National Aeronautics and Space Administration

NASA Subsonic Fixed Wing Project Overview

Dr. Rubén Del Rosario, Project Manager
Mr. John Koudelka, Deputy Project Manager (Acting)
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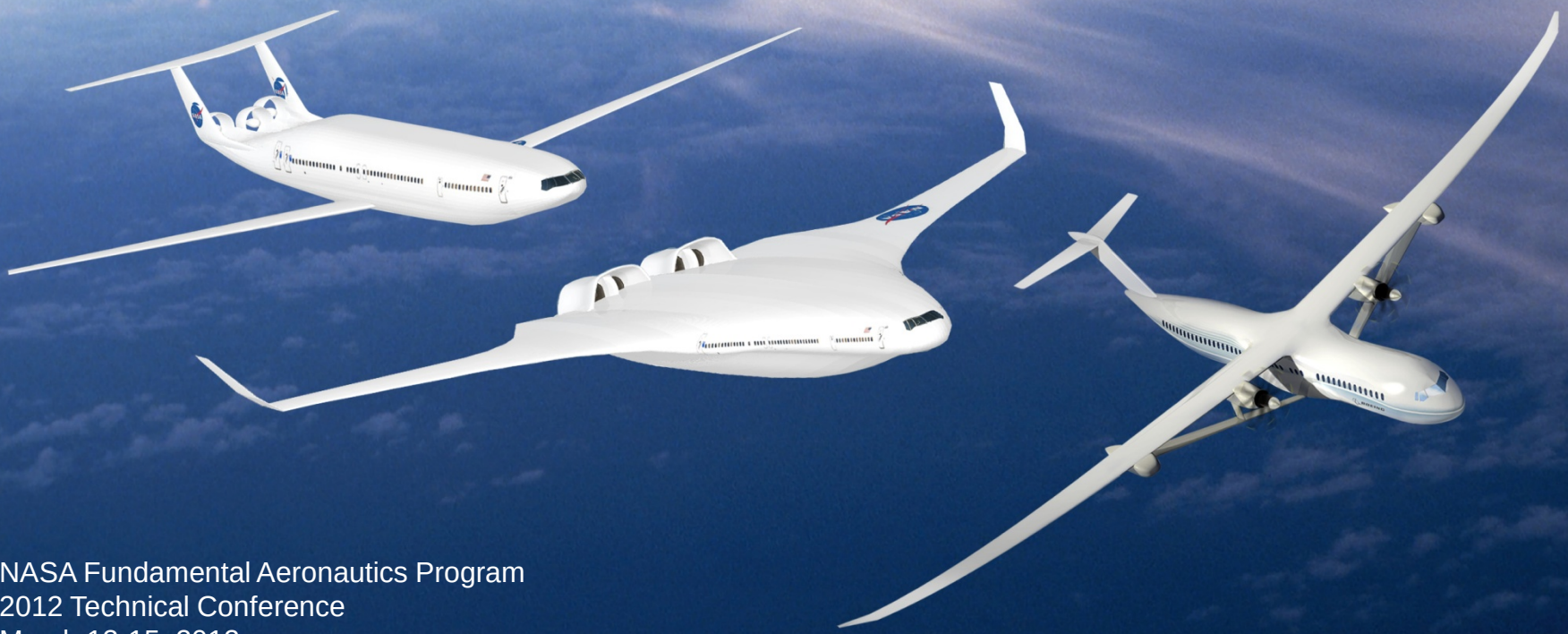
Dr. Nateri Madavan, Deputy Project Scientist

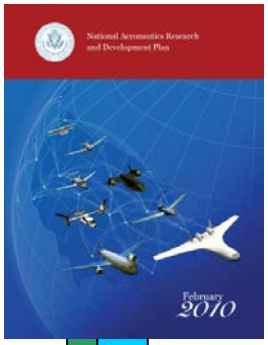


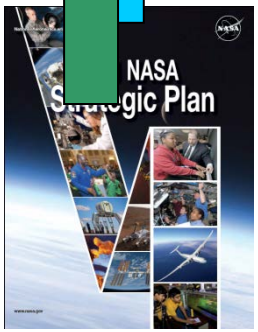
NASA Fundamental Aeronautics Program
2012 Technical Conference
March 13-15, 2012
Cleveland, OH

Outline

- SFW Strategic Framework and Linkage
- Metrics
- Goal-Driven Advanced Concept Studies
- Subsystem Concepts and Technical Challenges
- Concluding Remarks

SFW Strategic Framework and Linkage





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

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-71 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines, N+2 values are referenced to a 777-200 with GE90 engines

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

‡ CO_2 emission benefits dependent on life-cycle CO_{2e} per MJ for fuel and/or energy source used

SFW: Near-term research addressing revolutionary N+3 Goals

SFW Strategic Thrusts & Enduring Challenges

Energy Efficiency Thrust *(with emphasis on N+3)*
Economically practical approaches to improve aircraft efficiency

Environmental Compatibility Thrust *(with emphasis on N+3)*
Economically practical approaches to minimize environmental impact

Energy & Environment

Cross-Cutting Challenge *(pervasive across generations)*

EC1 - Reduce aircraft drag with minimal impact on weight — Drag

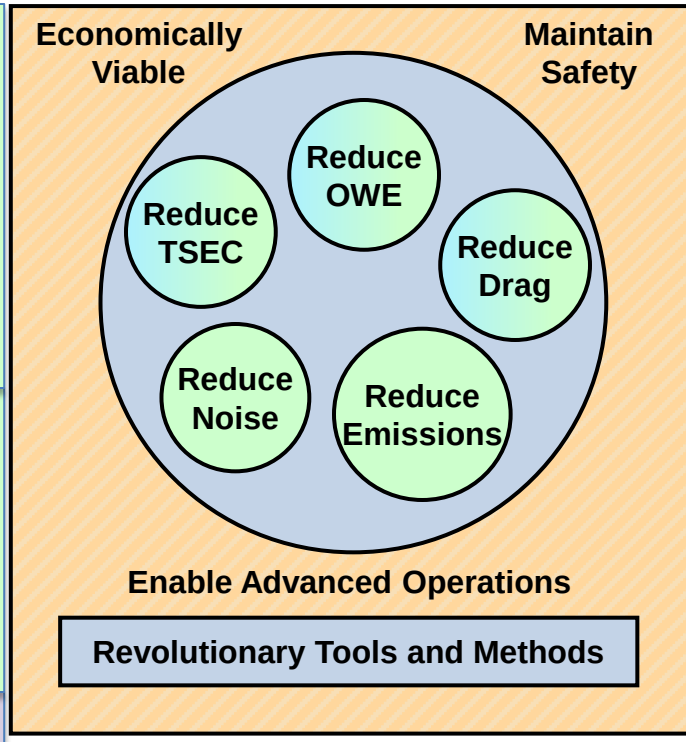
EC2 - Reduce aircraft operating empty weight with minimal impact on drag — Weight

EC3 - Reduce thrust-specific energy consumption while minimizing cross-disciplinary impacts — TSEC

EC4 - Reduce harmful emissions attributable to aircraft energy consumption — Clean

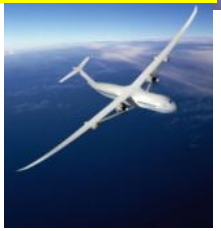
EC5 - Reduce perceived community noise attributable to aircraft with minimal impact on weight and performance — Noise

EC6 - Revolutionary tools and methods enabling practical design, analysis, optimization, & validation of technology solutions for vehicle system energy efficiency & environmental compatibility — Tools



Goal-Driven Advanced Vehicle Concept Studies (N+3)
summary

Boeing, GE, GA Tech



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

NG, RR, Tufts, Sensis, Spirit

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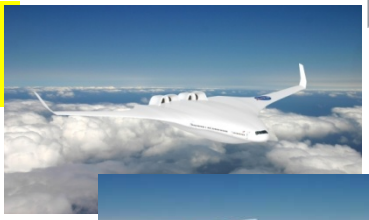
GE, Cessna, GA Tech

