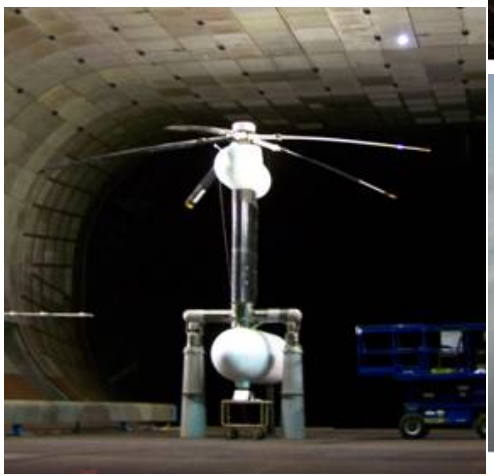
Fundamental Aeronautics Program

Dr. Ajay Misra

Acting Director, NASA Fundamental Aeronautics Program



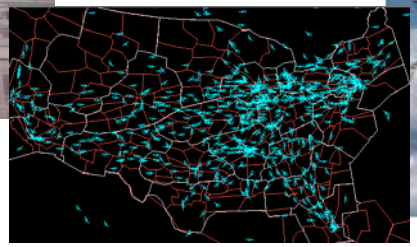
JPDO All Hands Meeting

February 5, 2009

NASA Aeronautics Programs

Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.



Fundamental Aeronautics Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.

Aeronautics Test Program

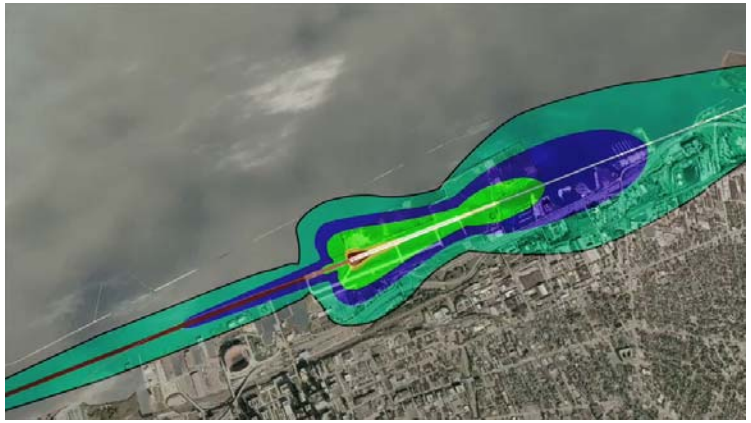
Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.

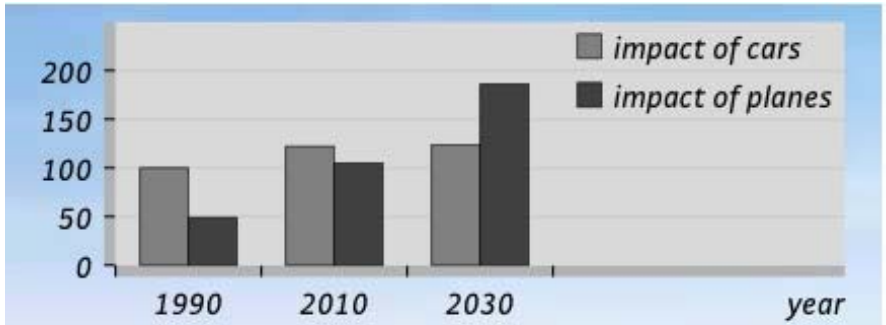
Fundamental Aeronautics Program Goals

- Conduct long-term cutting-edge research in all flight regimes to address main concerns of modern air transportation
  - Public concerns over *noise and emissions*
  - Sustainability of affordable air travel with **increasing cost and availability of jet fuel**
  - Providing for *mobility* to meet increasing demand for air transportation
  - Lack of progress towards *faster means of transportation*
- Enhance capability for future space exploration by addressing aeronautics-related challenges associated with
  - *Airbreathing access to space*
  - *Entry into a planetary atmosphere*

Noise, Emissions, and Fuel Burn / Performance Challenges

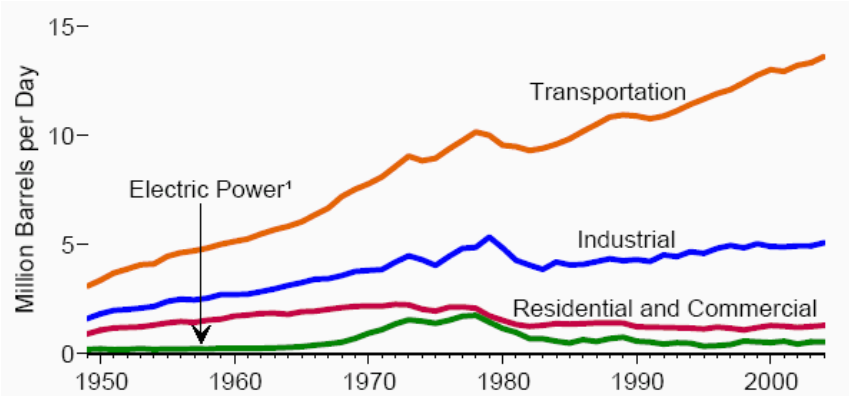
Noise: In 2007, 5 million people subjected to > 55 DNL, over 500,000 people subjected to > 65 DNL. Numbers will increase unless significant improvements are made in both future aircraft and their operation





Worldwide comparison cars and planes, impacts on climate change. Scale: cars in 1990 = 100. Source: OECD 2000

Emissions: aviation emissions growing relative to other sources. Local emission effects can be significant. High-altitude emissions, contrails, GHG, can have global climate impacts. Particulate matter (PM) health hazards.

