Integrated System Research Program
Environmentally Responsible Aviation (ERA) Project
A NASA Aeronautics Project focused on midterm environmental goals

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Topics Addressed

- ERA Goals, Objectives and System Level Metrics
- ERA Project Flow and FY11 President’s Budget
- “Technology Collectors” – Current Set
- Technical Approach - Accomplishing N+2 Goals
- Concluding Remarks
ERA Goals, Objectives & System Level Metrics

Over the next 5 years:

- Explore and mature alternate unconventional aircraft designs and technologies that have potential to simultaneously meet community noise, fuel burn, and NOx emission N+2 goals as described in the National Aeronautics R & D Plan
- Determine potential impact of these aircraft designs and technologies if successfully implemented into the Air Transportation System
- Determine potential impact of these technologies on advanced N+2 “tube and wing” designs

### CORNERS OF THE TRADE SPACE

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<thead>
<tr>
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<tbody>
<tr>
<td>Noise (cum below Stage 4)</td>
<td>-32 dB</td>
<td>-42 dB</td>
<td>-71 dB</td>
</tr>
<tr>
<td>LTO NOx, Emissions (below CAEP 6)</td>
<td>-60%</td>
<td>-75%</td>
<td>better than -75%</td>
</tr>
<tr>
<td>Performance: Aircraft Fuel Burn</td>
<td>-33%</td>
<td>-50%**</td>
<td>better than -70%</td>
</tr>
<tr>
<td>Performance: Field Length</td>
<td>-33%</td>
<td>-50%</td>
<td>exploit metro-plex* concepts</td>
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*** Technology Readiness Level for key technologies = 4-6. ERA will undertake a time phased approach, TRL 6 by 2015 for “long-pole” technologies

** RECENTLY UPDATED. Additional gains may be possible through operational improvements

* Concepts that enable optimal use of runways at multiple airports within the metropolitan area
### ERA Project Overview, Flow

**And Key Decision Point for Phase 2**

<table>
<thead>
<tr>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
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<tbody>
<tr>
<td>Prior Research</td>
<td>Formulation</td>
<td>Initial NRAs</td>
<td>Phase 1 Investigations</td>
<td>Phase 2 Planning</td>
<td>Phase 2 Investigations</td>
<td>Key Decision Point for Phase 2</td>
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<tr>
<td>$60.0M</td>
<td>$63.1M</td>
<td>$65.1M</td>
<td>$61.7M</td>
<td>$57.4M</td>
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Technical input from Fundamental Programs, NRAs, Industry, Academia, Other Gov’t Agencies
Technology “Collectors”
Advanced Configuration 1
N+2 Advanced “tube-and-wing“ 2025 Timeframe

- Composite wings and tails including PRSEUS stitched composite technology
- Hybrid Laminar Flow Control on wing upper surface
- Composite fuselage including PRSEUS stitched composite technology
- Natural Laminar Flow on nacelles
- All electric control system with electromechanical actuators
- Variable trailing edge camber
- Advanced engines
- Hybrid Laminar Flow Control on horizontal and vertical tails
- Riblets on fuselage
- SOFC/GT Hybrid APU
- Wing Aspect Ratio = 11
Advanced Configuration 2A
N+2 Advanced HWB300 2025 Timeframe

Composite centerbody
and wings including
PRSEUS stitched
composite technology

Hybrid Laminar Flow
Control on outer
wing sections

Riblets on
centerbody

All electric control
system with
electromechanical
actuators

Natural Laminar
Flow on nacelles

Advanced engines

Variable trailing
edge camber

SOFC/GT Hybrid
APU
Advanced Configuration 2B
N+2 HWB300 2025+ Timeframe

- Composite centerbody and wings including PRSEUS stitched composite technology
- Hybrid Laminar Flow Control on outer wing sections
- Laminar flow control on centerbody
- All electric control system with electromechanical actuators
- Embedded, boundary layer ingesting advanced engines
- Variable trailing edge camber
- SOFC/GT Hybrid APU
Specific System Level Metrics and Technical Approaches
NASA’s Noise Reduction Goals

- Relative ground contour areas for notional Stage 4 and N+1, N+2, and N+3 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
Addressing Noise Reduction

Airframe Noise
Addressing high-lift systems and landing gear

Propulsion Noise
Addressing fan, core, and jet noise

- Twin High Bypass Ratio Jet Simulators
- Simplified Fan Noise Simulator
- Instrumentation and Processing for Low Noise Levels

Open Rotor

UHB Turbofans

Propulsion Airframe Aeroacoustics
Addressing airframe/propulsion interaction - shielding
N+2 Fuel Burn (and CO$_2$) Reduction Goal

