National Aeronautics and Space Administration

NASA Aeronautics Propulsion Overview

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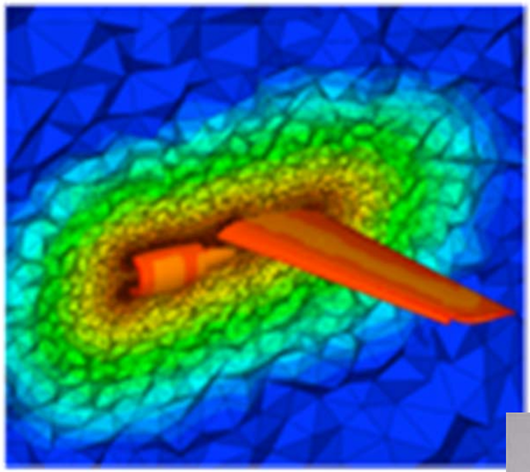
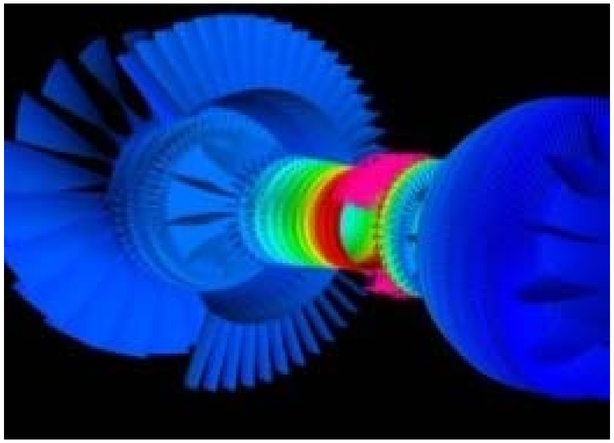
Outline

- NASA Aeronautics Overview & Goals
- Performance - Technical Highlights

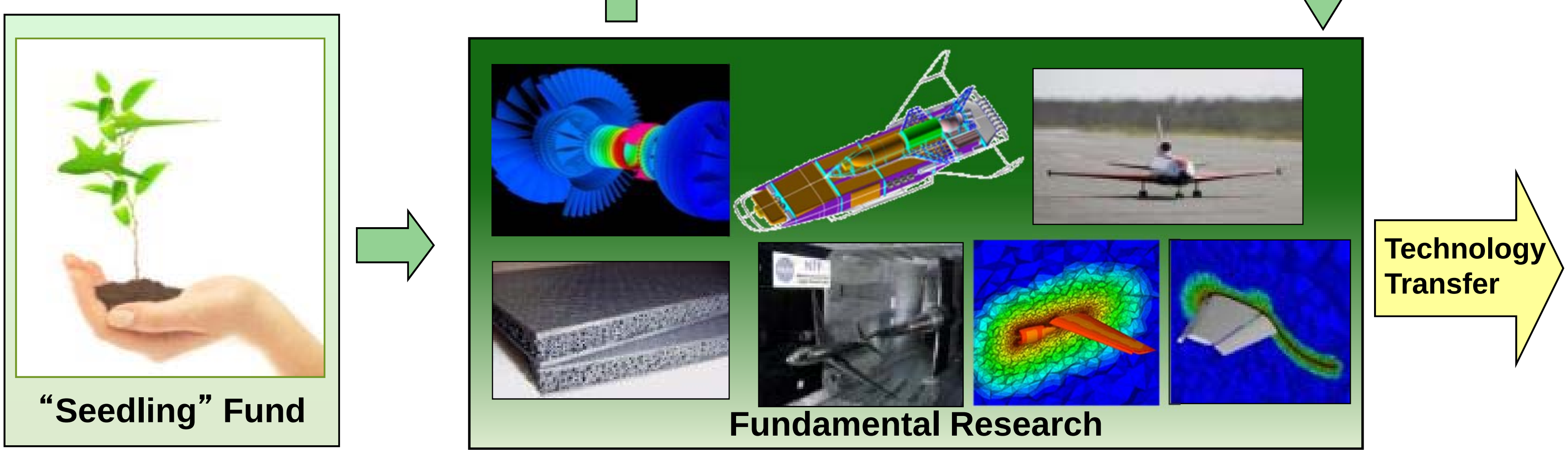




NASA Aeronautics Investment Strategy

ARMD Principles

- Valuing innovation and technical excellence
- Aligning our research to ensure a strong relevance to national needs
- Transferring technology in a timely and robust manner
- Maintaining strong partnerships with other government agencies, industry and academia
- Inspiring the next generation of engineers & researchers



