FAN & OPEN-ROTOR NOISE

This presentation is a technical progress report and near term outlook for work on fan (in-duct) and open-rotor (high speed propeller) noise funded by NASA's Fundamental Aeronautics Program, Subsonic Fixed Wing (SFW) Project and the Integrated Systems Research Program, Environmentally Responsible Aircraft Project. Sections of the presentation cover: the system level metrics are outlined for the SFW timeframes (2015, 2020, 2025); the Ultra-High Bypass ratio technology development roadmap; a feasibility study for a low technology readiness level fan test rig; the development plan for a turbomachinery oriented computational aero-acoustics code; and systems analysis work on open-rotor modeling.

National Aeronautics and Space Administration

Fan & Open-Rotor Noise

Acoustics Technical Working Group Meeting, Oct 2010

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Research supported by the Fundamental Aeronautics Program, Subsonic Fixed Wing Project, and the Integrated Systems Research Program, Environmentally Responsible Aircraft Project.

Fundamental Aeronautics Program Overview

Goal: Develop capabilities necessary to address national challenges in air transportation including noise, emissions, fuel consumption, acceptable supersonic flight over land, mobility, and the ability to ascend/descend through planetary atmospheres. These technological capabilities will enable feasible design solutions to performance and environmental challenges of future air vehicles – vehicles that fly through any atmosphere at any speed.

Subsonic Fixed Wing (SFW)

Develop improved prediction methods and technologies that enable dramatic improvements in noise and emissions reduction, and increased performance (fuel burn and reduced field length) characteristics of subsonic/transonic aircraft.

Subsonic Rotary Wing (SRW)

Radically improve the transportation system using rotary wing vehicles by increasing speed, range, and paylod while decreasing noise and emissions.

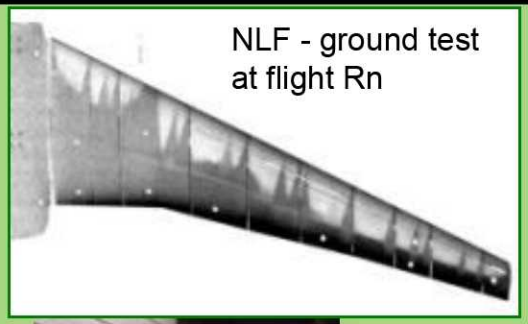
Supersonics

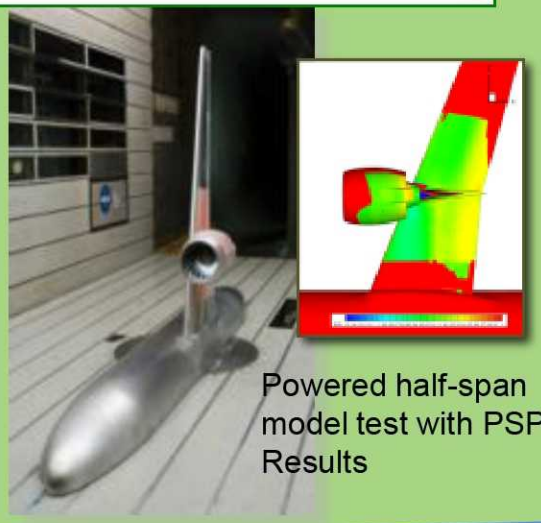
Eliminate environmental and performance barriers that prevent practical supersonic vehicles (cruise efficiency, noise and emissions, performance, boom acceptability).

Hypersonics

Enable airbreathing access to space and high mass entry into planetary atmospheres.

