National Aeronautics and Space Administration

Advanced Air Transport Technology (AATT)
August 2019

Mary Wadel, Project Manager (Acting)

Hamilton Fernandez, Deputy Project Manager

Scott Anders, Deputy Project Manager for Technology (Acting)

NASA Glenn Research Center

www.nasa.gov

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*

6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Innovation in Commercial Supersonic Aircraft
- Ultra-Efficient Commercial Transports
- Transition to Alternative Propulsion and Energy
- In-Time System-Wide Safety Assurance
- Assured Autonomy for Aviation Transformation

U.S. leadership for a new era of flight

Research Programs align with Strategic Thrusts

MISSION PROGRAMS

Airspace Operations & Safety

AOSP

Safe, Efficient Growth in Global Operations

Real-Time System-Wide Safety Assurance

Advanced Air Vehicles

AAVP

Ultra-Efficient Commercial Vehicles

Innovation in Commercial Supersonic Aircraft

Transition to Alternative Propulsion and Energy

Integrated Aviation Systems

IASP

Flight research-oriented, integrated, system-level R&T that supports all six thrusts

X-planes/ test environment

SEEDLING PROGRAM

Transformative Aeronautical Concepts

TACP

High-risk, leap-frog ideas that support all six thrusts

Critical cross-cutting tool development

Assured Autonomy for Aviation Transformation

Aeronautics Research Mission Directorate Programs

Advanced Air Vehicles Program

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

Integrated Aviation Systems Program

- UAS Integration in the NAS
- Flight Demonstrations and Capabilities
- Low Boom Flight Demonstrator

Airspace Operations and Safety Program

- Airspace Technology Demonstrations
- Air Traffic Management Exploration
- System-Wide Safety
- UAS Traffice Management

Transformative Aeronautics Concept Program

- Convergent Aeronautics Solutions
- Transformational Tools and Technologies
- University Innovation

http://www.aeronautics.nasa.gov/programs.htm

Advanced Air Transport Technology Project

Vision

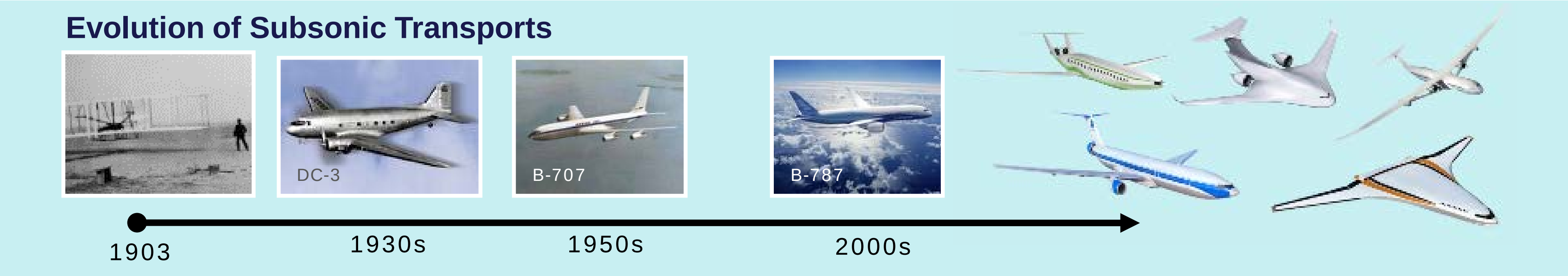
Enable Aircraft with Dramatically Improved Energy Efficiency, Environmental Compatibility, and Economic Impact for the Nation