Enabling "Game Changing" concepts and technologies

NASA Aeronautics Programs



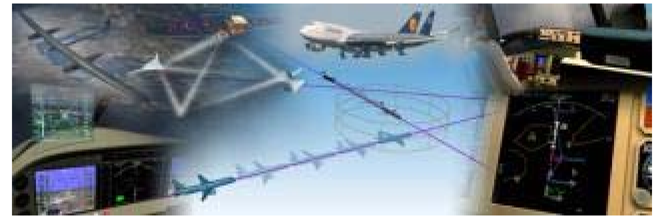

Fundamental Aeronautics Program

Conduct fundamental research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

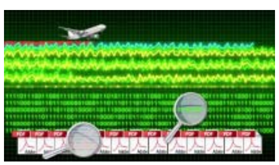
Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment





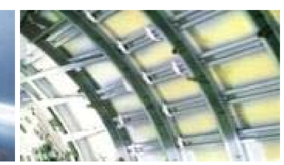
Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.



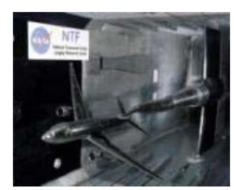

Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.


Aeronautics Test Program

Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.




Providing a Vision for Aviation

Challenges for Future Commercial Aircraft

The Need

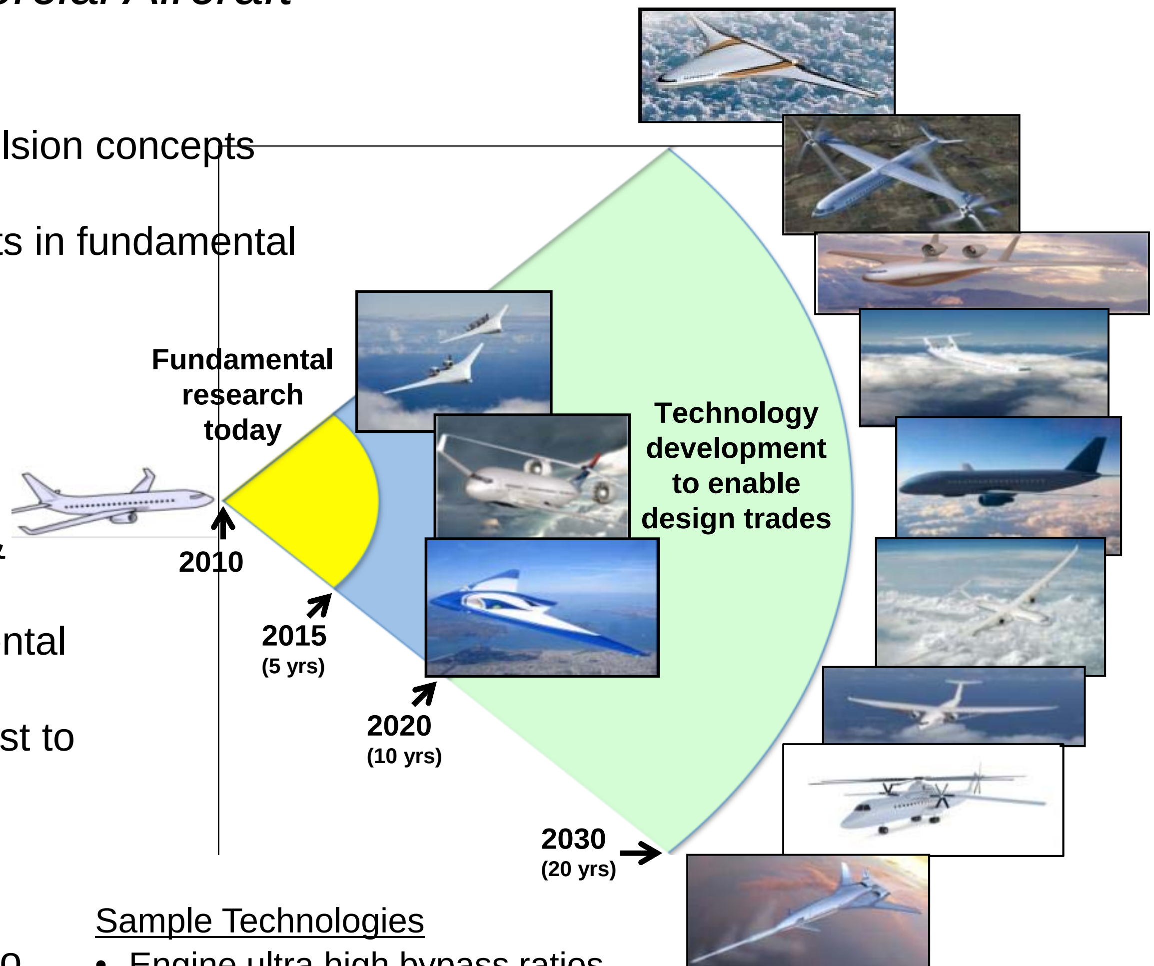
- Identify advanced airframe and propulsion concepts and enabling technologies
- Guidance for future NASA investments in fundamental research