SFW – Strategy and Direction


NLF - ground test at flight Rn


Powered half-span model test with PSP Results

NASA SFW

Near Term Technologies

- Support of CLEEN Partnership
- MDAO Generation 1
- Design Tool Updates

N+1 (2015)

NASA ERA

Emphasis on N+2 Systems Level

- Laminar Flow Control Exp.
- Next Generation Low NOx Combustor
- Acoustic Shielding Studies
- Advance Structures (PRSEUS)
- Propulsion Concepts (UHB, OR)
- Boundary Layer Ingestion Concepts
- N+2 NRA Studies

Mid-Term Technologies

- MDAO Generation 2
- High Lift / Cruise Efficient Concepts
- ANOPP – 2 Development
- Flight Control Research

N+2 (2020)

Long-Term Technologies

- N+3 NRA Studies and follow on activities: 4 External Teams and 2 Internal Advanced Concepts
- Characterization of Alternative Fuels for Aviation
- Foundational NRA Program with Industry and Academia

N+3 (2025)

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

Technology Challenge

Title	Description
Reduced Noise Aircraft	Enabling concepts and technologies to dramatically reduce perceived aircraft noise outside of airport boundaries.

Reduce Perceived Noise

- Innovative flow and noise diagnostic techniques for noise source characterization
- Multi-fidelity aircraft component and system noise prediction tools
- Propulsion & airframe noise reduction technologies
- Analysis of low-noise aircraft configurations

Fan / Open-Rotor Research Direction

- **Develop** fundamental technologies under Fundamental Aero. Program / Subsonic Fixed Wing Project

  Technology and tool development

  Low Technology Readiness Level (TRL) work: 1-4

  N+3 technology readiness in 2030-2035

- **Graduate** low Technology Readiness Level technologies to Environmentally Responsible Aviation Project

  UHB (GTF), Open Rotor

  Mid TRL: 5-6

  N+2 technology readiness in 2020

Presentation Focus: FY11 -

Technologies

- Ultra-High Bypass

  GTF fan technology (soft vane, over-the-rotor treatment) (Hughes)

  ANCF2 feasibility study (Sutliff)

- Un-Ducted (Open Rotor) (VanZante)

Tools

- Embedded engines / inflow distortion: distortion model, validation test (Koch)
- Turbomachinery: Computational Aero-Acoustics (Hixon)
- Open-Rotor Systems Analysis (Hendricks)

Testing

- Wind tunnel drive turbine muffler (Stephens)
- Array microphone techniques

UHB Engine Technology Development Roadmap

NASA/P&W Geared Turbofan (GTF) Gen 1 Ground Test

NASA/P&W GTF Gen 2 Aero/Acoustic Wind Tunnel Test

FAA CLEEN/P&W GTF Gen 2 Engine Demo

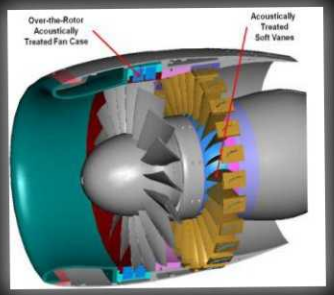
Potential NASA/FAA/P&W GTF Gen 2 Flight Demo