Mission

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

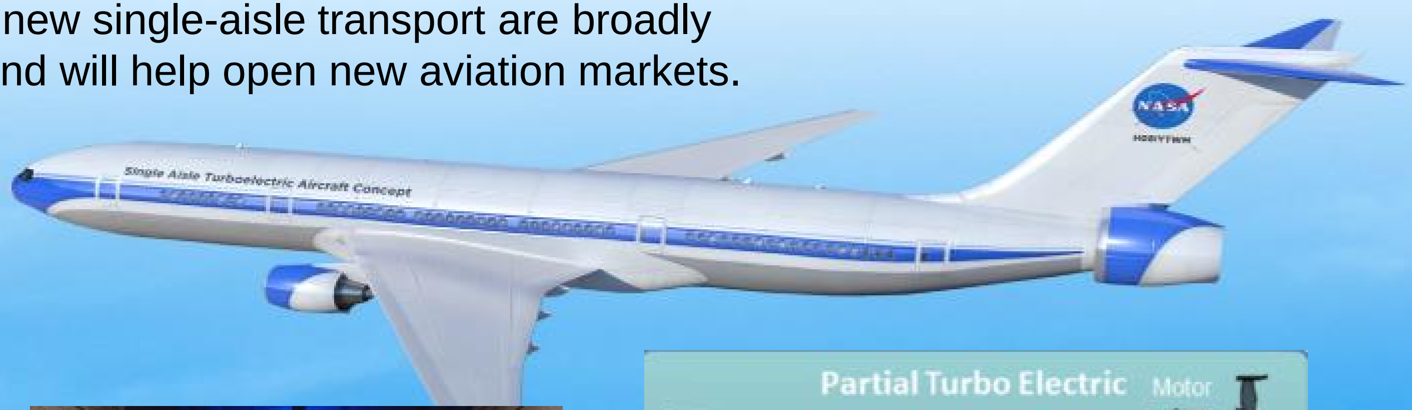
Scope

Subsonic fixed-wing commercial transport aircraft



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.

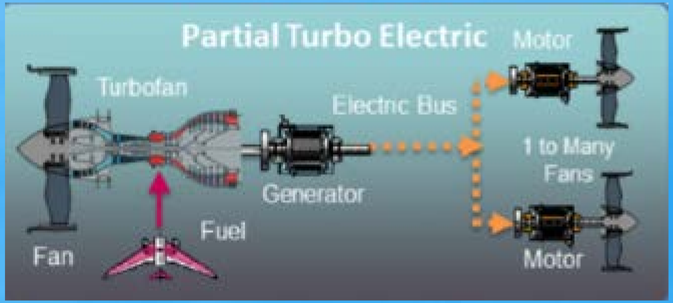


2036 Forecast

41,030
New Aircraft Deliveries

$6.1 Trillion
Market Value

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



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

A suite of technologies will be needed:

- Ultra-Efficient Wing
- Unconventional Structure
- Novel Propulsion-Airframe Integration
- Electrified Aircraft Propulsion
- Small Core Gas Turbine Engine

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

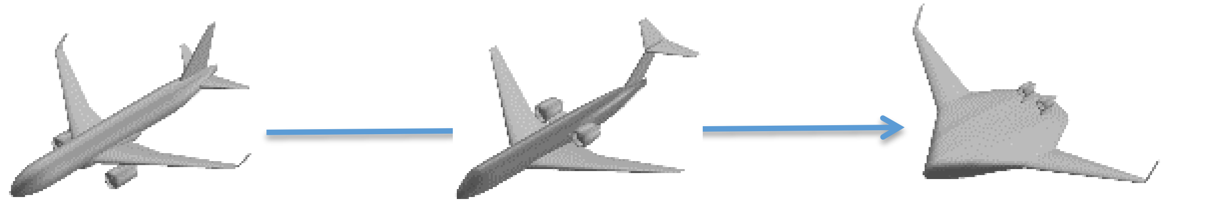
State of available technologies is not sufficient to meet U.S. industry decision criteria	NASA has made good progress in these areas but more work needed	Increased importance due to convergence of technical progress and industry pull

NASA Subsonic Transport System-Level Measures of Success

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 BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 5-6)		
	Near Term 2015-2025	**Mid Term** 2025-2035	**Far Term** beyond 2035
Noise Reduction (cum below Stage 4)	22 – 32 dB	32 – 42 dB	42 – 52 dB
LTO No_x Emissions Reduction (below CAEP 6)	70 – 75%	80%	> 80%
Cruise No_x Emissions Reduction (rel. to 2005 best in class)	65 – 70%	80%	> 80%
Fuel/Energy Consumption Reduction (rel. to 2005 best in class)	40 – 50%	50 – 60%	60 – 80%

*** Note:** Reference is best commercially available or best in class in 2005.



Evolutionary Revolutionary Transformational

AATT Project Organization FY20 and Beyond…

Acting, Project Manager
Mary Wadel

Acting, DPM for Technology
Scott Anders

Deputy Project Manager
Hamilton Fernandez

DPM for EAP Integration
TBD GRC

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*

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*

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

Small Core Gas Turbine Propulsion
SPM/DSPM
Kimlan Pham
TBD GRC
TLs
Laura Evans
Ken Suder
Mark Potapczuk
Ashlie Flegel
Engine Controls TL GRC

