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.
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 payload 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

Near Term Technologies
- Support of CLEEN Partnership
- MDAO Generation 1
- Design Tool Updates

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

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

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

N+1 (2015)
- NLF - ground test at flight Rn

N+2 (2020)
- Powered half-span model test with PSP Results

N+3 (2025)
- Dowered half-span model test with PSP Results

N+2 NRA Studies
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N=1 (2015)

N=2 (2020)

N=3 (2025)
NASA Subsonic Transport System Level Metrics
...technology for dramatically improving noise, emissions, & performance

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<tr>
<td>Noise (cum below Stage 4)</td>
<td>- 32 dB</td>
<td>- 42 dB</td>
<td>- 71 dB</td>
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<tr>
<td>LTO NOx Emissions (below CAEP 6)</td>
<td>-60%</td>
<td>-75%</td>
<td>better than -75%</td>
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<tr>
<td>Performance: Aircraft Fuel Burn</td>
<td>-33%**</td>
<td>-50%**</td>
<td>better than -70%</td>
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<tr>
<td>Performance: Field Length</td>
<td>-33%</td>
<td>-50%</td>
<td>exploit metroplex* concepts</td>
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*** 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**

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<td>Reduced Noise Aircraft</td>
<td>Enabling concepts and technologies to dramatically reduce perceived aircraft noise outside of airport boundaries.</td>
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**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

2008

P&W GTF Gen 1 Flight Test

2009

NASA UHB Tech Wind Tunnel Test

2011

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

2012

Shaped Memory Alloy Variable Area Nozzle

2013

NASA UHB Nacelle/Wing Installation Test

2014

FAA CLEEN/P&W GTF Gen 2 Engine Demo

2015

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

2016

GENERATION 1
Goals: ERA N+1 (2015)

GENERATION 2
ERA N+2 (2025)

National Aeronautics and Space Administration

TWG / Oct 2010 / Fan & Open-Rotor Noise
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
  - 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

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