2008 2009 2011 2012 2013 2014 2015 2016

P&W GTF Gen 1 Flight Test

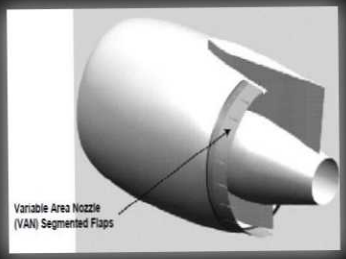
NASA UHB Nacelle/Wing Installation Test

NASA UHB Tech Wind Tunnel Test



Advanced, 2nd Gen Over-the-Rotor and Soft Vanes Acoustic Treatment

Shaped Memory Alloy Variable Area Nozzle



NASA UHB Technology Engine Demo

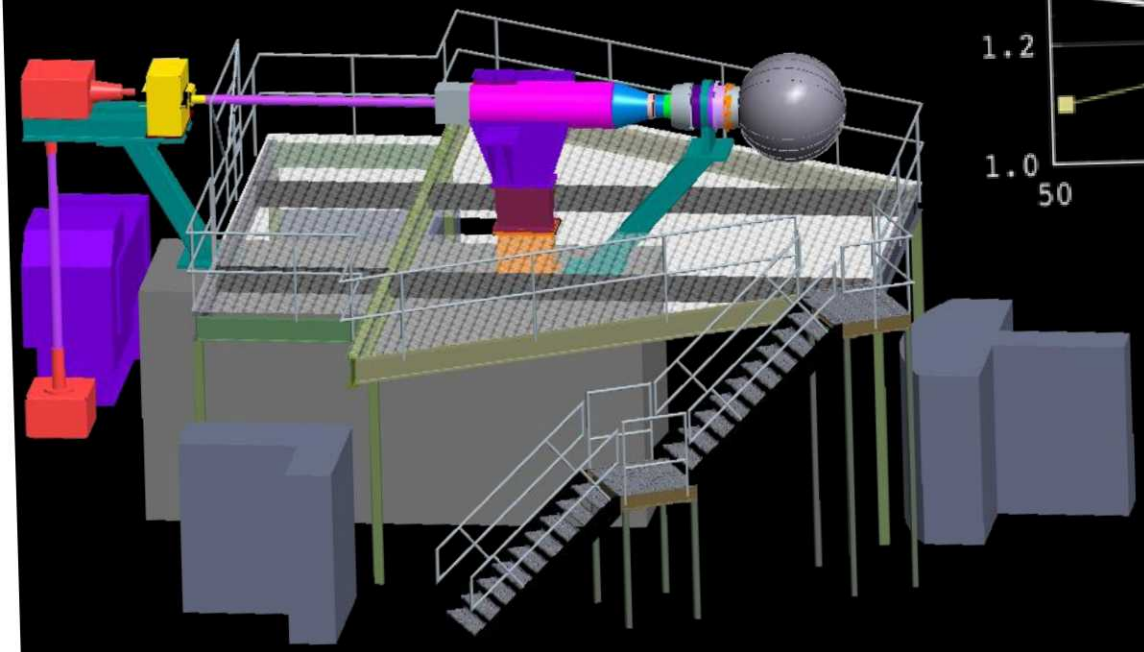
GENERATION 1
Goals: ERA N+1 (2015)

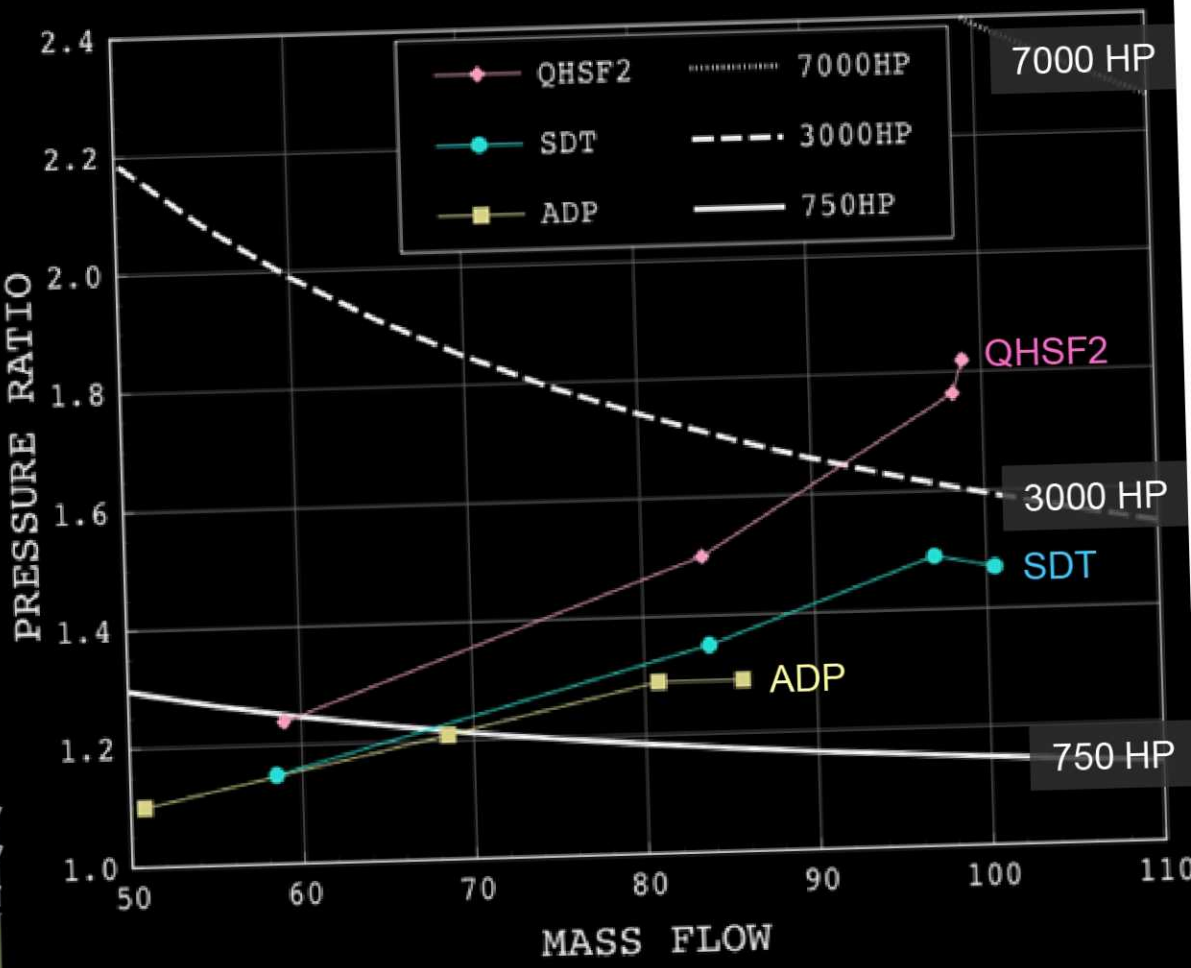
GENERATION 2
ERA N+2 (2025)

