Advanced Air Transport Technology (AATT)
August 2019
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NASA Glenn Research Center
NASA Aeronautics

NASA Aeronautics Vision for Aviation in the 21st Century

ARMD continues to evolve and execute the Aeronautics Strategy
https://www.nasa.gov/aeroresearch/strategy

U.S. leadership for a new era of flight
Research Programs align with Strategic Thrusts

**MISSION PROGRAMS**

- **Airspace Operations & Safety**
  - Safe, Efficient Growth in Global Operations
  - Real-Time System-Wide Safety Assurance
  - AOSP

- **Advanced Air Vehicles**
  - Ultra-Efficient Commercial Vehicles
  - Innovation in Commercial Supersonic Aircraft
  - Transition to Alternative Propulsion and Energy
  - AAVP

- **Integrated Aviation Systems**
  - Flight research-oriented, integrated, system-level R&T that supports all six thrusts
  - X-planes/test environment
  - IASP

**TRANSFORMATIVE AERONAUTICAL CONCEPTS**

- High-risk, leap-frog ideas that support all six thrusts
- Critical cross-cutting tool development
- Assured Autonomy for Aviation Transformation
- TACP

**SEEDLING PROGRAM**
Aeronautics Research Mission Directorate Programs

Advanced Air Vehicles Program
- Revolutionary Vertical Lift Technology
- Advanced Composites
- Commercial Supersonics Technology
- Aeronautical Evaluation & Test Capabilities
- Hypersonic Technology

Integrated Aviation Systems Program

Airspace Operations and Safety Program
- Airspace Technology Demonstrations
- Air Traffic Management Exploration
- System-Wide Safety
- UAS Traffic Management

Transformative Aeronautics Concept Program
- Convergent Aeronautics Solutions
- Transformational Tools and Technologies
- University Innovation

Advanced Air Transport Technology
- UAS Integration in the NAS
- Flight Demonstrations and Capabilities
- Low Boom Flight Demonstrator

http://www.aeronautics.nasa.gov/programs.htm
Advanced Air Transport Technology Project

Vision

Enable Aircraft with Dramatically Improved Energy Efficiency, Environmental Compatibility, and Economic Impact for the Nation

Mission

Explore and develop viable game-changing concepts, technologies, and tools to improve vehicle and propulsion system energy efficiency and environmental compatibility

Scope

Subsonic fixed-wing commercial transport aircraft

Evolution of Subsonic Transports

- DC-3
- B-707
- B-787

1903 1930s 1950s 2000s
New Technologies and Time/Cost to Market will be the Differentiators to Continued US Leadership

Technologies that will open the door to a new single-aisle transport are broadly applicable to smaller and larger aircraft and will help open new aviation markets.

The Single Aisle Aircraft market is the largest economic driver in aviation – but industry does not know how it will eventually develop a replacement.
- Performance must show significant improvement
- Must be able to build new aircraft at very high rates
- Must be affordable to build and operate
- International competition is intense

Electrified Aircraft Propulsion has been identified as a potential game changer
- Allows new architectures and flexibility in design and operation
- Potential for significant efficiency improvement
- 1MW machines have been identified as a “sweet spot” for aviation use
- This is a very challenging problem to be developed and validated

A suite of technologies will be needed:
- Ultra-Efficient Wing
- Unconventional Structure
- Novel Propulsion-Airframe Integration
- Electrified Aircraft Propulsion
- Small Core Gas Turbine Engine

### 2036 Forecast

- **41,030** New Aircraft Deliveries
- **$6.1 Trillion** Market Value

78% of New Aircraft Deliveries are Single Aisle Class (including Regional Jets)

State of available technologies is not sufficient to meet U.S. industry decision criteria

NASA has made good progress in these areas but more work needed

Increased importance due to convergence of technical progress and industry pull
Use industry pull to mature technology that enables aircraft products that meet near-term metrics and push to mature technology that will support development of new aircraft products that meet or exceed mid-term and far-term metrics.

### TECHNOLOGY GENERATIONS

<table>
<thead>
<tr>
<th>TECHNOLOGY BENEFITS*</th>
<th>Near Term 2015-2025</th>
<th>Mid Term 2025-2035</th>
<th>Far Term beyond 2035</th>
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<tbody>
<tr>
<td>Noise Reduction (cum below Stage 4)</td>
<td>22 – 32 dB</td>
<td>32 – 42 dB</td>
<td>42 – 52 dB</td>
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<td>LTO NO_x Emissions Reduction (below CAEP 6)</td>
<td>70 – 75%</td>
<td>80%</td>
<td>&gt; 80%</td>
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<tr>
<td>Cruise NO_x Emissions Reduction (rel. to 2005 best in class)</td>
<td>65 – 70%</td>
<td>80%</td>
<td>&gt; 80%</td>
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<td>Fuel/Energy Consumption Reduction (rel. to 2005 best in class)</td>
<td>40 – 50%</td>
<td>50 – 60%</td>
<td>60 – 80%</td>
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*Note: Reference is best commercially available or best in class in 2005.
AATT Project Organization FY20 and Beyond…