CGT and AAI Closeout
Power Extraction TC
Engine Core w/Icing TC

Ultra-Efficient Wing
SPM
Susan Wilz
TLs
Sally Viken
LaTunia Melton
Karen Taminger
Doug Nark

TTBW, HARW, ANR Closeout
EASI TC
ANA TC

Unconventional Structure
SPM
TBD LaRC
TLs
Karen Taminger
TBD LaRC

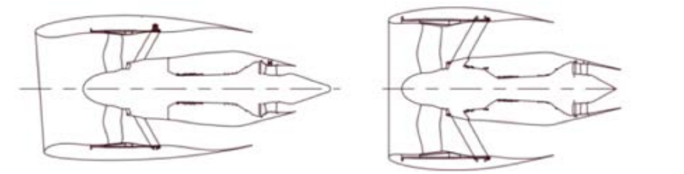
High-Rate Structures TC

Efficient Integration of Podded Engines - Proposed Future Work

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.

Barriers

- Aerodynamic installation penalties for wing & fuselage mounted nacelles
- Operability/aeromechanics penalties of compact nacelles and installations
- PAI challenges (propulsion, aero, structures, acoustics)
- Inclement weather operability

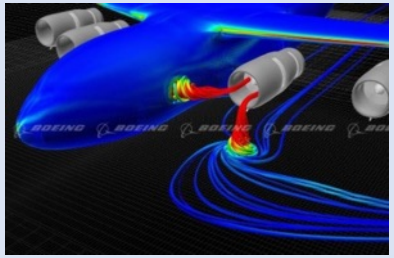


2013-16: BPR ~12   Far Term: BPR ~15-18

Notional Key Elements

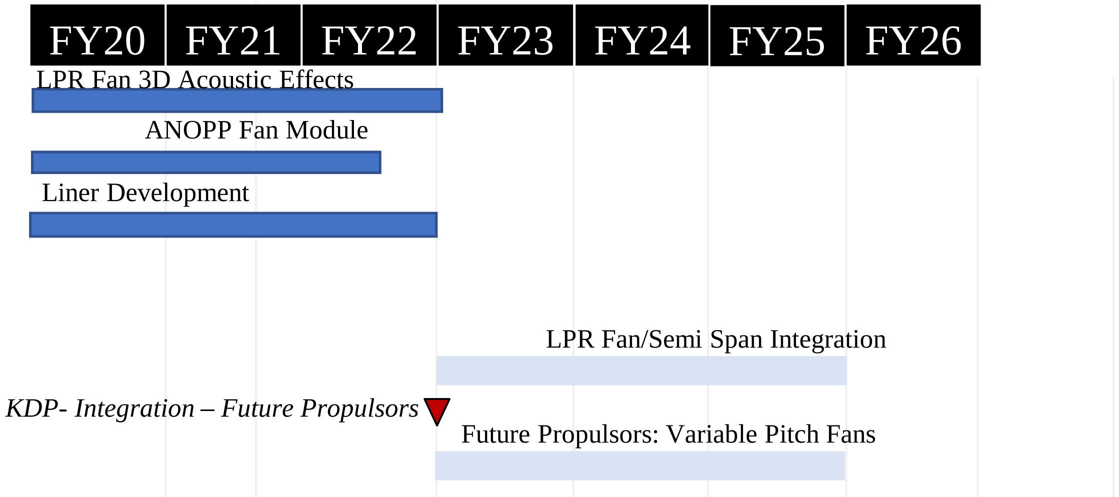
- LPR Fan/compact nacelle aero/acoustics/aeromechanics
- Fan off-design performance, aeromechanics (X-wind, grnd vortex)
- LPR Fan/compact nacelle acoustics and noise reduction technologies
- Propulsion Airframe Aeroacoustics
- Compact nacelle PAI
- Variable Pitch Fans

Near → Intermediate → Far Term



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



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)

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:

