Environmentally Responsible Aviation
N+2 Advanced Vehicle Concepts NRA Status

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Integrated Systems Research Program

Turbo Expo
June 6 - 10, 2011
### NASA’s Subsonic Transport System Level Metrics

... Innovative technology for dramatically reducing noise, emissions and fuel burn

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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>
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<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 Flow and Lifespan

<table>
<thead>
<tr>
<th></th>
<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>Phase 1 Investigations</td>
<td>Initial NRAs</td>
<td>Phase 2 Planning</td>
<td>Key Decision Point for Phase 2</td>
<td>Phase 2 Investigations</td>
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<td></td>
<td>$56.9 M</td>
<td>$73.1 M</td>
<td>$75.1 M</td>
<td>$71.7 M</td>
<td>$67.4 M</td>
<td>$67.4 M</td>
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Technical input from Fundamental Programs, NRAs, Industry, Academia, Other Gov’t Agencies
Where did the numbers come from?
Fuel Burn - Technology Readiness 2020

Technology Benefits Relative to Large Twin Aisle (Reference: 777-200LR “like” Vehicle)

Advanced “tube-and-wing”

- Composite Fuselage: -3.5% (-0.7%)
- Composite Wings & Tails: -3.6% (-1.3%)
- PRSEUS: -15.3% (-9.9%)
- Advanced Engines: -8.7% (-1.3%)
- HLFC (Wings, Tails, Nacelles): -9.9% (-1.3%)
- Riblets, Variable TE Camber, Increased Aspect Ratio: -1.3% (-1.3%)
- Subsystem Improvements: -1.3% (-1.3%)

Fuel Burn = 159,500 lbs
-120,300 lbs (-43.0%)

Reference Fuel Burn = 279,800 lbs

HWB300

- Composite Wings & Tails: -2.0% (-1.1%)
- PRSEUS: -15.9% (-1.1%)
- Advanced Engines: -8.6% (-1.1%)
- HLFC (Wings, Tails, Nacelles): -18.5% (-1.0%)

Fuel Burn = 140,400 lbs
-139,400 lbs (-49.8%)

HWB300 + more accelerated tech maturation

- Composite Wings & Tails: -1.7% (-0.9%)
- PRSEUS: -15.9% (-1.0%)
- Advanced Engines: -16.0% (-7.5%)
- HLFC (Outer Wings and Nacelles): -7.5% (-3.2%)
- Riblets, Variable TE Camber: -3.2% (-3.2%)
- Subsystem Improvements: -5.5% (-5.5%)
- Embedded Engines with BLI Inlets: -5.5% (-5.5%)
- LFC (Centerbody): -0.9% (-0.9%)

Fuel Burn = 128,500 lbs
-141,300 lbs (-54.1%)

Reference Fuel Burn = 279,800 lbs
Baseline engines 1D downstream of trailing edge

Simple shielding, engines move 2D upstream

Chevrons reduce source & increase shielding effectiveness (same area, more noise reduction)

Active Pylon adds more jet shielding effectiveness, elevons add more aft fan shielding

Favorable directivity of jet from crown pylon

Acoustic liner added to crown pylon for aft fan attenuation

Initial projection of more advanced crown pylon, chevrons, acoustic liner, quiet landing gear
The Study
- Twelve months in duration
- Five tasks
  - Tasks 1-4 relate to a full sized concept
  - Task 5 relates to a subscale testbed vehicle
- $10.9M total awarded to three teams

2 Options
- 50/50 cost share required, up to two awards, 17 months duration
- Option 1
  - Preliminary design of subscale testbed
  - NASA share: up to $12.5M per team
- Option 2
  - Testing to reduce risk / increase confidence of preliminary design
  - NASA share: up to $10M total
Task 1

• Future Scenario
  – What does the world that you are designing to look like?
    • Formation flight?
    • What are your assumptions that are driving your design?
  – What is the NextGen scenario in 2025 that you are designing to?
    • What level of completion is NextGen at?
  – What is the interplay between your concept and NextGen?
    • How would you like NextGen to be tweaked to accommodate your PSC?
Task 2