NASA's Approach

- Stimulate thinking in industry and academia on revolutionary aircraft solutions
- Determine high-payoff technologies & research opportunities
- Address energy efficiency, environmental compatibility, and operations goals
- Fundamental Research portfolio robust to many possible futures

NASA's Contribution

- Providing vision and focus for the fundamental research needed today to enable the far term outcomes/products, but with possibility of near/mid term impact



Sample Technologies

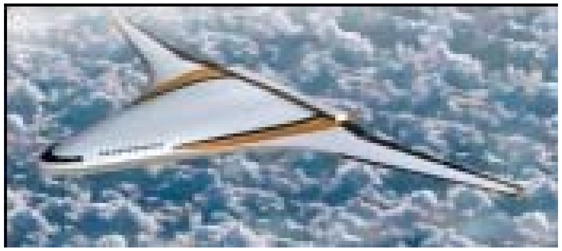
- Engine ultra high bypass ratios
- Small, high efficiency core engines
- Higher aspect ratio and laminar flow wings
- Alternative energy: conventional/biofuel/hybrid electric

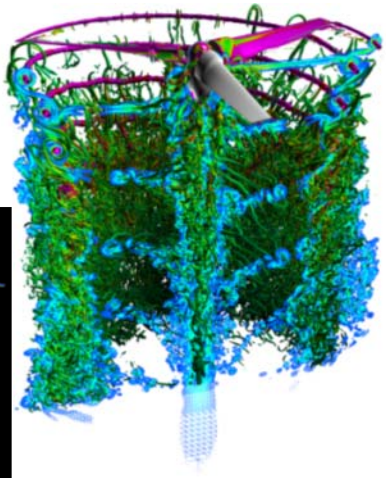
Aeronautics Strategic Guidance

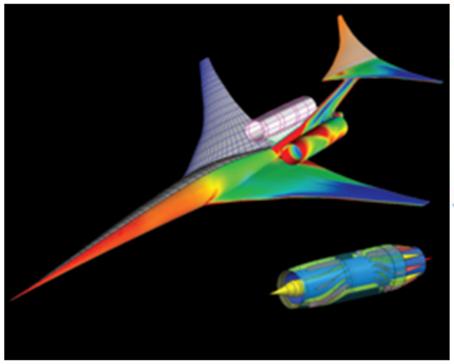
- National Aeronautics R&D Policy (Dec 2006) and Plan (Dec 2007, Feb 2010),
  - Mobility through the air is vital…
  - Aviation is vital to national security and homeland defense
  - Assuring energy availability and efficiency is central… and The environment must be protected…
- NASA Strategic Plan
  - Strategic Goal 4: Advance aeronautics research for societal benefit.
  - Strategic Outcome 4.1: Develop innovative solutions and advanced technologies through a balanced research portfolio to improve current and future air transportation.
- NextGen: The Next Generation Air Transportation System
  - Joint Planning Development Office (JPDO), Vision 100 (2003)
  - Revolutionary transformation of the airspace, the vehicles that fly in it, and their operations, safety, and environmental impact

Fundamental Aeronautics Program (FY13+)

Conduct fundamental research that will generate innovative concepts, tools, technologies and knowledge to enable revolutionary advances for a wide range of air vehicles.