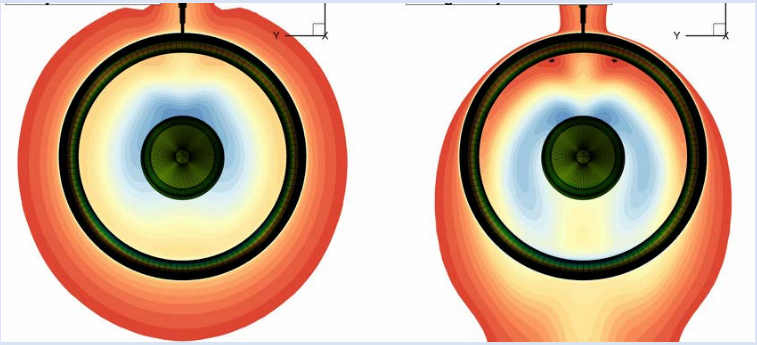
- NASA AATT and GE Aviation: Compact nacelle/LPR Fan CRM collaboration
- NASA AATT, FAA CLEEN and GE Aviation: Fan source noise reduction collaboration.
- NASA AATT and TTT: updates to ANOPP2

Cost share partnerships planned.

Boundary Layer Ingesting Tail Cone System – Proposed Future Work

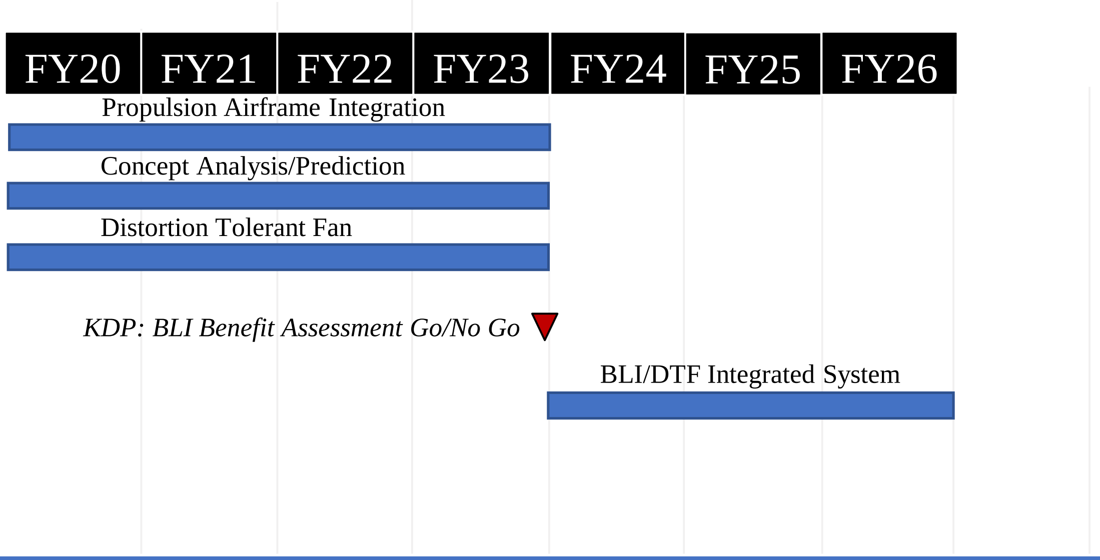
Boundary Layer Ingesting Tail Cone System: Assess vehicle efficiency and fuel burn benefits of tail cone thruster propulsion systems ingesting viscous boundary layers and distorted flow.

Barriers	Key Elements
• Airframe Aerodynamic installation penalties (Drag – Form, Pressure, and Interference) • Propulsion Aerodynamic penalties (aeromechanics, efficiency, etc.) • Weight (Structure and Propulsor) • Vehicle Complexity • Acoustic Penalties (Shielding) • Vehicle balance and controllability • Complexity (cost, manufacturability, maintainability, reliability) • Current Modeling Fidelity	• Propulsion Airframe Integration – Understand effects of tightly integrating propulsors with airframe • Distortion Tolerant Fan • Computational prediction validation • Integration of airframe and turbomachinery computational tools • Systems analysis of vehicle benefit



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

Perform a system level assessment of the STARC-ABL concept based on experimental fan efficiency values and airframe interactions from both the W8 Distortion Tolerant Fan and CRM Tail Cone Thruster Flow Thru Tests. (TRL 3)
Development and demonstration distortion tolerant fan for viscous PAI (Tail Cone Thruster) applications (TRL 3) – must include measured fan efficiency. W8 Facility will be used for fan efficiency and performance assessments leveraging recent upgrades.
Development of integrated CFD capability coupling TURBO and LAVA using validated TCT airframe data and validated TCT-based fan performance model. (TRL 3)
Develop hardware and conduct testing of both Screen Vane and annular (TCT) distortion tolerant fan in W8 using less hardware, at a reduced cost, and in a less complex facility to quantify fan performance and efficiency. (TRL 3)
Tail Cone Thruster test data and validated integrated computational modeling of Type 2 BLI (Tail Cone Thruster, STARC-ABL, STABL) (TRL 3)

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.