MIT, Aurora, P&W, Aerodyne



Trends:

- Tailored/Multifunctional Structures
- High AR/Active Structural Control
- Highly Integrated Propulsion Systems
- Ultra-high BPR (20+ w/ small cores)
- Alternative fuels and emerging hybrid electric concepts
- Noise reduction by component, configuration, and operations

NASA, VA Tech, GT

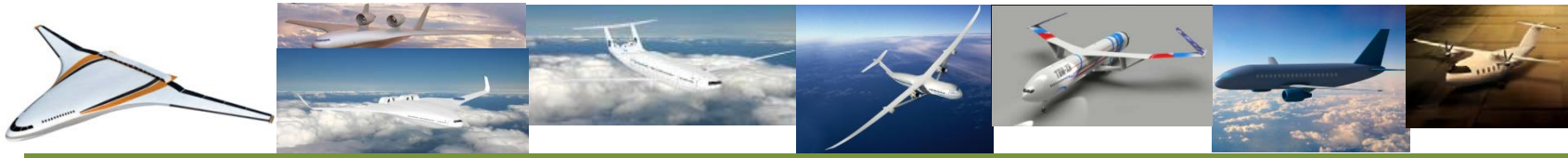
NASA

Advances required on multiple fronts…

Diversified Portfolio Addressing N+3 Goals

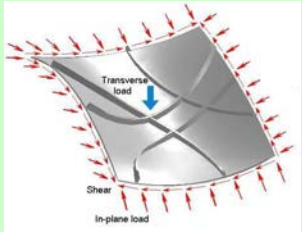
broadly applicable subsystems technical challenges

N+3 Vehicle Concepts

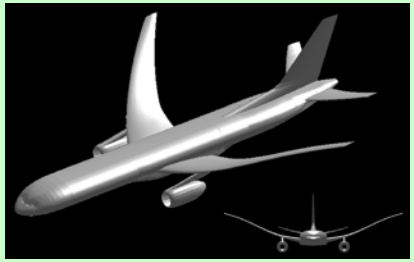


Enduring Challenges

Reduce Drag, Weight, TSEC, Emissions and Noise

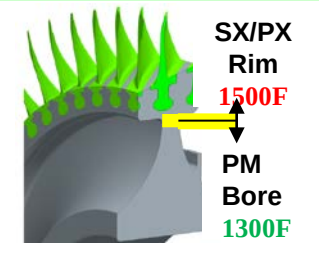


Tailored Fuselage

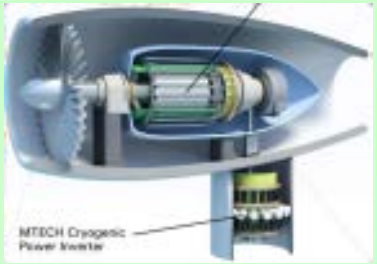


High AR Elastic Wing

Quiet, Simplified High-Lift



High Eff. Small Gas Generator



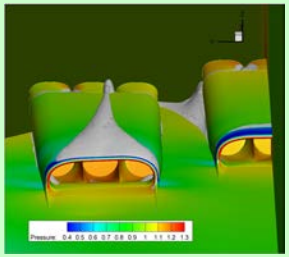
Hybrid Electric Propulsion

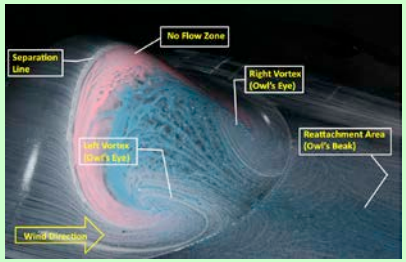
Propulsion Airframe Integration

Tools

Alternative Fuels

Technical Challenges





Tailored Fuselage

opportunity to reduce large structural weight, large wetted area

Objective Drag Weight TSEC Clean Noise

Explore and develop technologies to enable direct structural weight and skin friction reduction

Technical Areas

Tailored Load Path Concepts & Design

Designer Materials

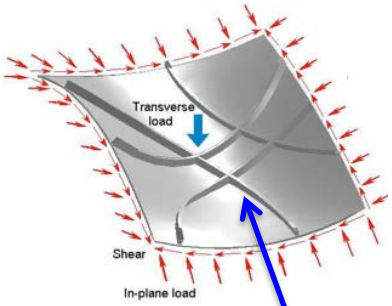
Turbulent Skin Friction Drag Reduction

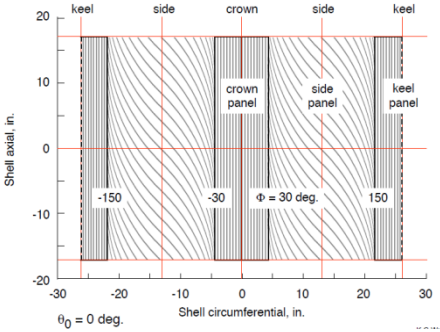
Benefit/Pay-off

- 25% fuselage structural weight reduction
- 10% fuselage turbulent boundary-layer drag reduction

large structure
large area

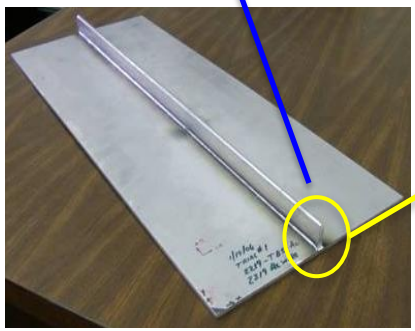
conventional and unconventional





metallic & composites

tailored load path design/build
tailored materials



Tailored Fuselage

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Technical Areas

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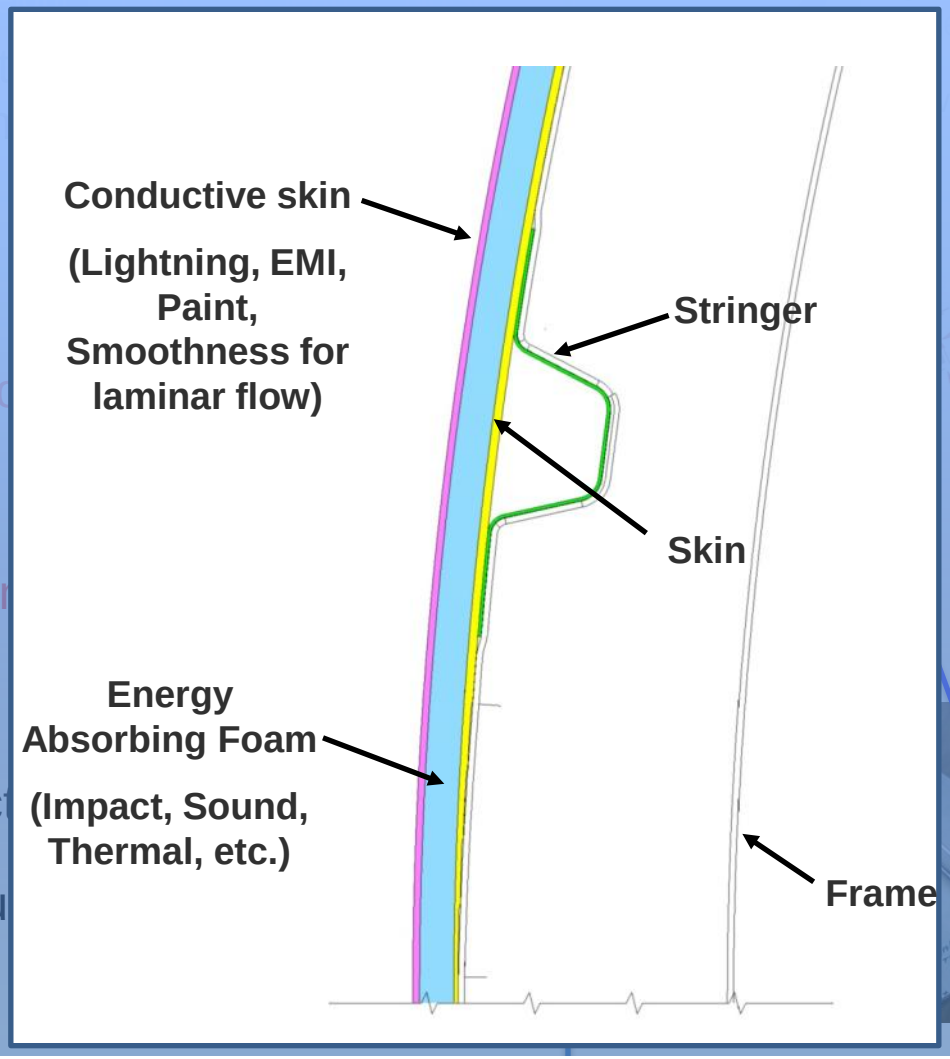