Fixed Wing (FW)

Explore and develop technologies, and concepts for improved energy efficiency and environmental compatibility of fixed wing, subsonic transports.

Rotary Wing (RW)

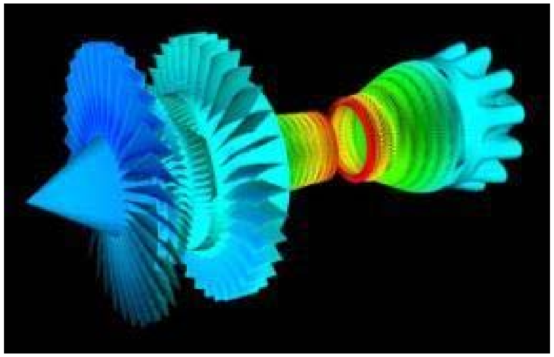
Develop and validate tools, technologies and concepts to overcome key barriers for rotary wing vehicles.

High Speed (HS)

Tool and technology development and validation to address challenges in high speed flight.

Aeronautical Sciences (AS)

Enable fast, efficient design & analysis of advanced aviation systems by developing physics-based tools and methods for cross-cutting technologies.



Aviation Safety Program

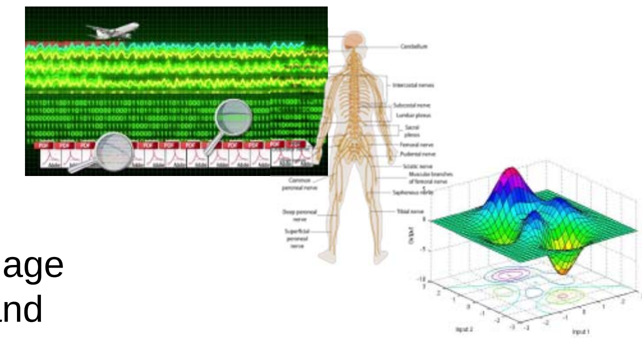
Program Goal: Proactively identify, develop, and mature tools, methods, and technologies for improving overall aircraft safety of new and legacy vehicles operating in NextGen

Projects

- *System-Wide Safety and Assurance Technologies (SSAT)*

  "Assure system-wide safety"

  – Provide knowledge, concepts, and methods to proactively manage increasing complexity in the design and operation of vehicles and the air transportation systems



- *Vehicle Systems Safety Technologies (VSST)*

  "Maintain and improve vehicle safety in key areas"

  – Identify risks and provide knowledge needed to avoid, detect, mitigate, and recover from hazardous flight conditions, and to maintain vehicle airworthiness and health

- *Atmospheric Environment Safety Technologies (AEST)*

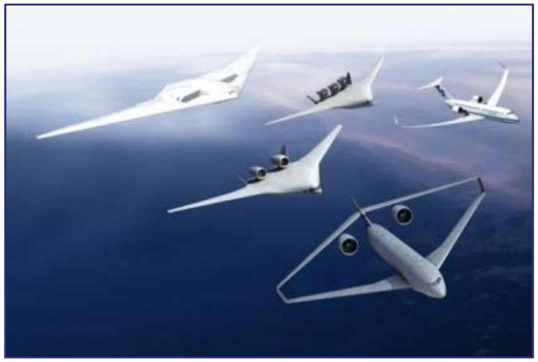
  "Deal with the presence of atmospheric risks"

  – Investigate sources of risk and provide technology needed to help ensure safe flight in and around atmospheric hazards

Integrated Systems Research Program

Program Goal:

Pursue innovative solutions to high priority aeronautical needs and accelerate implementation by the aviation community through integrated system level research on promising concepts and technologies, demonstrated in a relevant environment.