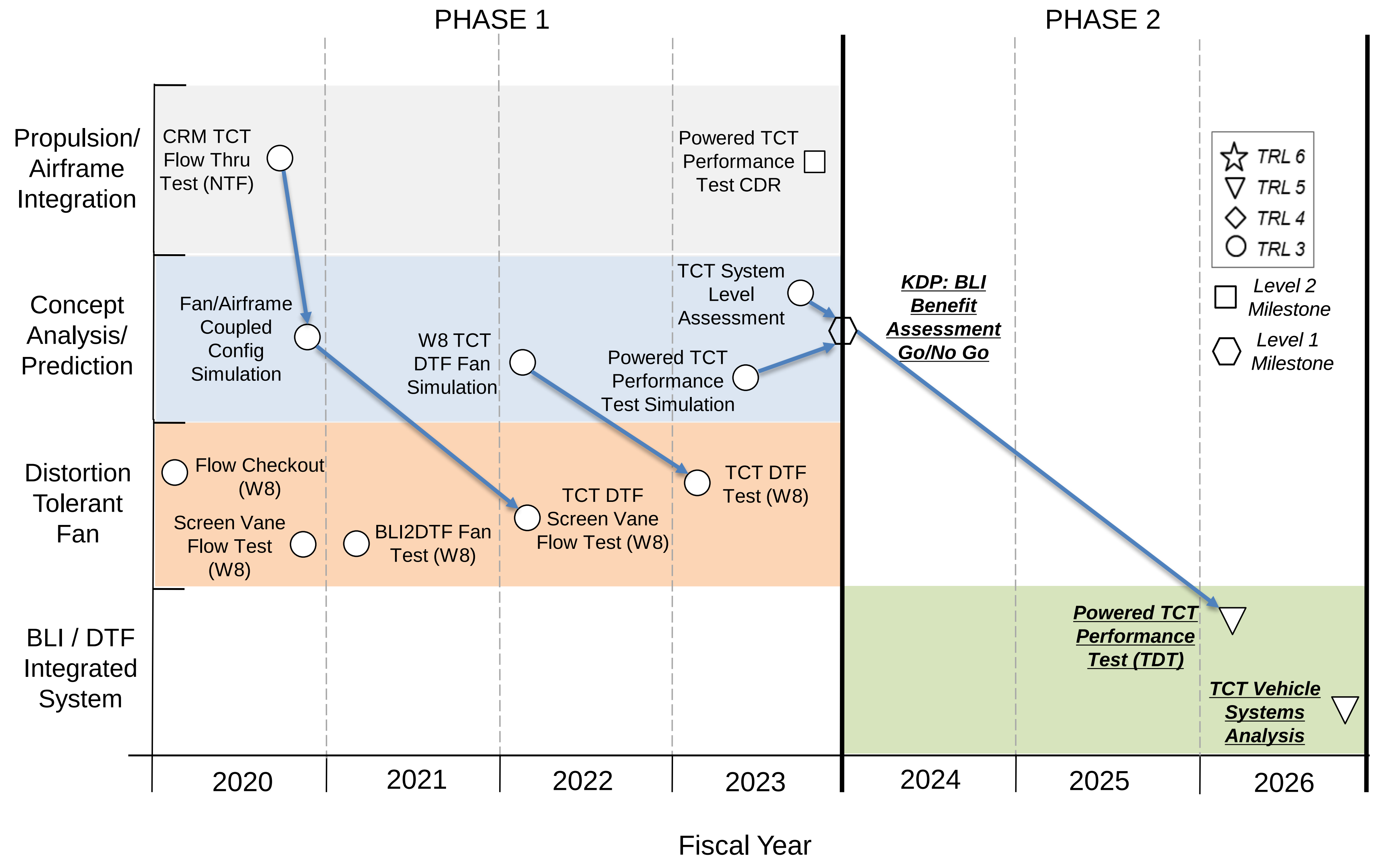
Key Elements:
- Propulsion Airframe Integration
- Propulsor performance
- Computational Capability (coupled CFD and validation)

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.

