Subsonic Fixed Wing Project
N+3 (2030-2035) Generation Aircraft Concepts - Setting the Course for the Future

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Outline

• US Policy on Aeronautics
• SFW System Level Metrics
• N+3 NRA Study Concepts
• N+3 NASA In-house Study Concepts
• Questions or Comments
• **Policy**
  
  – Executive Order signed December 2006
  – Outlines 7 basic principles to follow in order for the U.S. to “maintain its technological leadership across the aeronautics enterprise”
  – **Mobility**, national security, aviation safety, security, workforce, **energy & efficiency**, and **environment**

• **Plan (including Related Infrastructure)**
  
  – Plan signed by President December 2007
  – Goals and Objectives for all basic principles (except Workforce, being worked under a separate doc)
  – Summary of challenges in each area and the facilities needed to support related R&D
  – **Specific quantitative targets** where appropriate
  – More detailed document/version to follow later in 2008

*Executive Order, Policy, Plan, and Goals & Objectives all available on the web*

*For more information visit: http://www.ostp.gov/cs/nstc/documents_reports*
## SFW System Level Metrics

*technology for dramatically improving noise, emissions, & performance*

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<tr>
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<tbody>
<tr>
<td>Noise</td>
<td>-32 dB (cum below Stage 4)</td>
<td>-42 dB (cum below Stage 4)</td>
<td>55 LDN (dB) at average airport boundary</td>
</tr>
<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>-40%**</td>
<td>better than -70%</td>
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<tr>
<td>Performance: Field Length</td>
<td>-33%</td>
<td>-50%</td>
<td>exploit metro-plex* concepts</td>
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** An additional reduction of 10 percent may be possible through improved operational capability

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

--- EIS = Entry Into Service; IOC = Initial Operating Capability

**Approach**

- Enable Major Changes in Engine Cycle/Airframe Configurations
- Reduce Uncertainty in Multi-Disciplinary Design and Analysis Tools and Processes
- Develop/Test/Analyze Advanced Multi-Discipline Based Concepts and Technologies
- Conduct Discipline-based Foundational Research
Change in noise “footprint” area based on Subsonic Fixed Wing Project goals for a single landing and takeoff

**Current Noise Rule (Stage 4): Stage 3 – 10 dB CUM**
Area: ~55% of Baseline

**Current Generation of Quietest Aircraft (Gen. N): Stage 3 – 21 dB CUM**
Area: ~29% of Baseline

**SFW Next Generation Gen. N+1 Goal: Stage 3 – 42 dB CUM**
Area: ~8.4% of Baseline

**SFW Gen. N+2: Stage 3 – 52 dB CUM**
Area: ~4.6% of Baseline

**SFW Gen. N+3: Stage 3 – 81 CUM dB (55 LDN)**
Area: ~0.8% of Baseline

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**NOTES**

- Relative ground noise contour areas for notional SFW N+1, N+2, and N+3 generation aircraft
  - Independent of aircraft type/weight
  - Independent of baseline noise level
- Noise reduction assumed to be evenly distributed between the three certification points
- Simplified Model: Effects of source directivity, wind, etc. not included

Aircraft noise is completely contained within the airport boundaries.
SFW N+3 NRA Objectives

• Identify advanced airframe and propulsion concepts, as well as corresponding enabling technologies for commercial aircraft anticipated for entry into service in the 2030-35 timeframe, market permitting
  – Advanced Vehicle Concept Study
  – Commercial Aircraft include both passenger and cargo vehicles
  – Anticipate changes in environmental sensitivity, demand, & energy

• Results to aid planning of follow-on technology programs
N+3 Advanced Concept Study NRA

- 29 Nov 07 bidders conference
- 15 Apr 08 solicitation
- 29 May 08 proposals due
- 2 July 08 selections made
- 1 Oct 08 contract start

- Phase I: 18 Months
  - NASA Independent Assessment @ 15 months

- Phase II: 18-24 Months with significant technology demonstration
SFW N+3 NRA Requirements

- Develop a **Future Scenario** for commercial aircraft operators in the 2030-35 timeframe
  - provide a context within which the proposer’s advanced vehicle concept(s) may meet a market need and enter into service.

- Develop an **Advanced Vehicle Concept** to fill a broad, primary need within the future scenario.

- Assess **Technology Risk** - establish suite of enabling technologies and corresponding technology development roadmaps; a risk analysis must be provided to characterize the relative importance of each technology toward enabling the N+3 vehicle concept, and the relative difficulty anticipated in overcoming development challenges.

- Establish **Credibility and Traceability** of the proposed advanced vehicle concept(s) benefits. Detailed System Study must include:
  - A current technology reference vehicle and mission
    - to be used to calibrate capabilities and establish the credibility of the results.
  - A 2030-35 technology conventional configuration vehicle and mission
    - to quantify improvements toward the goals in the proposer’s future scenario due to the use of advanced technologies, and improvements due to the advanced vehicle configuration.
  - A 2030-35 technology advanced configuration vehicle and mission
A Wide Variety of Concepts Will Be Considered

Engineering, Operations & Technology | Phantom Works | Platform Performance Technology

- Joined Wing
- Hydrogen Powered
- Strut-braced Wing

- Aerial Refueling
- Hybrid Wing Body
- Formation Flight

- Changes in Mission & Operation
- Podded or Integral Batteries
- Other Concepts from Workal
NASA Subsonic Fixed Wing Advanced Concept
Studies for Subsonic Commercial Transport Aircraft
Entering Service in the 2030-2035 Time Period