Acting, DPM for Technology  
Scott Anders

Acting, Project Manager  
Mary Wadel  
Deputy Project Manager  
Hamilton Fernandez

DPM for EAP Integration  
TBD GRC

Strategic Integration Team

Strategic Advisors
- Airframe: Scott Anders
- Flight: Oscar Murillo
- Propulsion: Dale Van Zante
- EAP: Ralph Jansen

Systems Analysis & Integration
- Lead: William Haller
- Co-Lead: Jesse Quinlan

Project Planning and Control Team

Business Manager: Sheena Fussell

Center Project Integration Managers
- ARC – Robert Fong
- AFRC - Cheng Moua
- GRC - Anthony Nerone
- LaRC – vacant

Resource Analysts
- Warcquel Frieson, ARC
- Glenda Almeida, AFRC
- Sheena Fussell, GRC
- Rachael Buckman, LaRC

Scheduler: Leslie Letzinger
Risk Manager: Stephan Manchir
Project Coordinator: Keshia Newsome
Configuration and Data Mgr.: Barbara Kimbell

Acting, Project Manager
- Mary Wadel
- Deputy Project Manager
- Hamilton Fernandez

Acting, DPM for Technology
- Scott Anders

Small Core Gas Turbine

SPM/DSPM
- Kimlan Pham
- TBD GRC

TLs
- Laura Evans
- Ken Suder
- Mark Potapczuk
- Ashlie Flegel

Engine Controls TL GRC

Engine Core w/Icing TC

Viscous PAI TC  
Podded Engines TC

Electrified Aircraft Propulsion Powertrain

SPM/DSPM
- Amy Jankovsky
- Peggy Cornell

TLs
- Andrew Woodworth
- Roger Dyson

Powertrain TC

Novel Propulsion Airframe Integration

SPM/DSPM
- Anthony Nerone
- TBD Inter-Center

TLs
- Shishir Pandya
- Jeff Flamm
- Cliff Brown
- Doug Nark
- Mark Celestina

Viscous PAI TC  
Podded Engines TC

Podded Engines TC

Ultra-Efficient Wing

SPM
- Susan Wilz

TLs
- Sally Viken
- LaTunia Melton
- Karen Taminger
- Doug Nark

TTBW, HARW, ANR Closeout

EASI TC  
EAS TC

Unconventional Structure

SPM
- TBD LaRC

TLs
- Karen Taminger
- TBD LaRC

Viscous PAI TC  
Podded Engines TC

Podded Engines TC

Ultra-Efficient Wing

SPM
- Susan Wilz

TLs
- Sally Viken
- LaTunia Melton
- Karen Taminger
- Doug Nark

TTBW, HARW, ANR Closeout

EASI TC  
EAS TC

High-Rate Structures TC
Efficient Integration of Podded Engines: Enable efficient integration of higher propulsive efficiency engine systems on next generation aircraft (2030) for a 3% fuel burn and 4 EPNdB noise reduction without operability penalties.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Notional Key Elements</th>
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</thead>
<tbody>
<tr>
<td>• Aerodynamic installation penalties for wing &amp; fuselage mounted nacelles</td>
<td>• LPR Fan/compact nacelle aero/acoustics/aeromechanics</td>
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<tr>
<td>• Operability/aeromechanics penalties of compact nacelles and installations</td>
<td>• Fan off-design performance, aeromechanics (X-wind, grnd vortex)</td>
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<tr>
<td>• PAI challenges (propulsion, aero, structures, acoustics)</td>
<td>• LPR Fan/compact nacelle acoustics and noise reduction technologies</td>
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<tr>
<td>• Inclement weather operability</td>
<td>• Propulsion Airframe Aeroacoustics</td>
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<tr>
<td>2013-16: BPR ~12 Far Term: BPR ~15-18</td>
<td>• Compact nacelle PAI</td>
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<td></td>
<td>• Variable Pitch Fans</td>
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Acoustics, operability and aeromechanics challenges have arisen for turbofans as the pursuit of higher propulsive efficiency has pushed engine configurations and installations outside of the existing experience base. Near term research will inform integration of the next generation engine with the wing and provide learning for far term configurations.
Efficient Integration of Podded Engines - Proposed Future Work

Approach

Turbofans with compact nacelles and low pressure ratio (LPR) fans are optimal for short-medium range aircraft. For this new engine design space, NASA should establish a relevant compact nacelle, LPR Fan Common Research Model to enable tech maturation/validation.