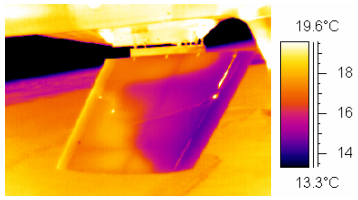


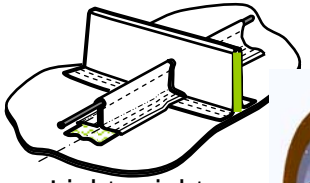
Fuel Burn: High cost of fuel has become a key driver. Transportation continues to have the largest reliance on oil, while some are predicting that we are nearing the peak of global oil supply.

FAP Aggressively Addressing Noise, Emission, and Fuel Burn Challenges

Wind tunnel test demonstrates nacelle-wing integration of GTF engine

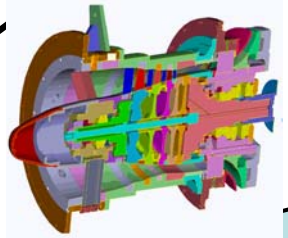
CFD models for laminar flow validated





Lightweight composite structural concept

High OPR core engine with low NOx



N + 1 (2015 EIS)

-33% Fuel burn

- 60% LTO NOx

- 32 dB noise

N + 2 (2020 IOC)

-40% Fuel burn

- 70% LTO NOx

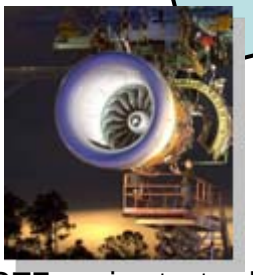
- 42 dB noise

N + 3 (2030-35 EIS)

-70% Fuel burn

Better than - 75% LTO NOx

55 LDN (dB) at airport boundary

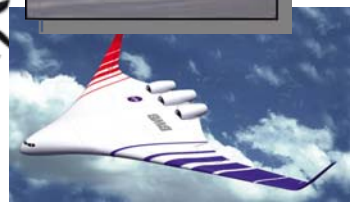


GTF engine test validates fan performance model

Over-the-rotor metal foam and soft vane reduces fan noise

Open rotor test in progress

> 30 X-48B flight tests complete



N+2 configuration to focus on achieving emission and noise goals simultaneously

N+3 concepts under development

Performance - Fuel Burn - N+1

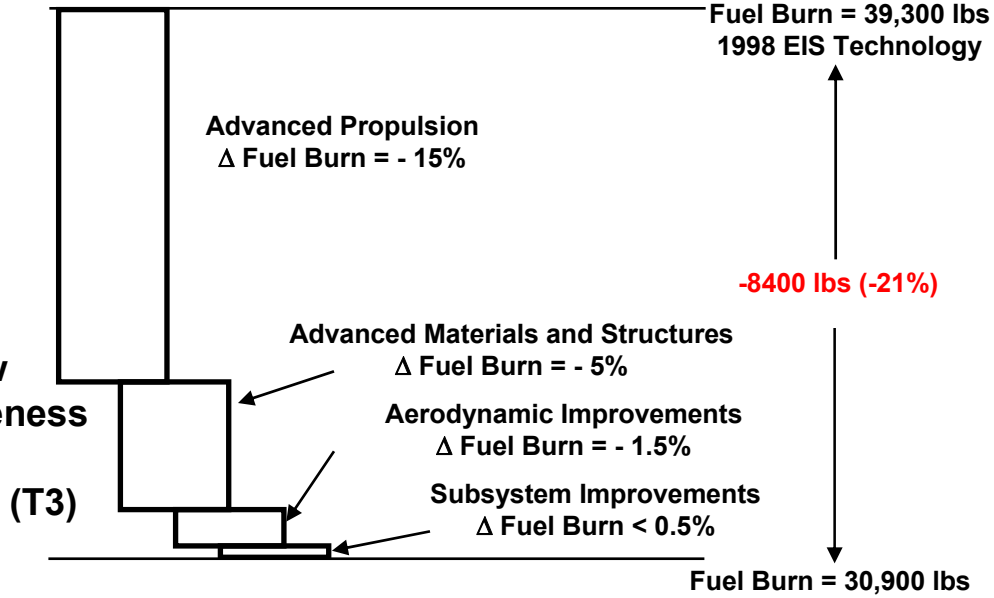
Detailed System Analysis

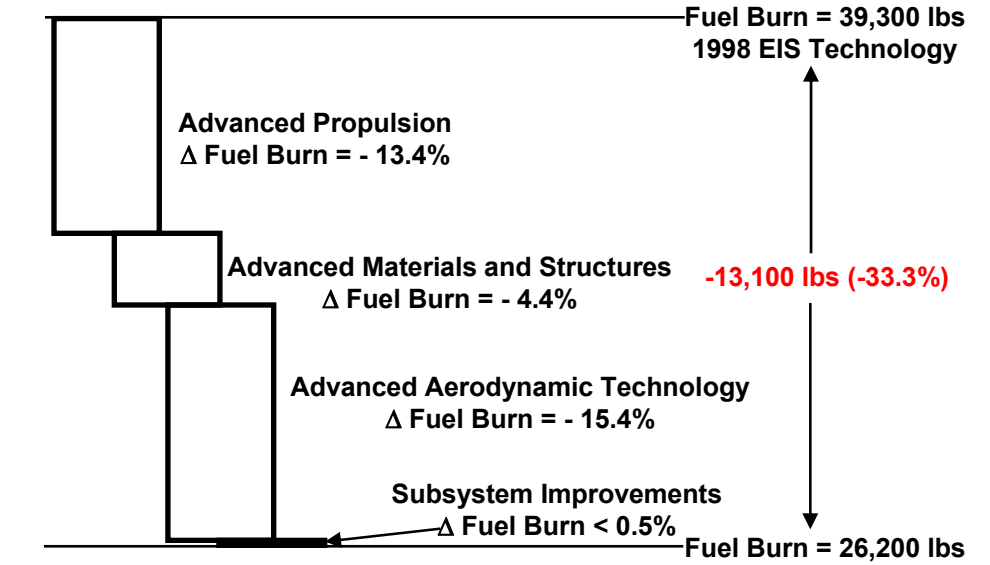
"N + 1" Conventional Small Twin

- 162 pax, 2940 nm mission baseline
- Ultra high bypass ratio engines, geared
- Key technology targets:
  - +1 point increase in turbomachinery efficiencies
  - 25% reduction in turbine cooling flow enabled by: improved cooling effectiveness and advanced materials
  - +50 deg. F compressor temperatures (T3)
  - +100 deg. F turbine rotor inlet temperatures
  - -15% airframe structure weight
  - -1% total vehicle drag
  - -15% hydraulic system weight