ANCF2 Test Rig Preliminary Design

The feasibility study has evaluated a range of drive concepts and resulting cost/performance options.

It is expected that this study will be presented to the project office in December and fan design discussion will be presented at the April 2011 TWG.





Tools: UHB Aero-Acoustics

Inflow Distortion (D. Koch)

- Reduced order response model
- ANCF test to generate validation data

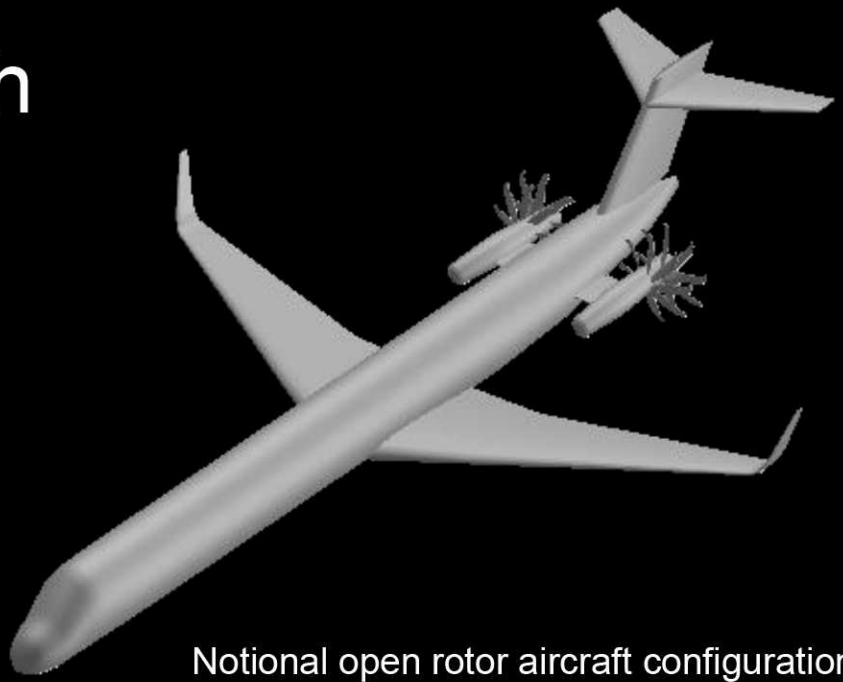
Computational Aero-Acoustics (R. Hixon)