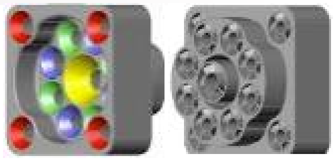
Participants:
- ARC, LaRC, GRC
- Airframe Company (proposed)
- Engine Company (proposed)

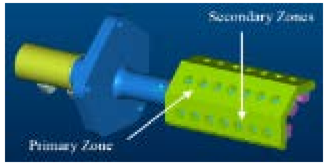
Boundary Layer Ingesting Tail Cone System - Proposed Future Work

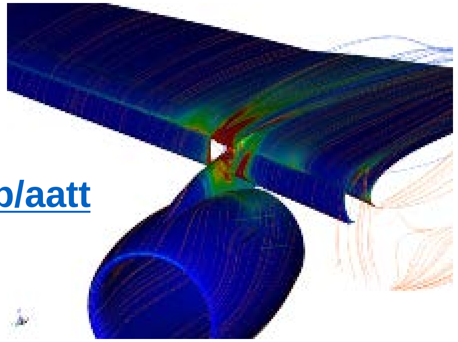


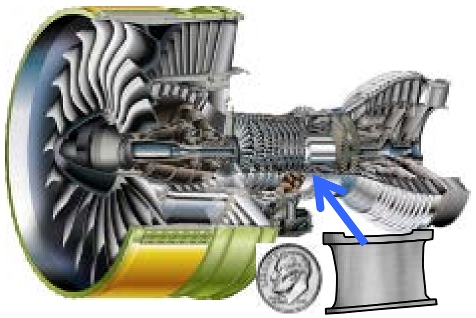
Concluding Remarks

- 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