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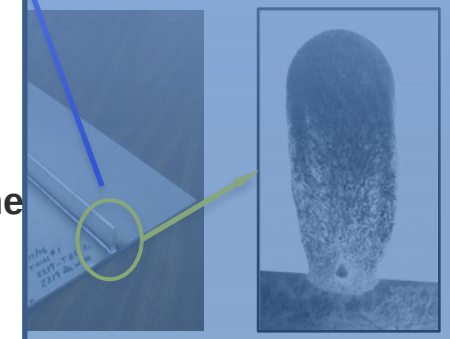
tailored load path design/build
tailored materials



STAR-C2: Smoothing, Thermal, Absorbing, Reflective, Conductive, Cosmetic

High Aspect Ratio Elastic Wing

changing the drag vs. weight trade space

Objective Drag | **Weight** | TSEC | Clean | Noise

Explore and develop technologies to enable lightweight high aspect ratio wings

Technical Areas

Tailored Load Path Concepts & Design

Designer Materials

Active Structural Control

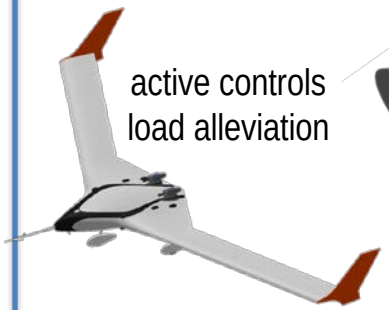
Aerodynamic Shaping

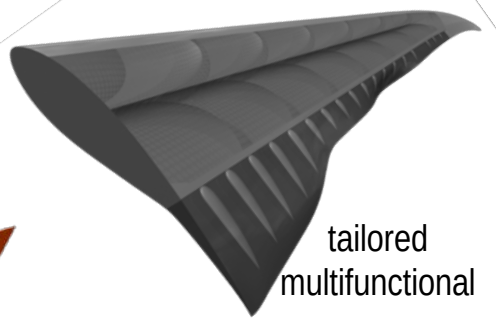
Elastic Aircraft Flight Control

Benefit/Pay-off

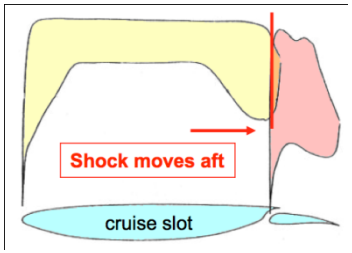
– 25% wing structural weight reduction

– AR increase of 30-40% for cantilever wings, 2X+ for braced



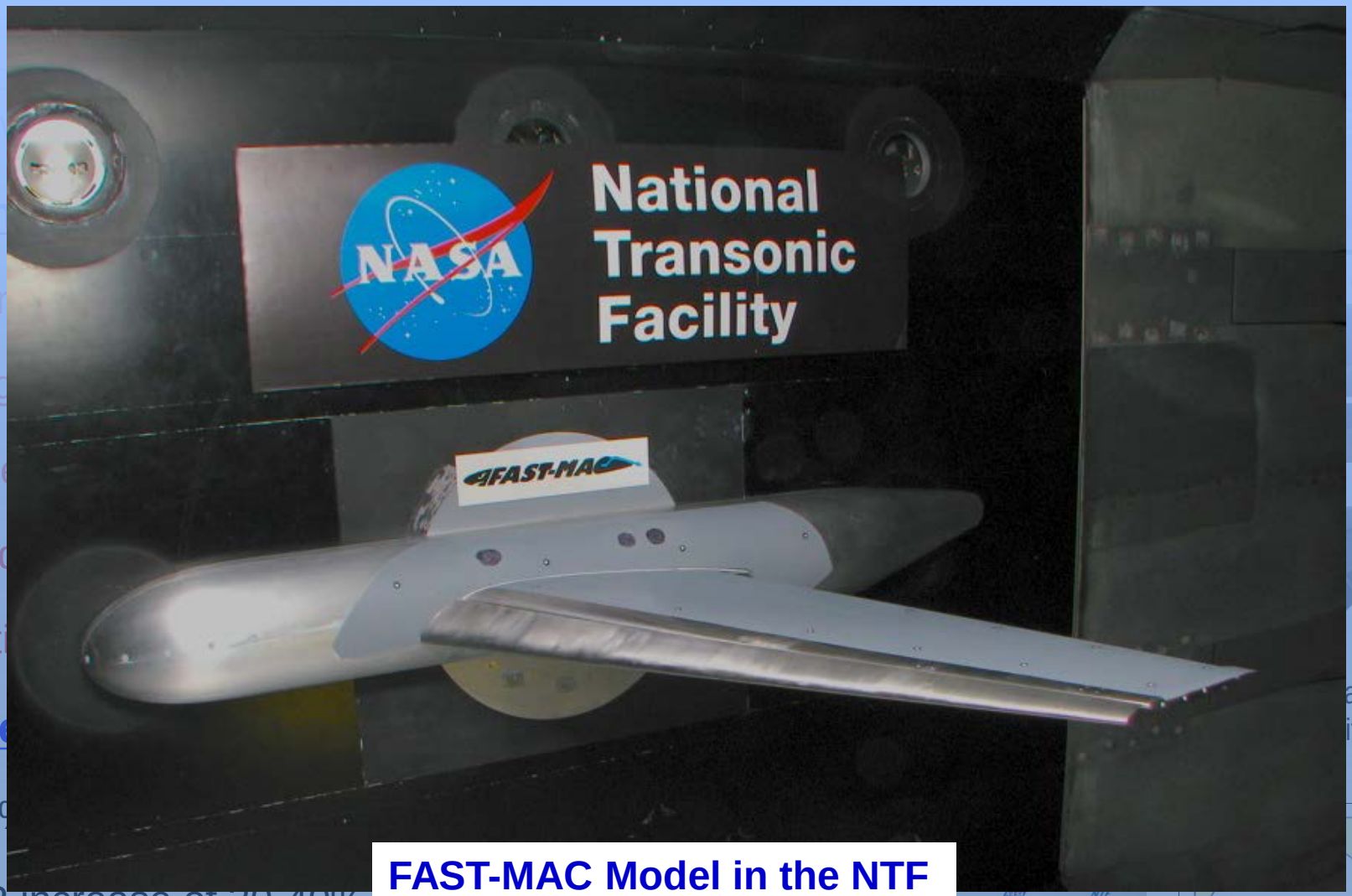


passive/active
advanced aerodynamics



High Aspect Ratio Elastic Wing

changing the drag vs. weight trade space



FAST-MAC Model in the NTF

– AR increase of 30-40% for cantilever wings; 2X+ for braced

Quiet, Simplified High-Lift

quiet systems with improved performance

Objective | Drag | Weight | TSEC | Clean | Noise

Explore and develop technologies to enable high performance, low noise high-lift systems