"N + 1" Advanced Small Twin

- All technologies listed above plus:
  - Hybrid Laminar Flow Control
    - 67% upper wing,
    - 50% lower wing,
    - tail, nacelle
  - Result = -17% total vehicle drag





Performance - Fuel Burn - N+2

Detailed System Analysis

Tube and Wing
Fuel Burn = 237,000 lbs
1997 EIS Technology

Hybrid Wing Body configuration
with composite fuselage
(Sandwich Construction)
Δ Fuel Burn = - 10%

300 pax, 7500 nm

Advanced Propulsion (Podded)
and Airframe Technologies
(composite wings)
Δ Fuel Burn = - 10%

-95,900 lbs (-40%)

Advanced Propulsion (Embedded)
and BLI inlets
Δ Fuel Burn = - 14%

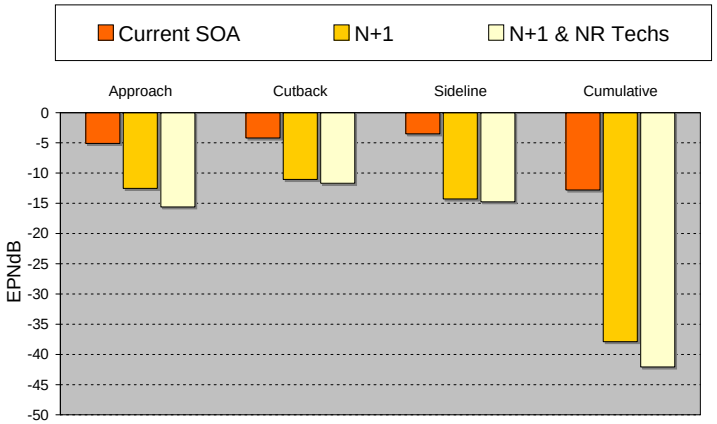
Aerodynamic Improvements
(Hybrid Laminar Flow Control)
Δ Fuel Burn = - 6%

Fuel Burn = 147,595 lbs

Noise Reduction

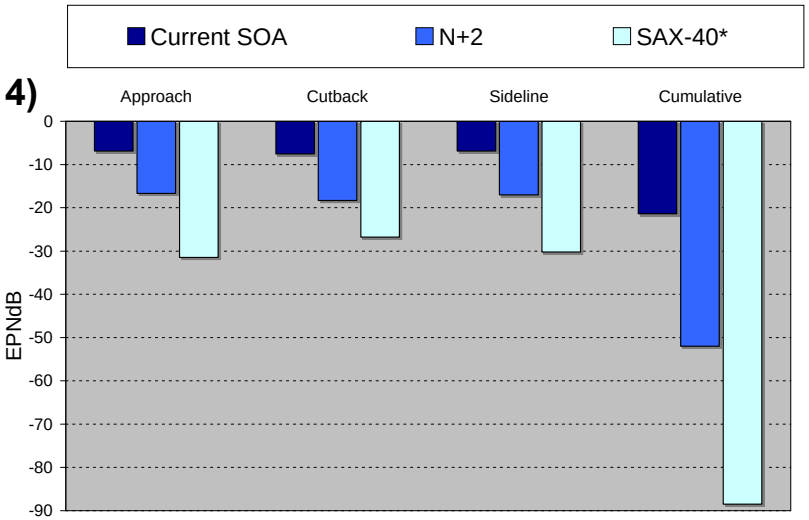
"N + 1" Conventional Small Twin

- 42 EPNdB cumulative below Stage 3 (32 wrt Stage 4)
- Target Next Generation Single Aisle (NGSA)
- Ultra-High Bypass (UHB) engines
- Noise Reduction (NR) technologies for fans, landing gear, propulsion airframe aeroacoustics
- Light weight acoustic treatment in multi-functional structures



"N + 2" Hybrid Wing/Body

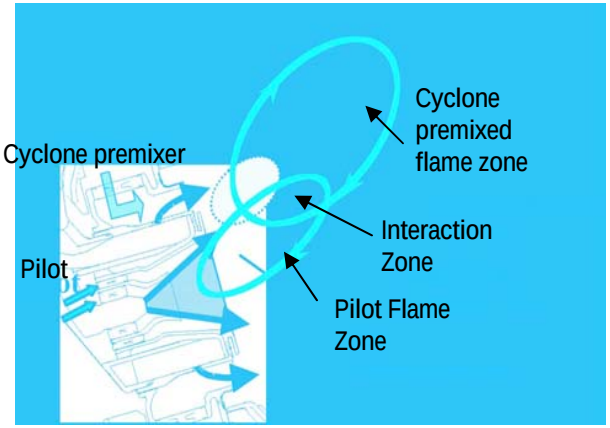
- 52 EPNdB cumulative below Stage 3 (42 wrt Stage 4)
- Will achieve significant noise reduction from wing shielding of engines
- Drooped leading edge
- Continuous mold line flaps
- Landing gear fairings
- Long duct, low drag acoustic liners
- Distortion tolerant fans with active noise control