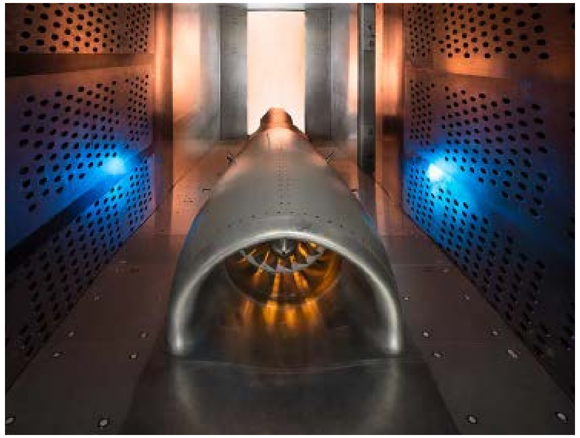






https://www.nasa.gov/aeroresearch/programs/aavp/aatt

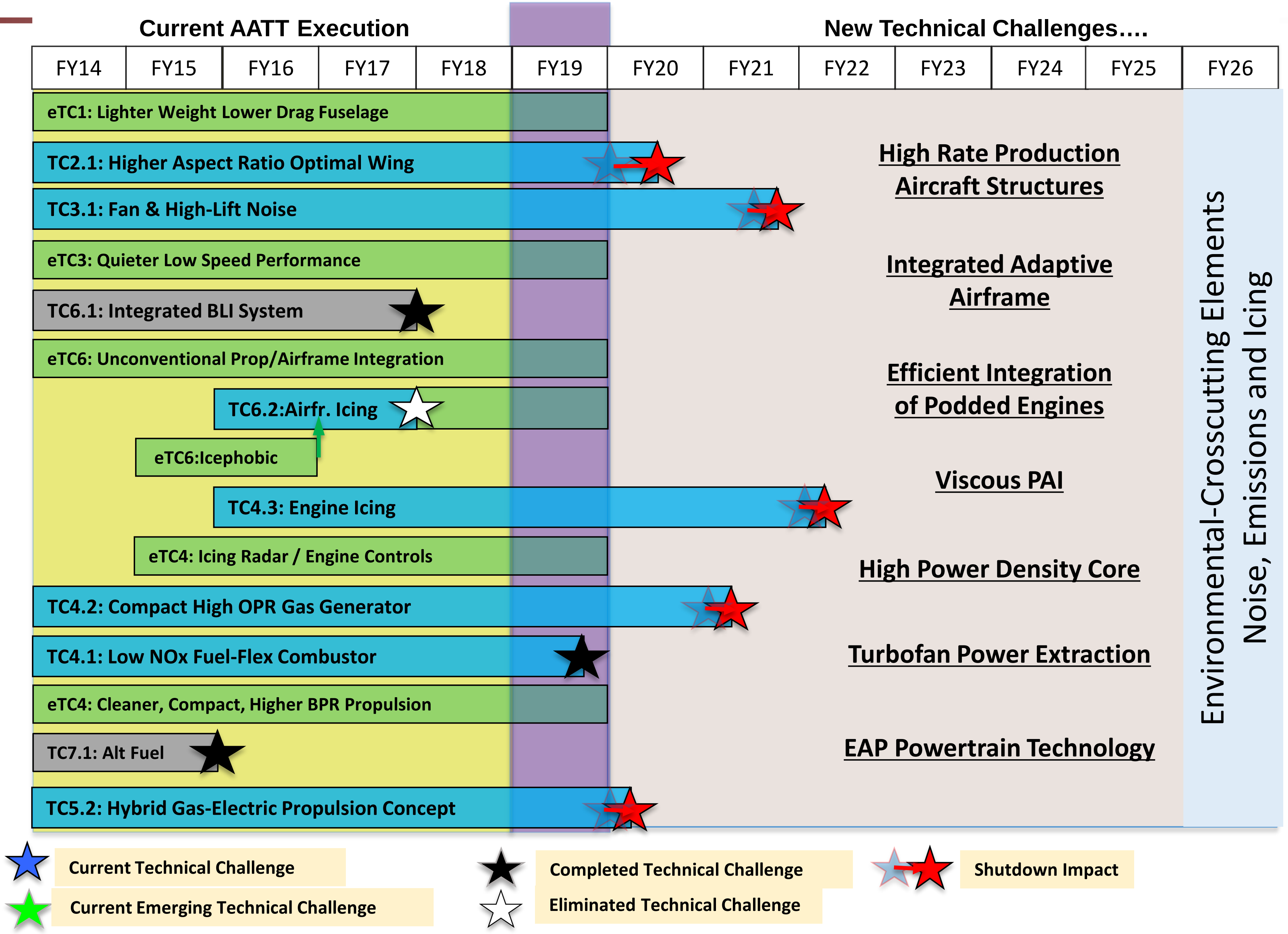
Mary.Wadel@nasa.gov

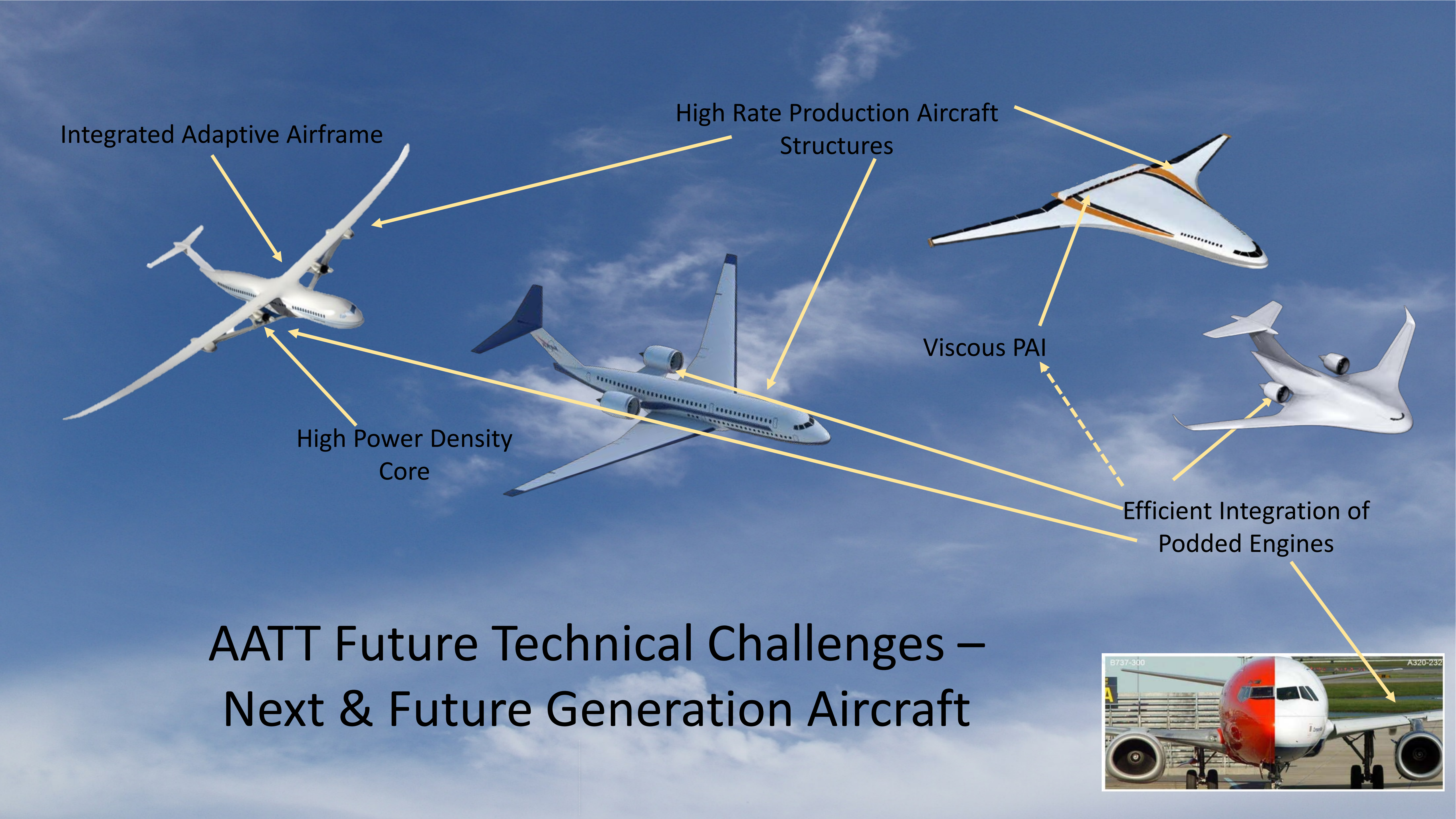


Concepts, Technologies and Knowledge

The End…

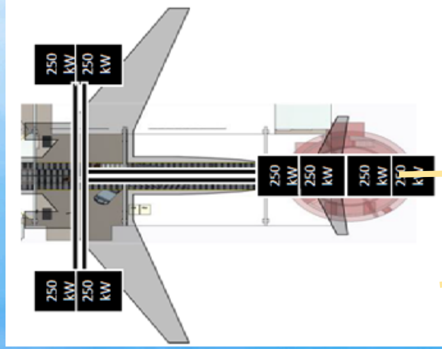
AATT Technical Challenge Status & Strategy

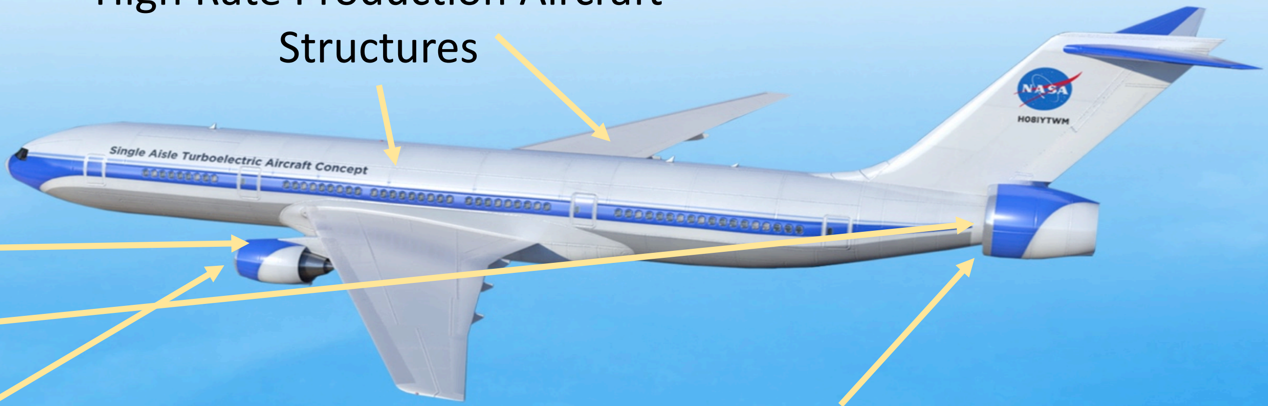



High Rate Production Aircraft Structures
Integrated Adaptive Airframe
Viscous PAI
High Power Density Core
Efficient Integration of Podded Engines
AATT Future Technical Challenges – Next & Future Generation Aircraft
B737-300
A320-232

AATT Future Technical Challenges – EAP Aircraft

High Rate Production Aircraft Structures





EAP Powertrain

Turbofan Power Extraction

Viscous PAI

High Power Density Core

Integrated Adaptive Airframe