Technical Areas

High-lift System Noise

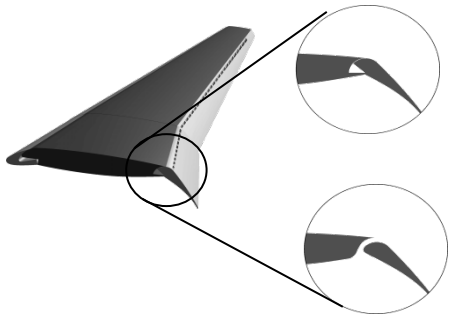
Landing Gear Noise

Active Flow Control

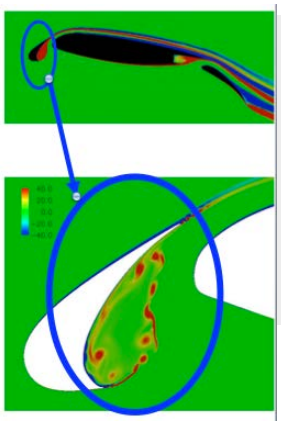
Benefit/Pay-off

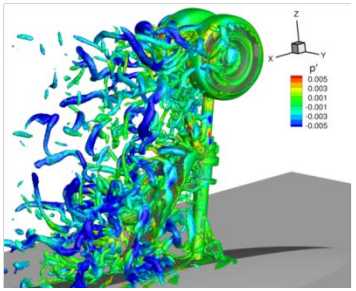
– 8-10 dB airframe noise reduction

– Reduced part count, reduced weight/drag



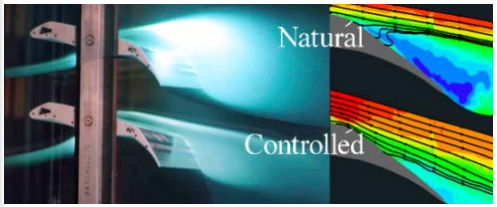
high-lift
stem concepts

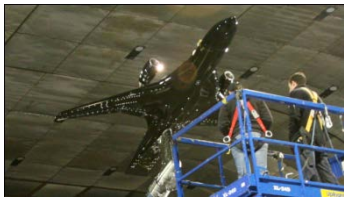




noise source physics
noise reduction concepts

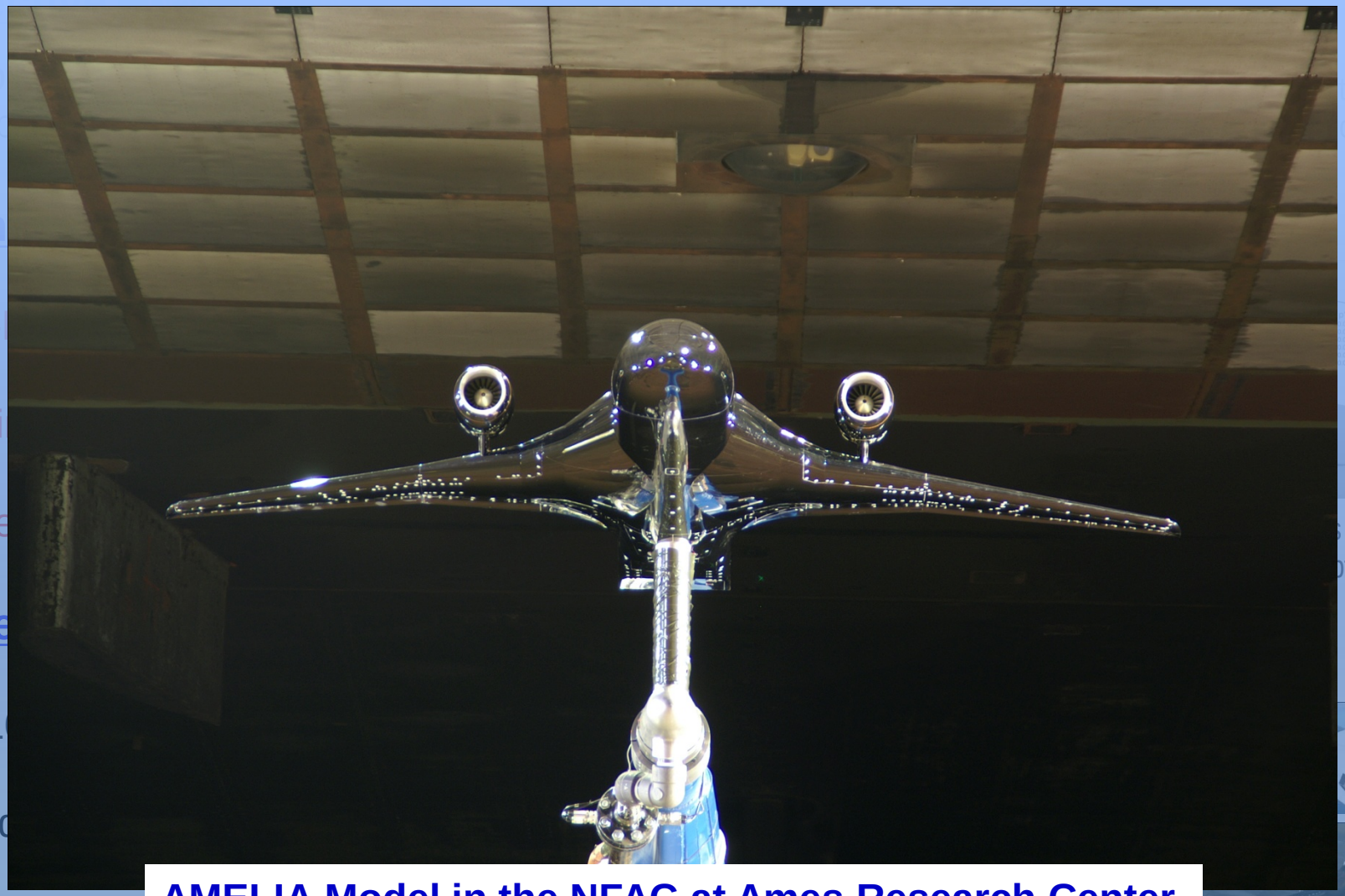
active flow control
performance & acoustics





Quiet, Simplified High-Lift

quiet systems with improved performance



AMELIA Model in the NFAC at Ames Research Center

High Efficiency Small Gas Generator

versatile core applicable to variety of propulsion systems

Objective

Drag | Weight | **TSEC** | Clean | Noise

Explore and develop technologies to enable advanced, small, gas-turbine generators with high thermal efficiency