LTO NO_x Emissions Reduction

Conventional Small Twin: N+1

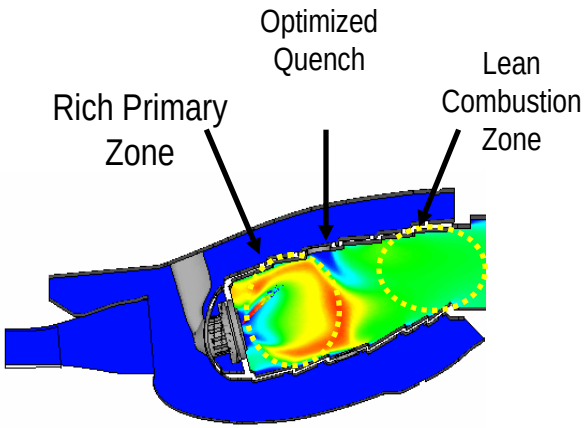
70% LTO NOx reduction below CAEP/2
Target Next Generation Single Aisle (NGSA)
Annular combustor TAPS (GE)
Improved fuel/air mixers
TALONX (P&W)
Optimized quench section for improved mixing
Improved fuel/air mixing in rich zone



Cyclone Main with Pilot Concept

Hybrid Wing/Body: N+2

80% LTO NOx reduction below CAEP/2
Improved CFD Modeling
Advanced combustor concepts
Advanced fuel/air mixers
Active combustion control
High temperature liners
Alternative fuels

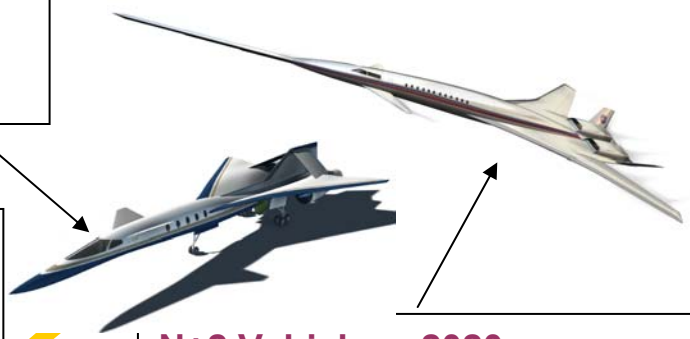


Rich Burn Quick Quench Lean Burn Concept

Lean Direct Injection Multipoint Concept

Vision for Supersonic Transport

N+1 Vehicle ~2015
- Mach 1.6- 1.8
- Payload 6-20 Pax
- Range 4000 mi
- Sonic boom 65-70 PLdB



Low Sonic Boom Validation
- Mach 1.4-1.6
- TOGW ~30,000 lbs
- Sonic boom 65-75 PLdB

N+2 Vehicles ~2020
- Mach 2.2
- Payload 35-70 Pax
- Range 4000 mi
- Sonic boom 65-70 PLdB

N+3 Vehicles ~ 2030
- Mach 1.4-2.0
- Payload 100-200 passengers
- Range 6000 mi
- Sonic boom 65-70 PLdB for low boom flight

Supersonic Overwater Aircraft
Search for new fundamental technology for boom Mitigation

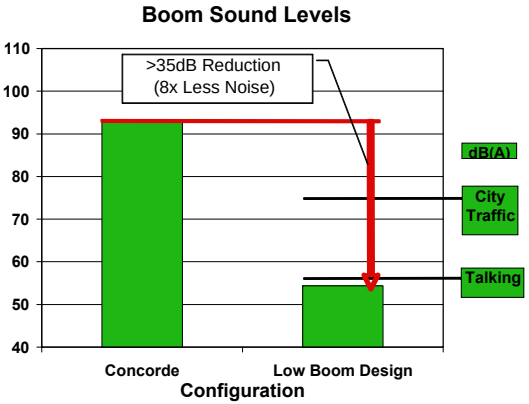
Sonic boom annoyance remains a major environmental challenge for supersonic flight over land

other challenges: Airport noise, High altitude emission, Cruise efficiency

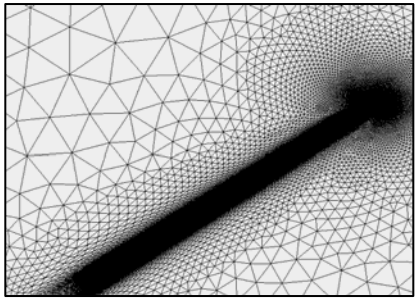
Sonic Boom Research

Progress So Far

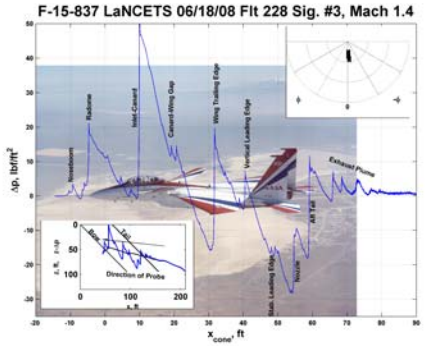
Flight validation of non-coalescing shocklets produced from Quiet Spike configuration



Feasibility of sonic boom shaping established to reduce sonic boom



Advanced unstructured grid generation for sonic boom prediction



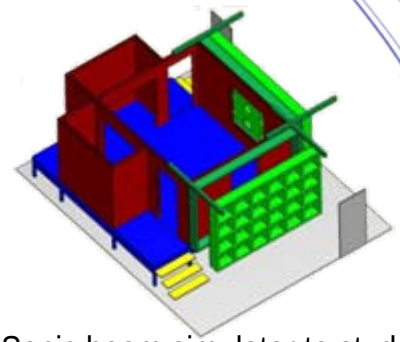
Effect of nozzle plume on sonic boom studied and models validated

Sonic boom model validation through wind tunnel testing

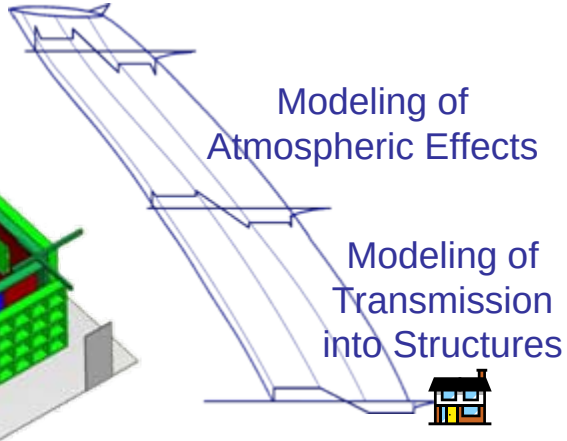
Future Research

Flight research aircraft approved for flight throughout the U.S.