NASA can mature and demonstrate novel noise reduction tech suitable for compact nacelles. Noise models for this new design space can be updated/generated. NASA can provide ‘early learning’ for operability, aeromechanics and icing challenges associated with these engine systems. NASA can analyze and demonstrate quiet, efficient integration onto next-gen airframes with our PAI/PAA capabilities.

Key Deliverables

• Compact nacelle/LPR Fan system established performance and acoustics (new Fan CRM) enabling:
  1. Aeromechanic assessment of Fan CRM in X-wind and ground vortex
  2. Noise reduction and low loss liner demonstrated at TRL 4 on Fan CRM
  3. Noise modeling tools for design/assessment capabilities

• Installation PAI/PAA TBD
• Variable Pitch Fan eTC

Key Performance Parameters

See goal statement.

Connections to other programs/ projects

• CST needs the fan noise modeling tools

Participants:

• NASA AATT and GE Aviation: Compact nacelle/LPR Fan CRM collaboration
• NASA AATT, FAA CLEEN and GE Aviation: Fan source noise reduction collaboration.
• NASA AATT and TTT: updates to ANOPP2

Cost share partnerships planned.

| TC Outcomes |

Aero, Acoustics, Operability, Aeromechanics of Open Source, Next Generation LPR Fan / Compact Nacelle including off-design distorted flow conditions (TRL4)

Application of advanced low drag liners to compact nacelles, including non-traditional installations, for noise reduction (TRL4)

Noise models for next generation propulsors including installation effects and advanced liners (ANOPP2)

Demo of aero and acoustically optimized LPR Fan / Compact nacelle and wing integration (Underwing & MFN) (TRL 4-5)
**Boundary Layer Ingesting Tail Cone System: Assess vehicle efficiency and fuel burn benefits of tail cone thruster propulsion systems ingesting viscous boundary layers and distorted flow.**

<table>
<thead>
<tr>
<th><strong>Barriers</strong></th>
<th><strong>Key Elements</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Airframe Aerodynamic installation penalties (Drag – Form, Pressure, and Interference)</td>
<td>• Propulsion Airframe Integration – Understand effects of tightly integrating propulsors with airframe</td>
</tr>
<tr>
<td>• Propulsion Aerodynamic penalties (aeromechanics, efficiency, etc.)</td>
<td>• Distortion Tolerant Fan</td>
</tr>
<tr>
<td>• Weight (Structure and Propulsor)</td>
<td>• Computational prediction validation</td>
</tr>
<tr>
<td>• Vehicle Complexity</td>
<td>• Integration of airframe and turbomachinery computational tools</td>
</tr>
<tr>
<td>• Acoustic Penalties (Shielding)</td>
<td>• Systems analysis of vehicle benefit</td>
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<tr>
<td>• Vehicle balance and controllability</td>
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<tr>
<td>• Complexity (cost, manufacturability, maintainability, reliability)</td>
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<tr>
<td>• Current Modeling Fidelity</td>
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Pursue integrated aerodynamic-propulsion concepts that enable higher performance, increased efficiency, and reduced fuel burn for annular type BLI configurations.
## Boundary Layer Ingesting Tail Cone System - Proposed Future Work

**TC Outcomes**

<table>
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<tr>
<th>FY20</th>
<th>FY21</th>
<th>FY22</th>
<th>FY23</th>
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<th>FY25</th>
<th>FY26</th>
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<tbody>
<tr>
<td>Propulsion Airframe Integration</td>
<td>Concept Analysis/Prediction</td>
<td>Distortion Tolerant Fan</td>
<td>KDP: BLI Benefit Assessment Go/No Go</td>
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**Approach**

- Conduct propulsion-airframe testing to 1) evaluate propulsion airframe integration interactions to assess the conditions a tail cone thruster will ingest, 2) to verify validate computation predictions and 3) inform distortion tolerant fan design.
- Utilize capability developed in W8 facility to evaluate the performance and efficiency of a tail cone thruster distortion tolerant fan to validate fan modeling for accurate system level predictions.
- Integrate airframe and turbomachinery computational tools (LAVA and TURBO) using test data in order to make system level predictions to evaluate effects from the fan on the airframe, and airframe on the fan.
- Using integrated computational tools and systems analysis with sub-system level tests, determine TCT BLI vehicle benefit for a KDP to decide whether the concept is viable for further research and development.