Technical Areas

Hot Section Materials

Tip/Endwall Aerodynamics

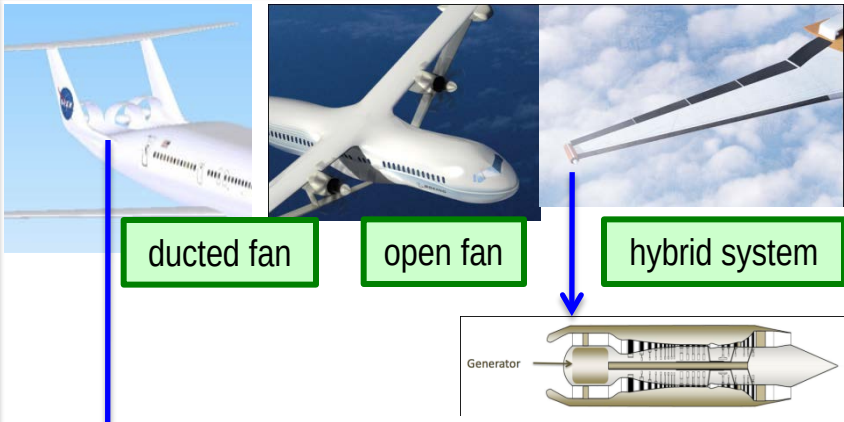
Fuel-Flexible Combustion

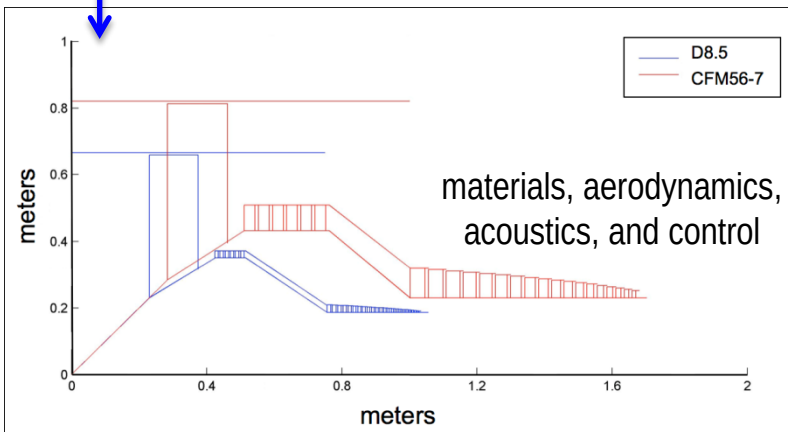
Decentralized Control

Core Noise

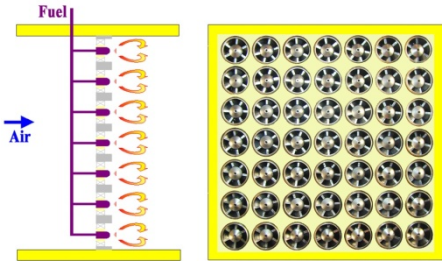
Benefit/Pay-off

- BPR 20+ growth by minimizing core size
- Low emission, fuel-flexible combustors with NOx reduction of 80% below CAEP6





materials, aerodynamics, acoustics, and control



multi-point lean direct injection

High Efficiency Small Gas Generator

versatile core applicable to variety of propulsion systems

Explore an
advanced,
high therma

Technical

Hot Section

Tip/Endwal

Fuel-Flexible Combustion

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- BPR 20+ growth by minimizin
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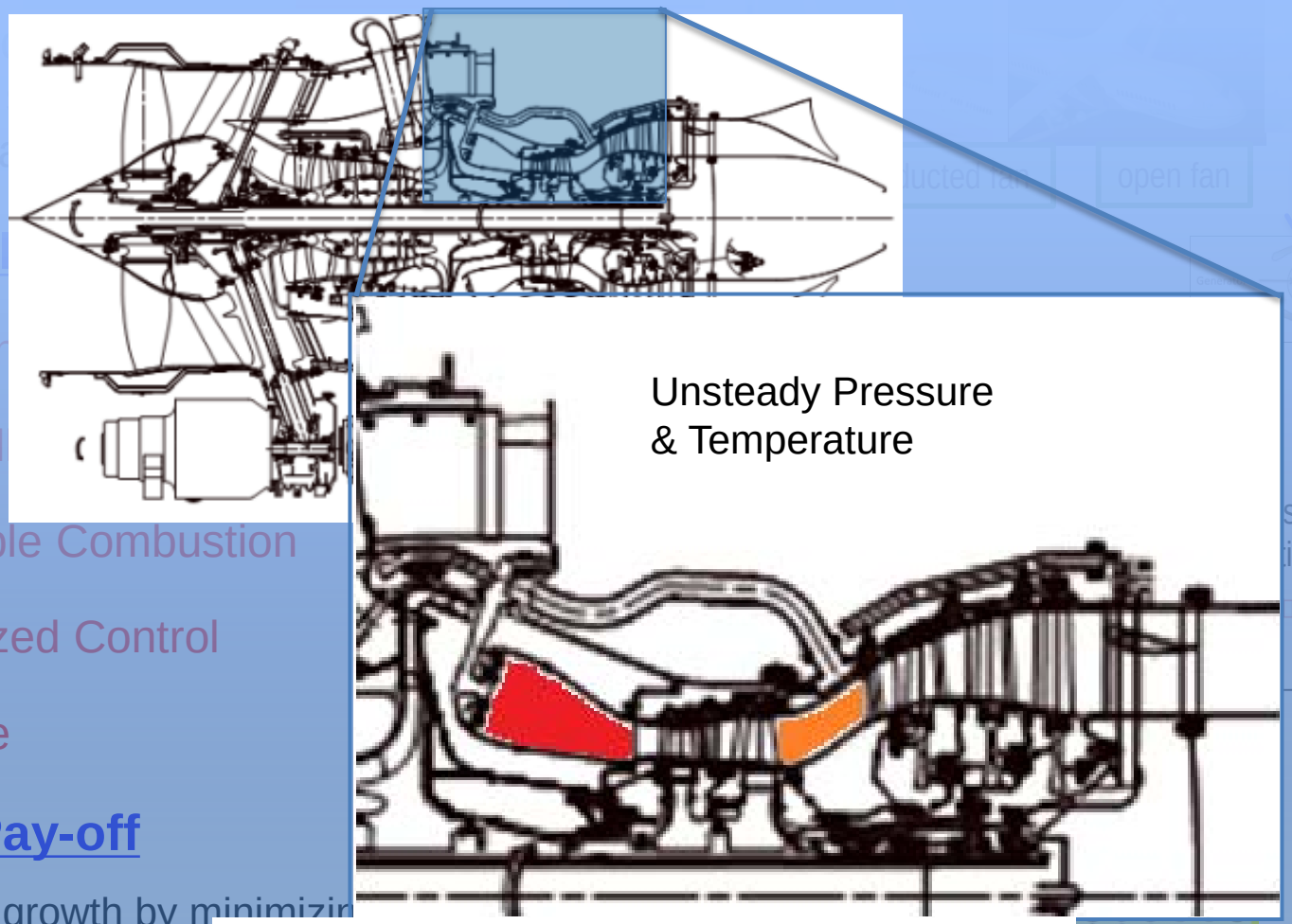
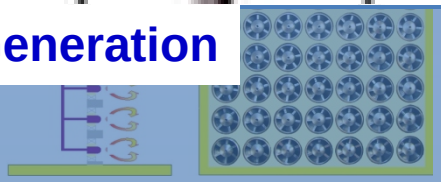


Understanding Core Noise Generation



multi-point
lean direct injection

Hybrid Electric Propulsion
changing the paradigm

Objective Drag Weight **TSEC** Clean Noise

Explore and develop technologies to enable hybrid gas-turbine/electric propulsion architectures

Technical Areas

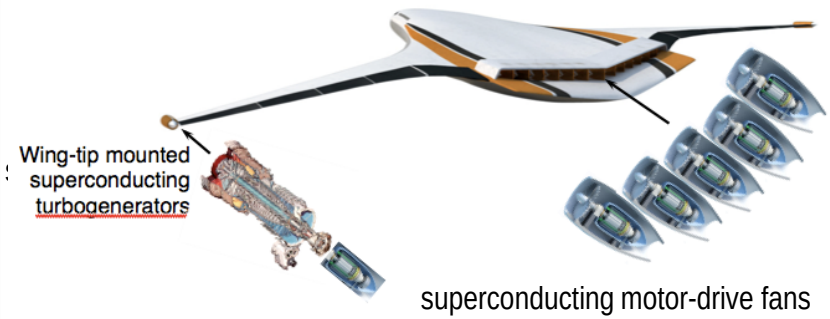
Transmission and Winding Materials

Gas-Turbine/Electric Hybrids

Aircraft Power Distribution

Benefit/Pay-off

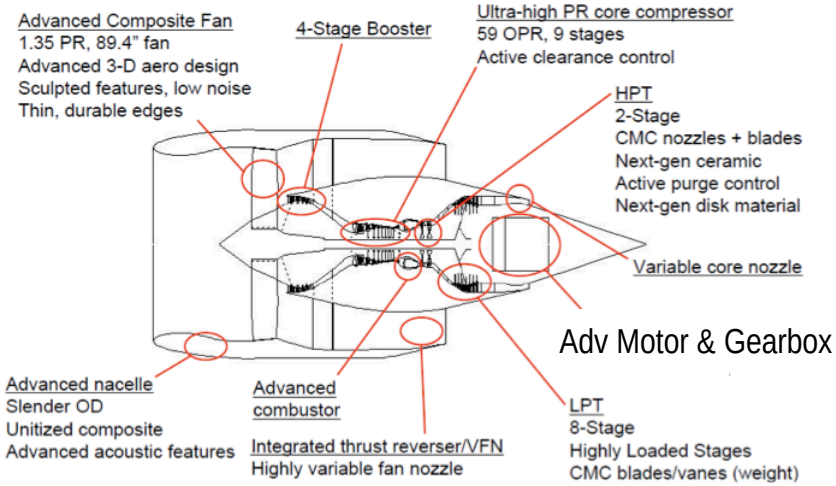
- Low noise and zero emission (onboard) electric drives
- Renewable energy sources for aviation use
- Electric transmission to enable decoupled distributed propulsion