- Incorporates full spectrum of low sonic boom features to validate boom shaping technology
- Generate data for judgment of sonic boom acceptability



Sonic boom simulator to study human response to boom



Modeling of Atmospheric Effects

Modeling of Transmission into Structures

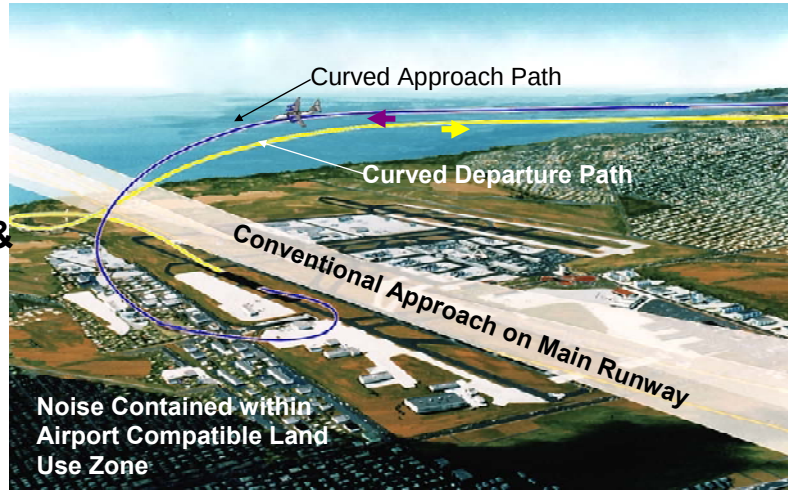
Modeling of Human Response to Booms

Continuation of Sonic Boom Modeling Research

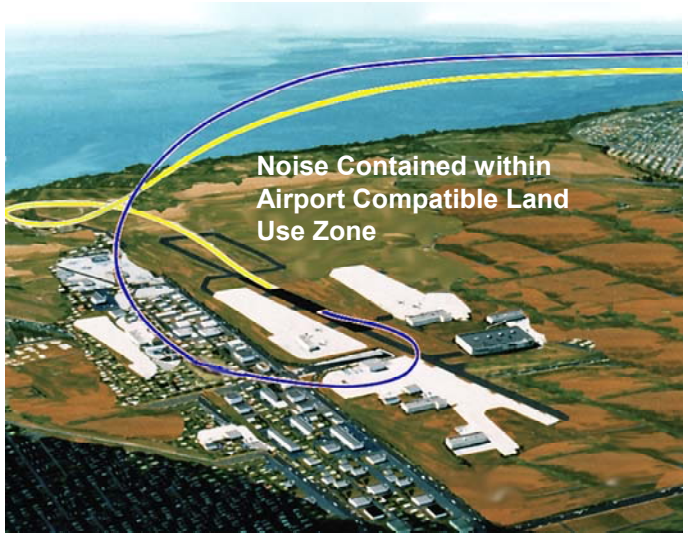
Mobility Challenge

Need to increase capacity of air transportation system to handle 2-3 times traffic it currently handles

Simultaneous & Non-Interfering (SNI) Operations



System capacity improvements at hub airports by using unused or underutilized runways



Point-to-point service using unused or underutilized airports in metroplex concept

Hybrid wing CESTOL concept

Both concepts would require new vehicles:

- Fixed wing aircraft with reduced field length capability
- Rotorcraft with capability for increased speed, range, payload, and reduced noise

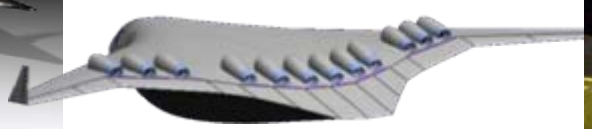
Large civil tiltrotor

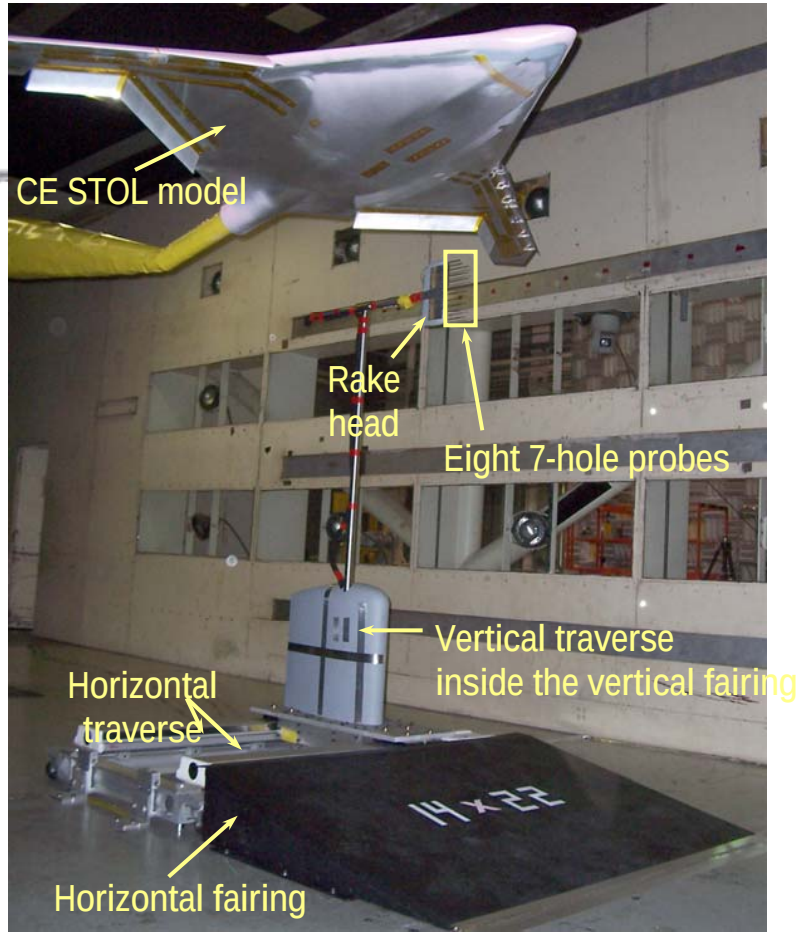
Research to Reduce Field Length

Cruise Efficient STOL Aircraft Concepts

N+1

N+2





Key Aircraft Capability

•STOL with low noise and efficient high-speed cruise (Mach 0.8+)