**Key Elements:**
- Propulsion Airframe Integration
- Propulsion performance
- Computational Capability (coupled CFD and validation)

**Key Performance Parameters:**
Determine the vehicle level efficiency and fuel burn benefits for baseline future aircraft of a TCT concept.

**Connections to other programs/ projects:**
Podded Efficient Engines TC in AATT will need distortion tolerant fan technology for low pressure ratio fans and short inlets.

**Participants:**
- ARC, LaRC, GRC
- Airframe Company (proposed)
- Engine Company (proposed)
Boundary Layer Ingesting Tail Cone System - Proposed Future Work

- **Propulsion/ Airframe Integration**
  - CRM TCT Flow Thru Test (NTF)
  - Fan/Airframe Coupled Config Simulation
  - W8 TCT DTF Fan Simulation
  - Powered TCT Performance Test Simulation

- **Concept Analysis/ Prediction**
  - Flow Checkout (W8)
  - Screen Vane Flow Test (W8)
  - BLI2DTF Fan Test (W8)
  - TCT DTF Screen Vane Flow Test (W8)

- **Distortion Tolerant Fan**
  - TCT DTF Fan Test (W8)

- **BLI / DTF Integrated System**
  - KDP: BLI Benefit Assessment Go/No Go
  - Powered TCT Performance Test CDR

**Milestone**
- Level 2
- TRL 6
- TRL 5
- TRL 4
- TRL 3

**Fiscal Year**
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025
- 2026

**Integration**
- Propulsion/
- Airframe
- Integration

**Distortion**
- Tolerant
- Fan

**BLI / DTF**
- Integrated System

**PHASE 1**

**PHASE 2**
- TCT Vehicle Systems Analysis
- Powered TCT Performance Test (TDT)
Concluding Remarks

- Improving the performance of subsonic aircraft and addressing economic and environmental challenges
- Looking forward to charting next steps in subsonic transport future in partnership with ARMD, Centers, and external partners

https://www.nasa.gov/aeroresearch/programs/aavp/aatt

Mary.Wadel@nasa.gov
The End…
# AATT Technical Challenge Status & Strategy

## Current AATT Execution

<table>
<thead>
<tr>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
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<td>eTC1: Lighter Weight Lower Drag Fuselage</td>
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<td>TC2.1: Higher Aspect Ratio Optimal Wing</td>
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<td>TC3.1: Fan &amp; High-Lift Noise</td>
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<td>eTC3: Quieter Low Speed Performance</td>
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<td>TC6.1: Integrated BLI System</td>
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<td>eTC6: Unconventional Prop/Airframe Integration</td>
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<td>TC6.2: Airframe Icing</td>
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<td>eTC6: Icephobic</td>
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<td>TC4.3: Engine Icing</td>
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<td>eTC4: Icing Radar / Engine Controls</td>
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<td>eTC4: Cleaner, Compact, Higher BPR Propulsion</td>
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<td>TC7.1: Alt Fuel</td>
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<td>TC5.2: Hybrid Gas-Electric Propulsion Concept</td>
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## New Technical Challenges....

- High Rate Production
  - Aircraft Structures
- Integrated Adaptive
  - Airframe
- Efficient Integration
  - of Podded Engines
- Viscous PAI
- High Power Density Core
- Turbofan Power Extraction
- EAP Powertrain Technology

## Environmental-Crosscutting Elements

- Noise, Emissions and Icing

### Current Technical Challenge

- eTC1: Lighter Weight Lower Drag Fuselage
- TC2.1: Higher Aspect Ratio Optimal Wing
- TC3.1: Fan & High-Lift Noise
- eTC3: Quieter Low Speed Performance
- TC6.1: Integrated BLI System
- eTC6: Unconventional Prop/Airframe Integration
- TC6.2: Airframe Icing
- eTC6: Icephobic
- TC4.3: Engine Icing
- eTC4: Icing Radar / Engine Controls
- TC4.2: Compact High OPR Gas Generator
- TC4.1: Low NOx Fuel-Flex Combustor
- eTC4: Cleaner, Compact, Higher BPR Propulsion
- TC7.1: Alt Fuel
- TC5.2: Hybrid Gas-Electric Propulsion Concept

### Completed Technical Challenge

### Eliminated Technical Challenge

### Shutdown Impact
AATT Future Technical Challenges – Next & Future Generation Aircraft

- Integrated Adaptive Airframe
- High Rate Production Aircraft Structures
- High Power Density Core
- Viscous PAI
- Efficient Integration of Podded Engines
AATT Future Technical Challenges
– EAP Aircraft

High Rate Production Aircraft Structures

Viscous PAI

EAP Powertrain

Turbofan Power Extraction

High Power Density Core

Integrated Adaptive Airframe