Northrop Grumman
Massachusetts Institute of Technology
Aircraft & Technology Concepts for an N+3 Subsonic Transport

- MIT
- Aurora
- Aerodyne
- Pratt & Whitney
- Boeing PW
Small Commercial Efficient & Quiet Air Transportation for 2030-2035

NASA Fundamental Aeronautics Program Annual Meeting
7 October 2008
Truss-Braced Wing (TBW) Research
NASA In-house, NIA, Virginia Tech, Georgia Tech N+3 Study

- **What:** Develop and design a revolutionary Truss-Braced-Wing (TBW) subsonic transport aircraft concept.
- **Why:** In 1988, Dennis Bushnell, Langley Chief Scientist challenged the aeronautic community to develop a passenger transport aircraft with Lift/Drag ratio of 40. BWB & Pfenninger’s TBW have the potential to meet this challenge.
- **How:** Develop full Multidisciplinary Design Optimization (MDO) analysis tool for TBW design to increase span, reduce weight and drag with thin wing for natural laminar flow, reduced wetted area, folding wing & flight-control, vortex control, advanced composite, efficient engine in fuselage, bio-fuel.

- Revolutionary: If successful, this design will Double the Lift/Drag ratio of a conventional transport aircraft
Distributed Turboelectric Propulsion Vehicle

NASA In-house N+3 Study (Workshop in progress at GRC)

**Lightweight High Temperature Superconducting (HTS) Components**
- Superconducting motor and generator structures
- Low-loss AC superconductor
- Compact cryocooler
- LH2 tankage (if desired)
- HTS electric power distribution components

**Turboelectric Engine Cycle**
- Decoupling of the propulsive device (fans) from the power-producing device (engine core) -> High performance and design flexibility of aircraft
- High effective bypass ratio -> High fuel efficiency due to improved propulsive efficiency and maximum energy extraction from the core
- Distributed power to the fans -> Symmetric thrust with an engine failure

**Propulsion Airframe Integration**
- Large BLI high aspect ratio short inlet and vectoring nozzle
- Distributed fan noise reduction through wing and jet-to-jet shielding
- Engine core turbomachinery noise suppression
- Direct spanwise powered lift
- Aircraft control using fast response electric fan motor and/or vectoring nozzle
- Wing-tip mounted engine core/generator
  - Aeroelasticity, tip vortex interaction
N3-X Distributed Turboelectric Propulsion System

Wing-tip mounted superconducting turbogenerators

Superconducting motor driven fans in a continuous nacelle

Felder, Kim, Brown
Cryogenic Cooling Options

- Jet fuel with Refrigeration
  - Jet-A fuel weight is baseline for comparison
- Liquid Hydrogen cooled and fueled
  - No refrigeration required
  - 4 times the volume & 1/3 the weight of the jet fuel baseline
- Liquid Methane cooled and fueled
  - 5% of the baseline refrigeration
  - 64% larger volume & 14% less weight the jet fuel baseline
- Liquid Hydrogen cooled and Hydrogen/Jet-A fueled
  - No refrigeration required
  - 32% larger volume & 6% less weight than the jet fuel baseline
- Liquid Methane/Refrigeration cooled and Methane/Jet-A fueled
  - 5% of the baseline refrigeration
  - 17% larger volume & 2% less weight than the jet fuel baseline

Felder, Kim, Brown
Structural Concepts for Storing the LH2

Velicki and Hansen
Structural Concepts for Storing the LH2

View Looking Inboard at Rib X = 68.5 (Cabin Divider)

Landing Gear Bulkhead

Velicki and Hansen
The turboelectric/hybrid wing body approach may meet 3 of the ‘N+3’ goals as well as reduce runway length.

**Fuel Burn/NOX:**
- BLI drag reduction
- 14 fans allows clean integration of large fan area from low fan pressure ratio
- Large turbomachinery core with many embedded, distributed propulsors = very high bypass ratio
- Fan/turbine at any desired speed
- Clean air to turbogenerators
- Asymmetric thrust reduces aero surface drag for control and trim
- <0.5% transmission loss

**Noise:**
- Low pressure fans for low fan nozzle velocity
- Fan nozzle at surface back from trailing edge
- Low turbogenerator exhaust velocity
- Asymmetric thrust reduces control deflection
- Low cabin noise due to remote location of fans and turbogenerators.

**Field Length:**
- Blowing at low speed/high power delays separation and increasing lift coefficient
- “Blown” pitch effector
- Higher static thrust

Felder, Kim, Brown
Exotic fuel trades

For same aircraft configuration

- **Liquid hydrogen**
  - Lower takeoff gross weight, possibly higher empty weight (tankage)
  - Many operational and engineering challenges to solve
  - Method of $\text{H}_2$ production (present method very pollutive), and infrastructure issues

- **Liquid Methane**
  - Positive benefits lie in-between kerosene and Hydrogen
  - Modest reduction in $\text{CO}_2$ and NOx

- **Nuclear-powered**
  - Weight of reactor dependent on shielding requirements
  - $\text{CO}_2$ depends on fuel (but greatly reduced). NOx production probably substantially less or about equal to base (based on study assumptions)
  - Safety and acceptance difficult

- **Fuel cell powered**
  - True zero-emissions (depending on source of H2)
  - Fuel cell technology has a long way to go for transport application (20-25 years)