Key Partnership for Tool & Technology Development

•NASA/OGA/Industry - AF, Boeing PW, LM, Northrop Grumman

Key Aircraft Technology

•Powered Lift/Flow Control Concepts for Reduced Field Length

Key Tools

•3D Flow Control Prediction Tools (CFD)

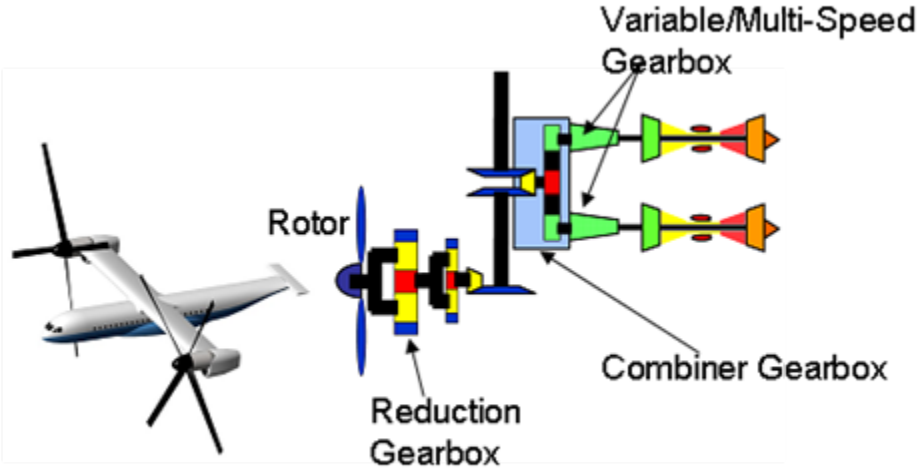
•3D Flow Control Test Capability (WT)

Goal: 50% reduction in field length by 2020 (N+2) and enable metroplex concepts by 2030-35 (N+3)

Advanced Rotary Wing Vehicle Research

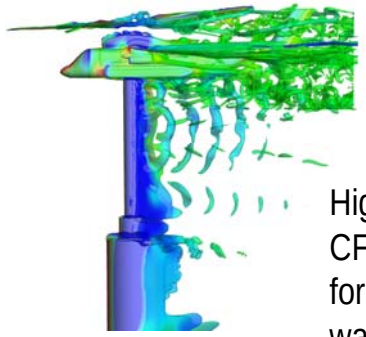
Rotorcraft With Increased Speed, Range, Payload, and Reduced Noise

Actively controlled blade trailing edge flaps for noise and vibration control



Hover Ratio 131.4:1 Forward Flight Ratio 243.6:1

Variable/Multi-speed drive system to enable 50% reduction in rotor speed from hover to cruise



High fidelity CFD tools for rotor wake prediction

Goals:

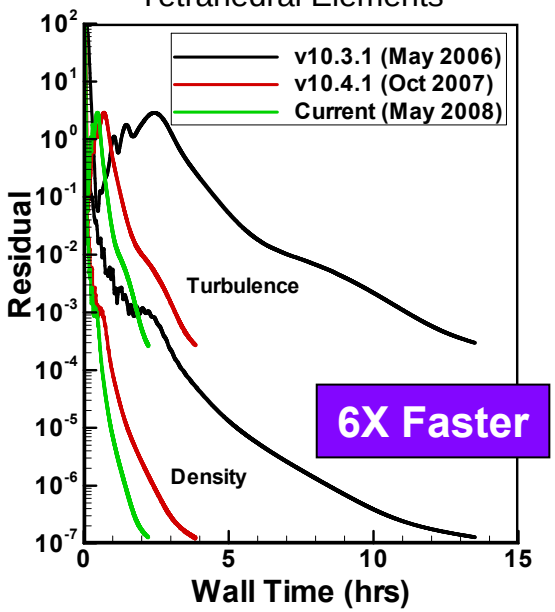
- Increase cruise speed by 100 knots
- External noise contained within landing area and internal noise reduced to 77 dB
- Increase payload to enable 90 passenger capability

Improving Time-to-Solution for Unstructured Grids

L-1

Improve FUN3D Efficiency

Tetrahedral Elements



6X Faster

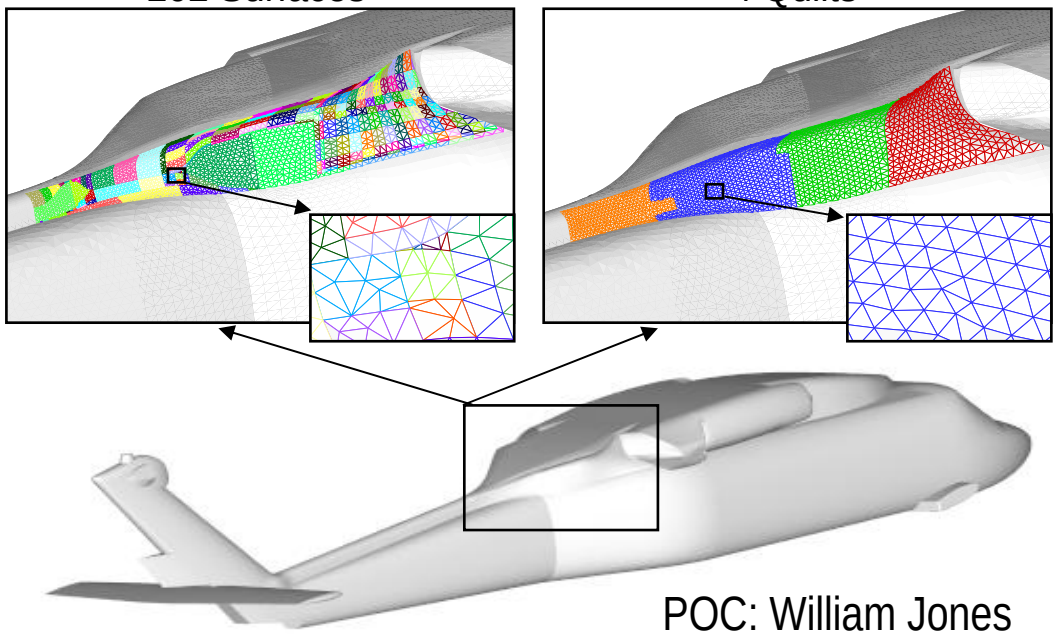
- 5.6M node Drag Prediction Workshop Wing/Body
- 64 Processors
- 3.6 Ghz P4 2GB w/GigE