- BASS

	FY10	FY11	FY12	FY13	FY14
Vortical inflow, stators	3D				
Acoustic transmission, stators		2D			
Acoustic transmission, rotors			2D	3D	
Turbulent inflow, stators				2D,3D	
Turbulent inflow, rotors					3D
Full inflow-rotor-stator-outflow					X

SAD&O Open Rotor Research

- NASA SAD&O goal is to have an analysis capability to evaluate open rotor engines and aircraft in terms of performance, weight and noise and compare these concepts with other advanced technology aircraft
- This goal requires collaboration with acoustics and aircraft analysis experts to develop and integrate analysis tools
- Current SAD&O focus is on analytically modeling a counter-rotating, pusher architecture in NPSS
  - Legacy GE36 UDF MD-81 demonstrator
  - Proposed CFM N+1 LEAP-X open rotor configuration (modern core + F7/A7 rotor)



Notional open rotor aircraft configuration

Proposed CFM open rotor configuration based on LEAP-X engine architecture

Open Rotor Analytical Modeling Status

Open rotor modeling in NPSS:

- New counter-rotating propeller performance library element coded for use in engine cycle simulations
- Performance map socket developed based on legacy F7/A7 (8+8) rotor tests, circa 1989
- WATE++ library element under development

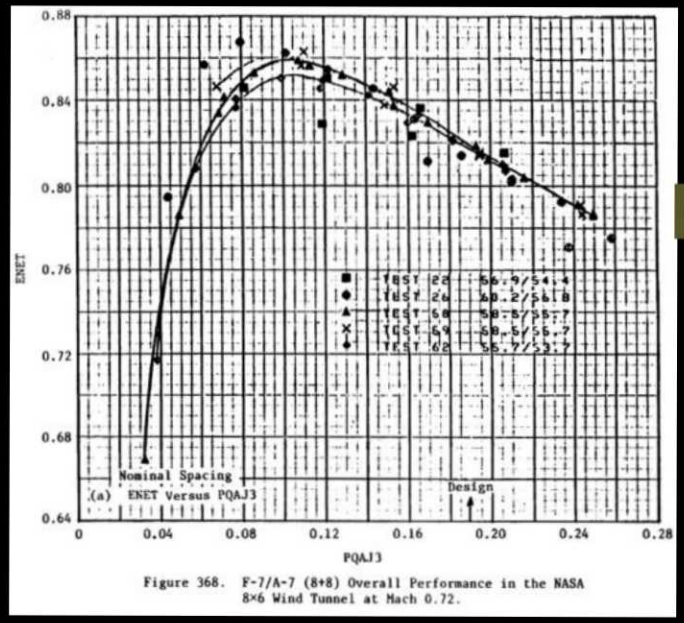
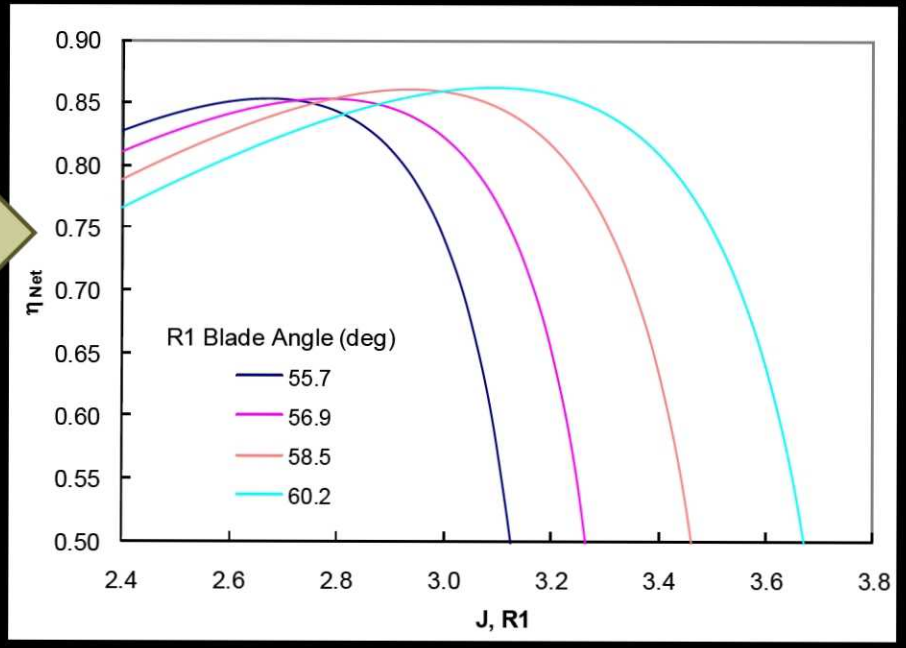