- Develop a $M = 0.7 - 0.85$ conceptual design of a 2025 EIS subsonic transport that simultaneously meets the Noise, Emissions and Fuel Burn goals
- Design Mission

<table>
<thead>
<tr>
<th>Cargo</th>
<th>Payload</th>
<th>Range</th>
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<tbody>
<tr>
<td>100,000 lbs</td>
<td>50,000 lbs</td>
<td>8,000 nm</td>
</tr>
<tr>
<td>6,500 nm</td>
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- Repeat for:
  - 1998 tube and wing
    - Baseline toolset
  - 2025 EIS tube and wing
    - Separate configuration from technology
- Provide concept data packages for all designs
Tasks 3 & 4

• Technology Maturation Plans (TMP’s)
  – 15 year Roadmap for each of the critical technologies
    • Key research, analyses, tool and method development
    • Necessary ground and flight tests
  – Starting and ending TRL & SRL
  – Cost, schedule and technical outcome
  – Useful for advocacy beyond ERA Project timeframe
  – “Is the problem physics, or is it money?”

• FY 2013 – 2015 Critical Technology Demonstrations
  – Long poles, enabling technologies, or first victories
  – Scalability beyond PSC
  – Sorted by:
    • Airframe
    • Propulsion
    • Integrated Propulsion/Airframe
    • Subscale Testbed
  – How to de-scope from deluxe to bare bones (cost, complexity, schedule, risk)
  – Provides guidance to Phase II of ERA Project
Task 5

- Conceptual Design of a Subscale Testbed Vehicle (STV)
- Proposal for completing Preliminary Design of the STV
- **ROM** cost and schedule for completing design, construction and initial flight testing of the STV

- STV requirements
  - Same configuration as the PSC
  - Same Mach and cruise speed as PSC
  - Retractable Landing Gear
  - Sufficient scale to demonstrate noise, emissions & fuel burn goals
    - Notionally ~ 50% or larger
  - Adaptable for future modifications
    - Engines
    - To demonstrate UAS in the NAS technologies
  - Projected 20 year research life
## Schedule

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<thead>
<tr>
<th>2010</th>
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<tbody>
<tr>
<td>Nov</td>
<td>Contract Start</td>
<td>Down Select</td>
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<tr>
<td>Dec</td>
<td>Kick-Off</td>
<td>Option 1 Award</td>
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<tr>
<td>Jan</td>
<td>3 Month TIM</td>
<td>PSC Review</td>
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<tr>
<td>Feb</td>
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<td>Conceptual Design Review</td>
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<tr>
<td>Mar</td>
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<td>Final Presentations</td>
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<td>Apr</td>
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<td>Dec</td>
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The Awardees...
Lockheed Martin
• The Lockheed Martin ERA design is a non-traditional “Box Wing” concept for improved structural and aerodynamic efficiency.
• It incorporates advanced technologies in the areas of:
  – advanced propulsion for significant fuel burn and noise reduction
  – new light weight materials
  – laminar wing aerodynamics
  – other efficiency technologies
• The concept is envisioned to integrate into existing airport infrastructure without significant changes and to provide a passenger experience consistent with the best of today’s airliners.
Innovative Configurations and Technologies Enable Efficient Long-Endurance Performance in Future Systems
• Technologies and configurations that improve energy efficiency are beneficial to both military and civil aircraft
  – Civil or military applications only become important in the integration of the technologies
  – Application can affect the degree of benefit the system sees from a particular technology
• Technologies and configurations that improve energy efficiency generally work in one of three ways
  – Reducing drag
  – Reducing weight
  – Increasing efficiency of propulsion systems
• Reductions in drag and weight, and increases in efficiency of propulsion systems are just as applicable to civil aircraft as military aircraft
Boeing
Boeing’s Blended Wing Body (BWB) proposal takes advantage of the improved L/D of the BWB platform, and will use many of the technologies that have previously been identified with the BWB:
  – PRSEUS lightweight, damage arresting composite structure
  – Laminar flow
  – Acoustic shielding inherent in the configuration
  – Proven low speed flight controls
  – High efficiency, new technology engines

Boeing’s study will investigate both geared turbo fans and open rotors