POC: Eric Nielsen

"Quilting" for Grid Generation

202 Surfaces

4 Quilts



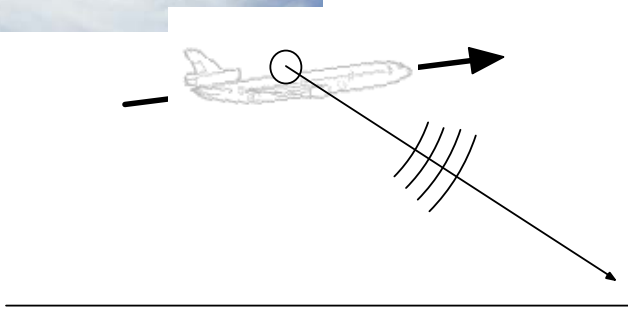
POC: William Jones

- **Higher-Order Time (4th) for Moving Grids**
- **Overset Mesh-Movement Masking**
- **$1/N_{BLADE}$ per Revolution Loose Coupling**

FUN3D collaborative software development framework: new capabilities continuously and seamlessly inherited by all code users

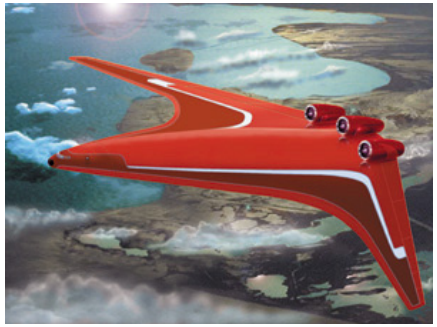
Aircraft System Noise Prediction Paradigm Shift

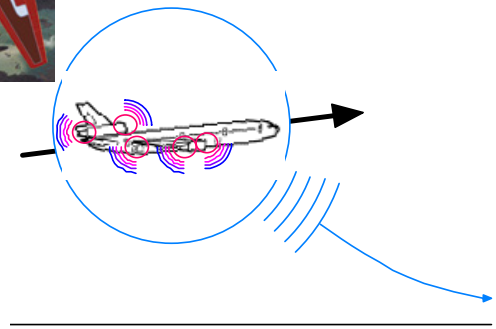
ANOPP (Current)



- Aircraft noise sources are placed at a single point
- Effects of engine installation are added based on past experience
- Effects of atmosphere are primitive
- Cannot venture too far outside experience base

ANOPP II (Future)

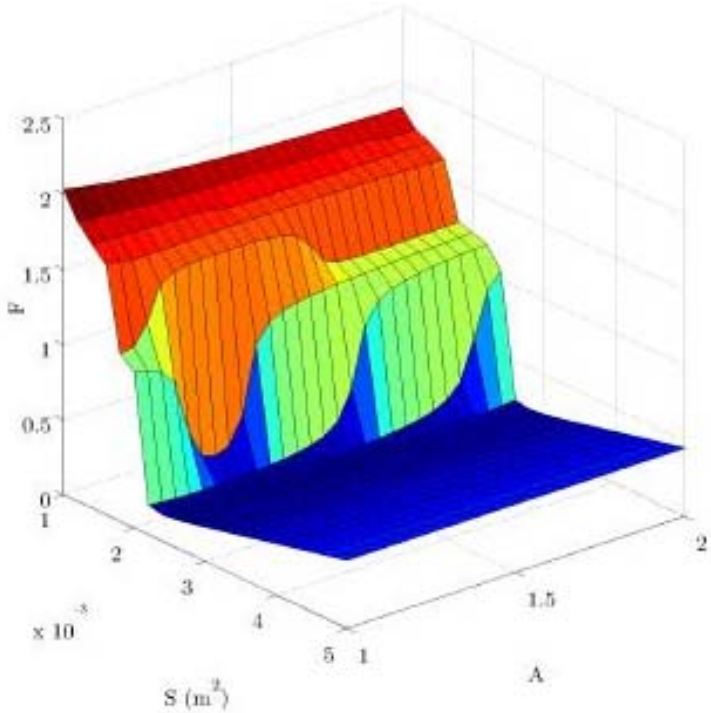




- Aircraft noise sources are in their true locations.
- Account for all interaction effects: engine installation, airframe configuration, scattering
- Effects of atmosphere (gradients, winds) and terrain are included.
- Can (and **must**) venture outside experience base

Multidisciplinary Analysis and Optimization is a Key Element of All Projects

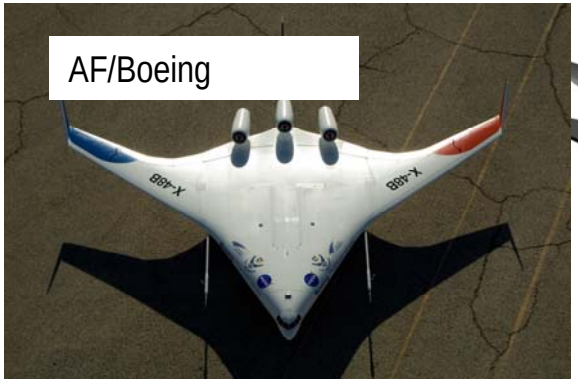
"Develop fast and effective physics based multi-disciplinary analysis and design tools with quantified levels of uncertainty that enable virtual expeditions through the design space."