Figure 368. F-7/A-7 (8+8) Overall Performance in the NASA 8×6 Wind Tunnel at Mach 0.72.



Measured F7/A7 efficiency performance data transformed to NPSS map socket data (Ref.: NASA CR185158)

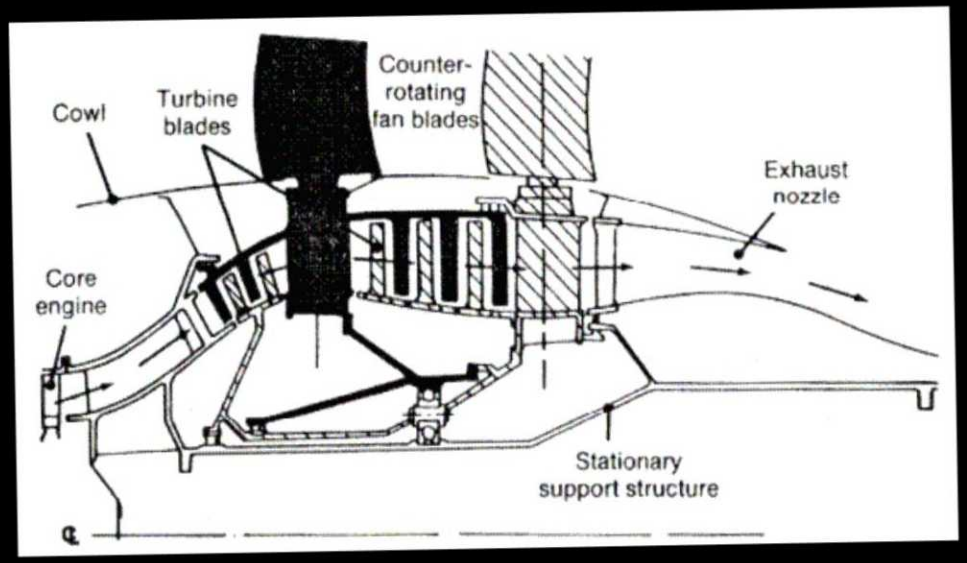
Open Rotor Analytical Modeling Status

Power turbine modeling in NPSS:

- Blade rows in the counter-rotating turbine alternated direction of rotation
- Counter-rotating turbine model: conventional turbine analysis with scaled maps
- Future turbine performance modeling improvements:

  Development of counter-rotating analysis capabilities in NPSS/OTAC

  Model each blade row as a distinct turbine element with alternating shaft connection



GE36 UnDucted Fan propulsor arrangement
(Ref.: AIAA-88-3082)

Possible Collaboration Areas

- Resurrection of legacy GE and United Technologies analysis codes from Advanced Turboprop Project

  Legacy codes will provide performance and acoustic analysis capability beyond the public-domain F7/A7 rotor data

  Potential to wrap these performance codes in NPSS element rather than use map socket static data

- Incorporation of performance and acoustic test data from collaborative GE/NASA open rotor test program
- Development of new analysis codes for counter-rotating propellers and turbines based on experimental data
- To improve collaboration, researchers from several branches at NASA GRC have begun bi-weekly open rotor meetings to coordinate research efforts and share information

Wind Tunnel Model Drive Muffler

David Stephens


NASA