single power source to multiple, decoupled fans

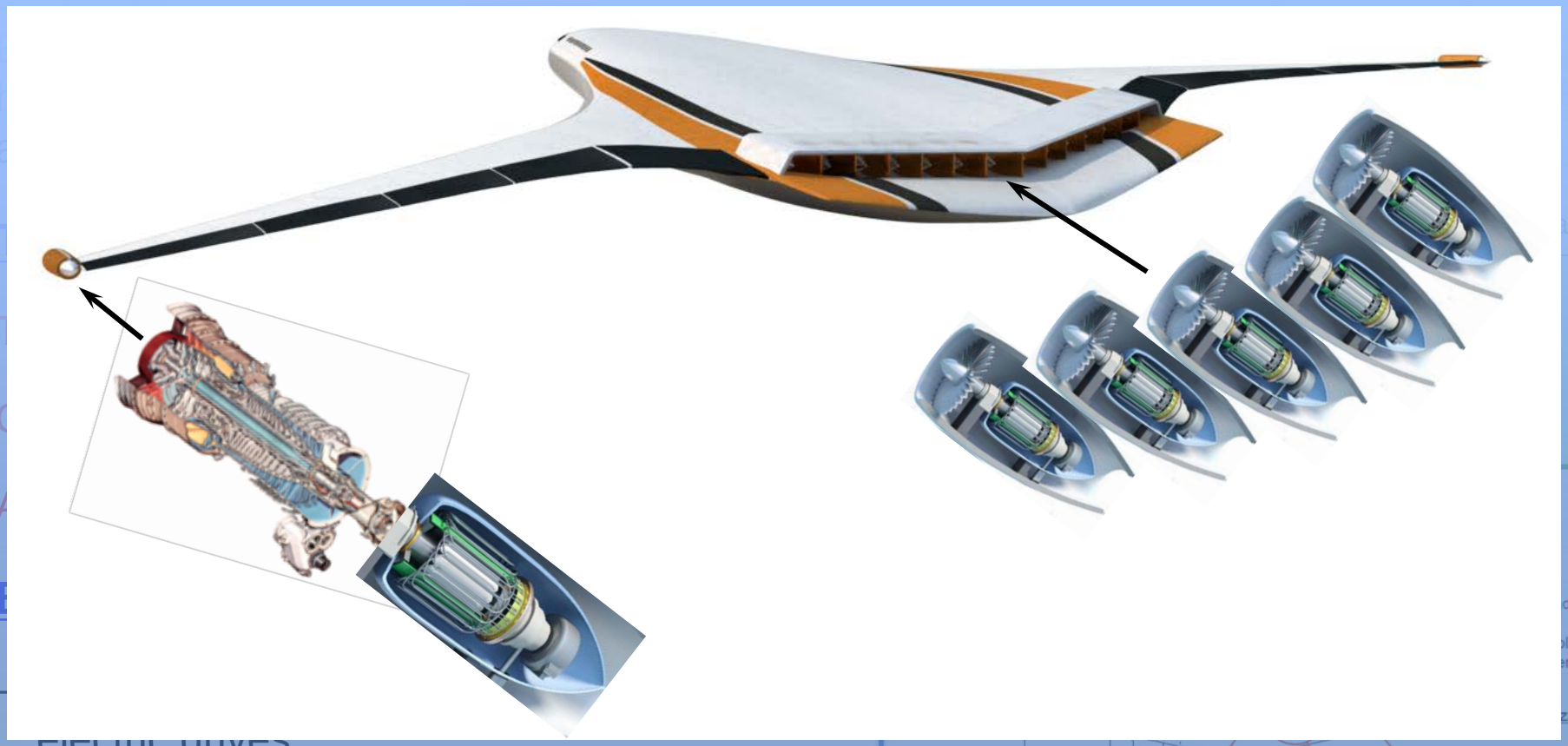
stable, wide area power transmission

dual power to single fan



adv conventional to hybrid to (eventually) all electric

Hybrid Electric Propulsion
changing the paradigm



Turbo Electric Distributed Propulsion

– Renewable energy sources for aviation use

– Electric transmission to enable decoupled distributed propulsion

Adv Motor & Gearbox

Slender OD
Unitized composite
Advanced acoustic features

combustor

Integrated thrust reverser/VFN
Highly variable fan nozzle

LPT
8-Stage
Highly Loaded Stages
CMC blades/vanes (weight)

adv conventional to hybrid to (eventually) all electric

Propulsion Airframe Integration

increasingly synergistic integration

Objective | Drag | Weight | TSEC | Clean | Noise

Explore and develop technologies to enable highly coupled, synergistic aero-propulsive-control

Technical Areas

Aerodynamic Configuration

Adaptive, Lightweight Fan Blade

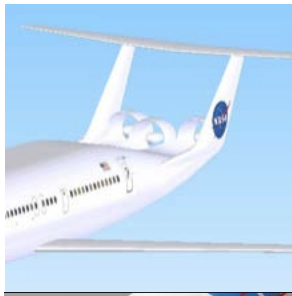
Distortion-Tolerant Fan

Acoustic Liners

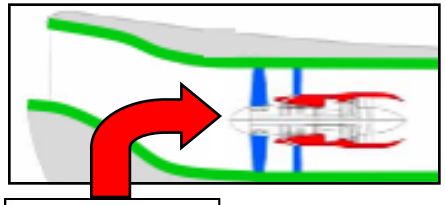
Propulsion Airframe Aeroacoustics

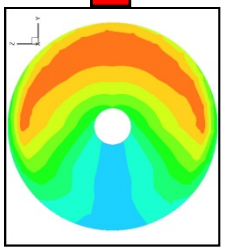
Benefit/Pay-off

– Improved multidisciplinary performance and noise characteristics; benefits tradable for specific missions



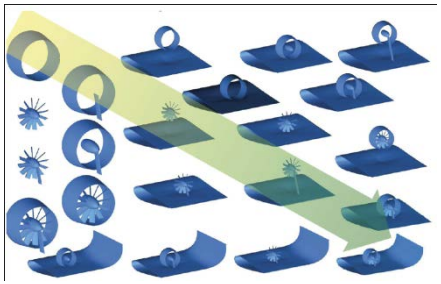
boundary-layer ingesting concepts
thrust vectoring