Virtual Expeditions through Design Space

- Enable unconventional vehicle synthesis and analysis through a shift from *empirically based, non-integrated, low fidelity deterministic methods* to more *physics based, integrated, variable fidelity probabilistic methods*.
- Enable the critical sizing and early configuration trade studies of both conventional and unconventional designs.

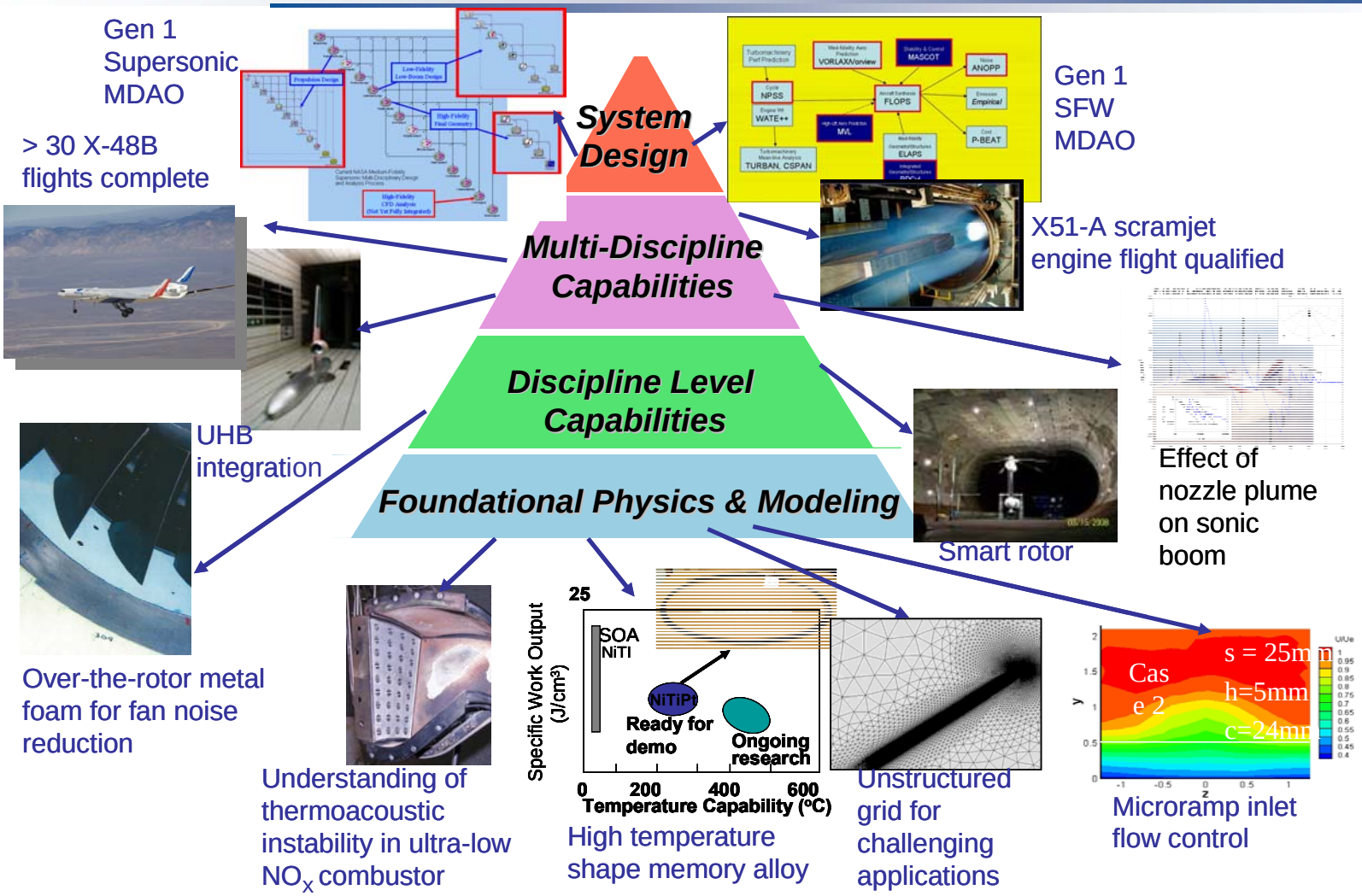
Partnerships Play a Key Role in Achieving Program Goals



AF

GE Aviation

Significant Progress Being Made For All Levels of ARMD Pyramid



As technologies mature at foundational and discipline levels, system level experimentation will be required to address integration challenges, verify corners of design trade space, and validate models

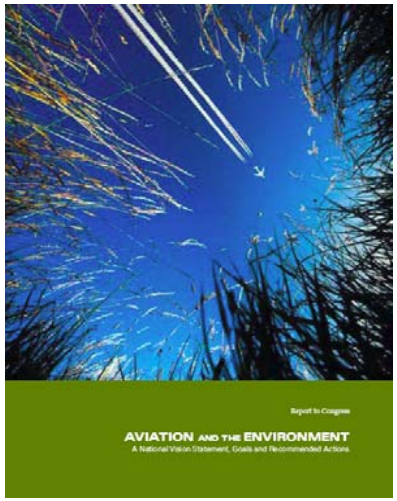
The Challenge: Next Generation Air Transportation System (NextGen)

NextGen Vision for Environment/Performance:

Provide environmental protection that allows sustained aviation growth

Factors:

- 2X increase in system by 2025
- Fundamental system changes
- Significant energy/fuel crisis
- Increased importance of environment
- Vision to grow aviation while reducing *significantly* its environmental impact



NASA Research Activities:

- Aggressive goals for reducing noise, emissions, and fuel burn for subsonic fixed wing, supersonic, and subsonic rotary wing vehicles
- Research the issues associated with deploying new or advanced air vehicles within NextGen