**Reference Fuel Burn = 277,800 lbs**

“777-200LR-like” Vehicle

**Advanced Configuration #1**
N+2 “tube-and-wing”
2025 EIS (TRL=6 in 2020)
- Fuel Burn = 159,700 lbs
  -42.5%

**Advanced Configuration #2A**
N+2 HWB300
2025 EIS (TRL=6 in 2020 assuming accelerated technology development)
- Fuel Burn = 144,200 lbs
  -48.1%

**Advanced Configuration #2B**
N+2 HWB300
2025 EIS (TRL=6 in 2020 assuming accelerated technology development)
- Fuel Burn = 130,900 lbs
  -52.9%

**Advanced Engines**
\( \Delta \text{Fuel Burn} = -14.8\% \)

**Composite Fuselage**
\( \Delta \text{Fuel Burn} = -0.8\% \)

**Composite Wings & Tails**
\( \Delta \text{Fuel Burn} = -3.5\% \)

**PRSEUS**
\( \Delta \text{Fuel Burn} = -3.7\% \)

**HLFC (Wings, Tails, Nacelles)**
\( \Delta \text{Fuel Burn} = -9.6\% \)

**Riblets, Variable TE Camber**
Increased Aspect Ratio
\( \Delta \text{Fuel Burn} = -8.8\% \)

**Subsystem Improvements**
\( \Delta \text{Fuel Burn} = -1.3\% \)

**Composite Wings & Tails**
\( \Delta \text{Fuel Burn} = -2.0\% \)

**PRSEUS**
\( \Delta \text{Fuel Burn} = -2.7\% \)

**Advanced Engines**
\( \Delta \text{Fuel Burn} = -19.1\% \)

**Composite Wings & Tails**
\( \Delta \text{Fuel Burn} = -1.8\% \)

**PRSEUS**
\( \Delta \text{Fuel Burn} = -2.4\% \)

**Advanced Engines**
\( \Delta \text{Fuel Burn} = -16.6\% \)

**HLFC on Outer Wings and Nacelles**
\( \Delta \text{Fuel Burn} = -7.9\% \)

**Subsystem Improvements**
\( \Delta \text{Fuel Burn} = -1.0\% \)

**Embedded Engines with BLI Inlets**
\( \Delta \text{Fuel Burn} = -3.3\% \)

**LFC (Centerbody)**
\( \Delta \text{Fuel Burn} = -5.6\% \)
Magnitude of emissions growth and gap is dependent upon aviation traffic growth assumptions.
Addressing Fuel Burn (CO₂ Emissions)

**DRAG REDUCTION via Laminar Flow**
- Addressing concepts & barriers to achieving practical laminar flow on transport a/c
- HLFC - revisit crossflow expt
  - understand system weight
- NLF - ground test at flight Rn

**WEIGHT REDUCTION via Advanced Structures**
- Moving from “safe-life” to “fail-safe” design with a lightweight composite structure
- Pultruded Rod Stitched Efficient Unitized Structure PRSEUS

**SFC REDUCTION via UHB**
- Addressing multidisciplinary challenges from subcomponent to installation to achieve ultra-high by-pass ratio

- [Diagram of Open Rotor Propulsion Rig]
- [Diagram of Powered half-span model test]
- [Diagram of PSP Results]
N+2 LTO NO$_x$ Reduction Goal – More Insight

- B777/GE90: 55% below CAEP 6
- RR Trent 1000: ~50% below CAEP 6 (Predicted)
- PW 810: ~50% below CAEP 6 (Estimated)

N+1, FAA CLEEN

N+2 Goal
Addressing Reduced LTO NO\textsubscript{x} Emissions

**ERA CMC Combustor Liner**
CMC combustor liner enables new engine designs incorporating higher engine temperatures and reduced cooling air flows

**Active Combustion Instability Control**
Demonstrating the capability to suppress combustor instabilities for low emission combustors

**High Temperature SiC electronics**
circuits and dynamic pressure sensors

**SIC CMC** – enable higher temperature engine

**Fuel Modulation** – high frequency fuel delivery systems

**Innovative Injector Concept**

**Alternative fuel**

**Innovative Injector Concept**

**ASCR Combustion Rig**

**Low Nox, Fuel-Flexible Combustor**

- High Bypass Ratio/High Pressure Combustor
- Superior Alternative Fuel properties
- Enhance Fuel/Air Mixing
- Advanced Ignition
Concluding Remarks

• NASA intends to release a BROAD solicitation in a month to:
  – Seek up to 4 subsonic transport vehicle concepts capable of simultaneous achievement of the N+2 noise, NOX and fuel burn system level metrics
  – Develop 15-year technology maturation roadmaps – addressing propulsion and airframe and integration requirements
  – Determine initial system readiness levels, and plot expected system readiness maturation with execution of the 15-year technology roadmaps
  – Explore two additional options -
    • Option 1 – Select up to 2 of subsonic transport vehicle concepts to develop preliminary designs (of sufficient scale to demonstrate goals)
    • Option 2 – Identify risk reduction testing and assessment programs associated with the scaled vehicles.
  – Period of performance is 27 months