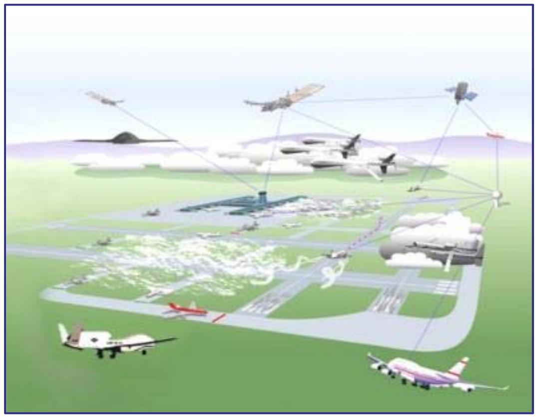


Environmentally Responsible Aviation (ERA) Project

Mature technologies and study vehicle concepts that together can simultaneously meet the NASA Subsonic Transport System Level Metrics for noise, emissions and fuel burn in the N+2 timeframe.

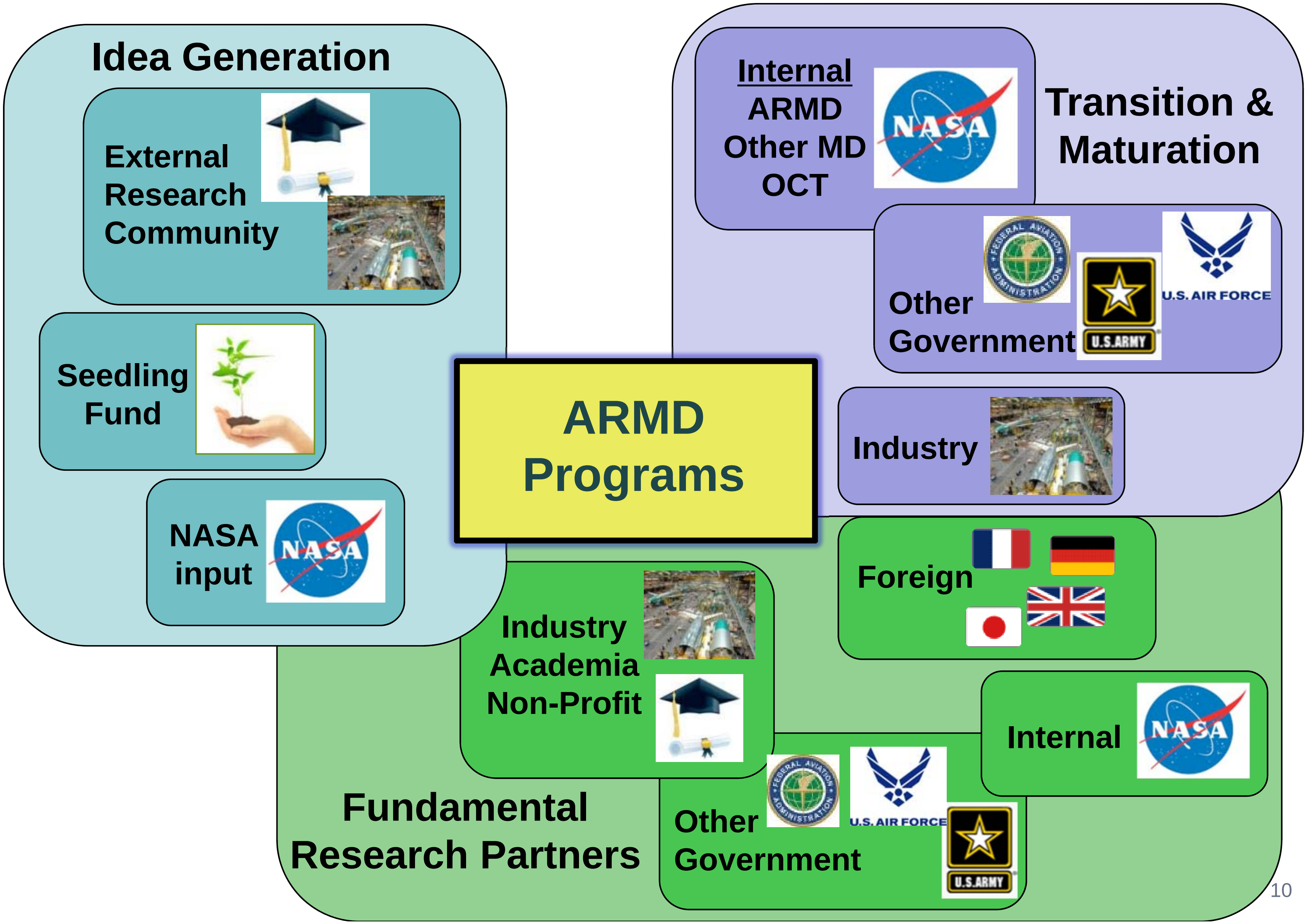
Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

