Evaluate and publish exhaust measurement from the AAFEX-2 using biofuels (APG)

SFW Conference Sessions

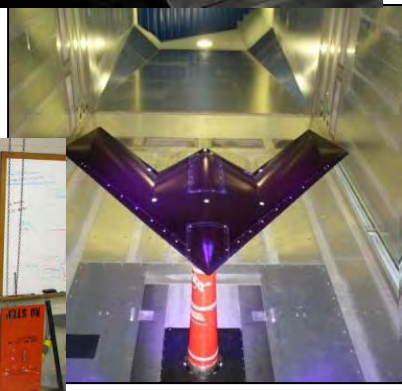
- Tue 1400: N+3 Subsonic Vehicle Concepts
- Wed 0800: Reduce Perceived Noise
- Wed 1030: Reduce Harmful Emissions
- Wed 1400: Feedback Session (One-on-One)
- Thu 0800: Tools & Capabilities for SFW R&D
- Thu 0800: Aerodynamic Efficiency I (Parallel Session)
- Thu 1030: Structural Efficiency
- Thu 1330: Aerodynamic Efficiency II
- Thu 1530: Propulsion Efficiency

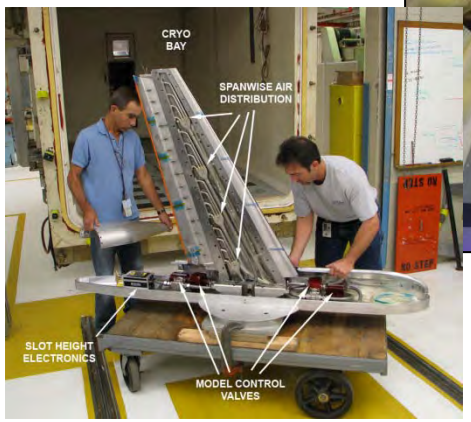
Note: All SFW Sessions in Same Room (except Thu 0800 Aero. Eff. I Parallel Session)

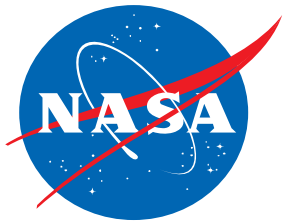
SFW Project Summary

- Addressing the environmental challenges and improving the performance of subsonic aircraft
- Undertaking and solving the enduring and pervasive challenges of subsonic flight
- Understanding and assessing the game changers of the future
- Strong foundational research in partnership with industry, academia, and other Government agencies

Technologies, Tools, Concepts and Knowledge






NASA