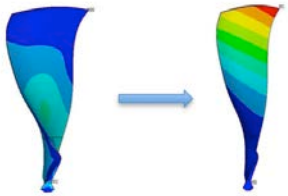




distortion tolerance

jet/surface interaction acoustics





adaptive fan blades

Propulsion Airframe Integration

increasingly synergistic integration

Explore an
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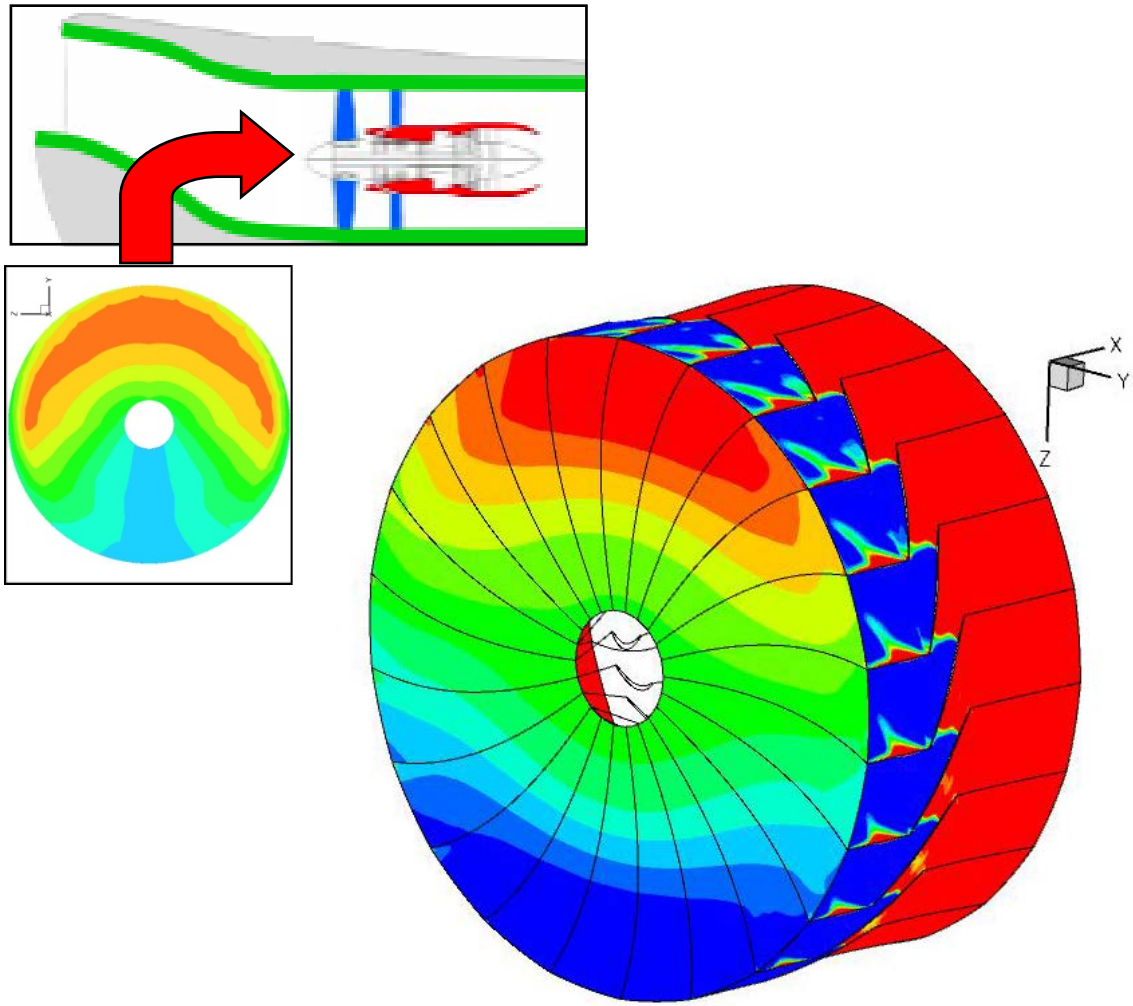
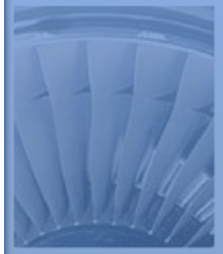
Propulsion

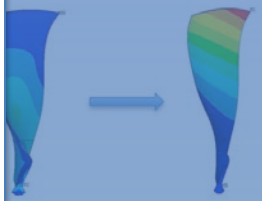
Benefit/F

– Improve
noise ch
specific missic



Aeroelastic Analysis of Distortion Tolerant Fan





adaptive fan blades

Tools

cross-cutting and foundational

Objective | Drag | Weight | TSEC | Clean | Noise

Explore and develop tools for the practical design, analysis, optimization, and validation of technology solutions for components and vehicle systems

Technical Areas

MDAO

Systems Analysis/Conceptual Design

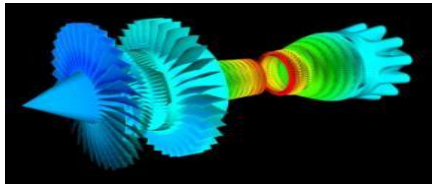
Physics-based

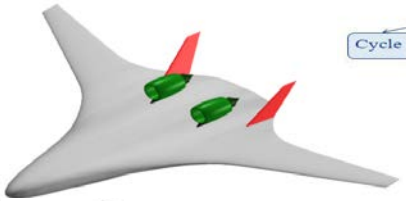
Benefit/Pay-off

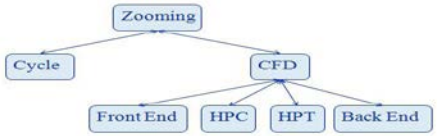
– High confidence, cost-effective variable-fidelity tools available for analysis and design from subcomponents to full vehicle systems

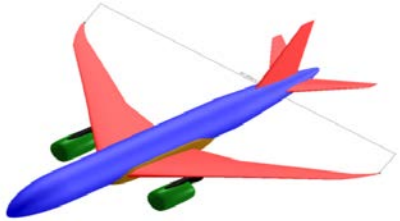
open source python OpenMDAO.org

open Source MDAO engineering framework



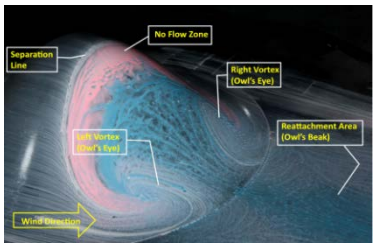


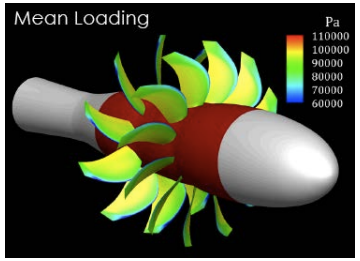




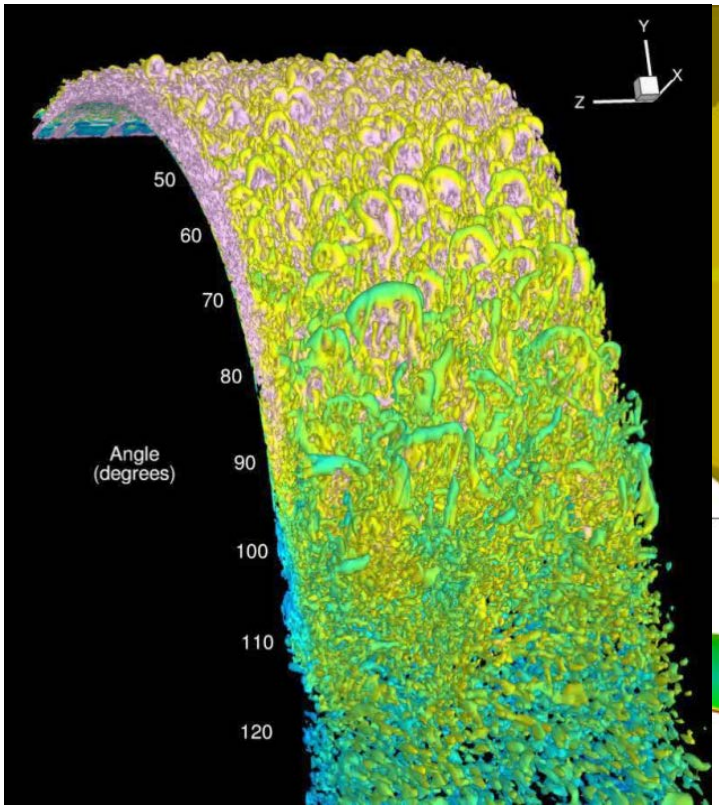
Vehicle Sketch Pad geometry

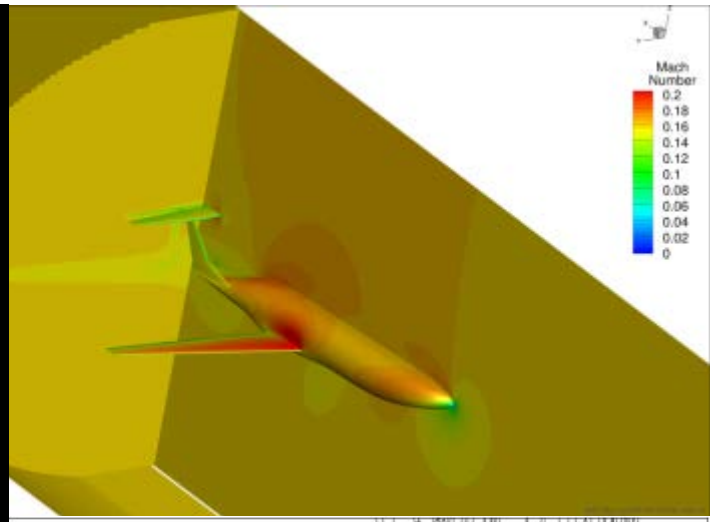
high-fidelity tools/models and validation experiments

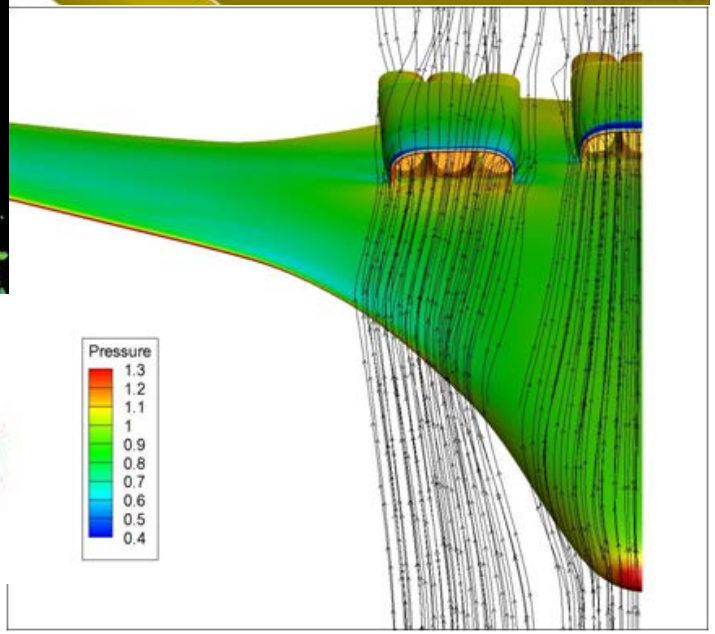


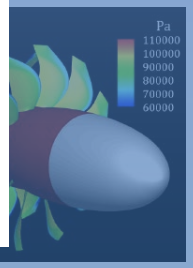


Tools
cross-cutting and foundational









Subsonic Fixed Wing Project
Fundamental Aeronautics Program
21

Alternative Fuels

characterization of alternative fuels in the near- and mid-term

Drag | Weight | TSEC | **Clean** | Noise

Objective

Fundamental characterization of alternative fuel properties and emissions to reduce impact of aviation on the environment

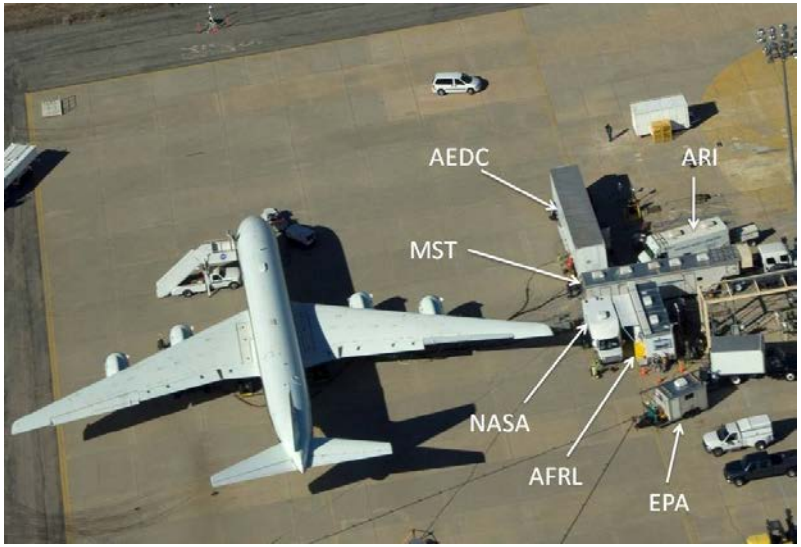
Technical Areas

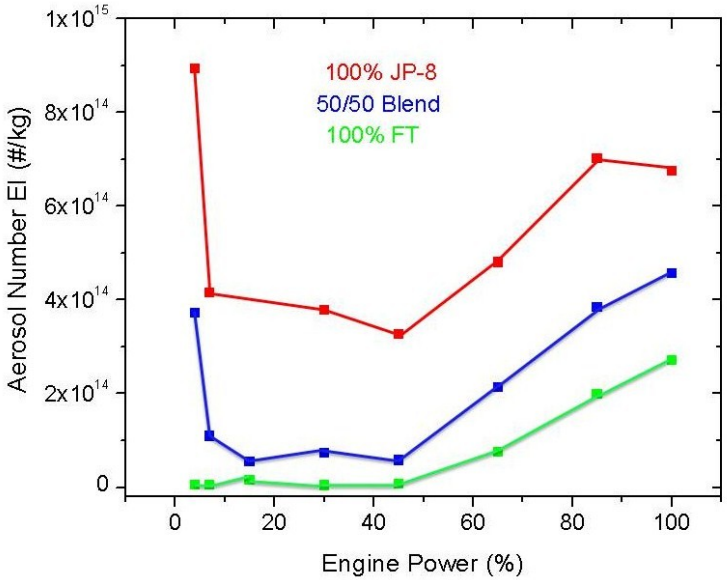
Fuel Property Characterization

Emission & Performance Characterization

Benefit/Pay-off

- Broad use and understanding of alternative aviation fuels
- Low emission, fuel-flexible combustors with NOx reduction of 80% below CAEP6
- Reduce aircraft engine particulate matters and gas phase emissions





Alternative Fuels

characterization of alternative fuels in the near- and mid-term

Objec

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NOx

– Red
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Alternative Aviation Fuel Experiment

Major Ongoing SFW Activities

- Assess and improve fan and rotor noise prediction codes
- Phase 2 of N+3 Advanced Concepts Studies NRA
- Processing and publication of FAST-MAC data
- Planning and execution of FAST-MAC2
- Checkout and validation of W-6 single-spool turbine facility
- Conduct cross-project turbulence modeling focused-research NRA
- Complete design and fabrication of distortion-tolerant fan
- Evaluate and publish exhaust measurement from the AAFEX-2 (APG)
- Planning of ACCESS flight using alternative fuels (FT and Biofuels)

SFW Conference Sessions

- Tue 1400: Advanced Concepts and System Studies: 2030 and Beyond
- Tue 1600: Aerodynamic Efficiency
- Wed 0800: Reduce Perceived Noise
- Wed 1030: Systems Analysis and Integration
- Wed 1400: Propulsion Efficiency I
- Wed 1600: Propulsion Efficiency II
- Thu 0800: Structural Efficiency
- Thu 1030: Computational Tools
- Thu 1400: Reduce Harmful Emissions

Note: All SFW Sessions in Same Room