Capitalizing on NASA's unique capabilities, the project will utilize integrated system level tests in a relevant environment to eliminate or reduce critical technical barriers of integrating Unmanned Aircraft Systems into the National Airspace System



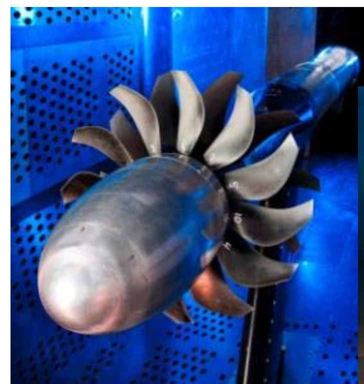
By focusing on technologies that have already proven their merit at the fundamental research level, this program helps transition them more quickly to the aviation community, as well as inform future fundamental research needs

Research Partnership Examples



ERA Phase 1 FY12 Accomplishments

- Semi-span High Speed Ultra High Bypass (UHB) Integration Powered Test at the ARC 11'x11' Transonic Wind Tunnel first entry completed in January 2012. Second entry will begin in September.
- PW Geared Turbofan Gen 2 technology test in GRC 9'x15' scheduled to begin mid-September.
- Advanced nozzle/pylon configurations testing completed at the Boeing Low Speed Acoustic Facility in December 2011.
- Pratt & Whitney low NOx, 3-sector combustor hardware was delivered to GRC in March. Testing partially complete in the GRC Advanced Subsonic Combustor Rig (ASCR); resuming in September. Testing of GE hardware to follow the P&W test.
- Gen 1 and Gen 2 Open Rotor Test Campaigns completed. Gen 2 Aero and acoustic data with GE and FAA delivered week of March 12, 2012.
- First flight of X-48C was completed on August 7, 2012.



Open Rotor Propulsion System Assessment

Problem

Open rotor propulsion systems possess the potential for dramatic reductions in fuel burn provided the new generation of blade geometries can provide an acceptable acoustic signature

Objective

Independently assess fuel burn & community noise of an open rotor system on an advanced, single-aisle (737-class) transport and compare with an ultra-high bypass (ducted) turbofan

Approach

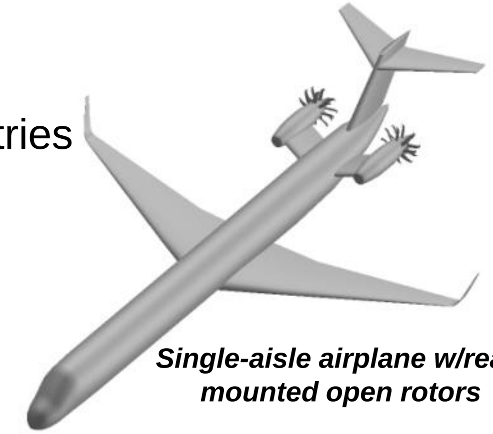
- Joint assessment effort between NASA's ERA and SFW projects, in collaboration with GE Aviation
- Experimental data from ERA-sponsored scale model tests of GE's modern open rotor blade geometry
- SFW systems analysts modeled/estimated fuel burn and noise levels, GE provided cycle data for comparison
- GE and NASA collaborated on development of a consistent open rotor acoustic prediction methodology

Results

Open Rotor system shows potential to be more fuel efficient than ducted turbofan but with less potential to reduce noise

Significance

Results provide industry and regulatory community data from which to make informed decisions on open rotor fuel efficiency and noise trade-offs



Single-aisle airplane w/rear-mounted open rotors

Open Rotor Propulsion Rig installed in GRC's 8x6 (left) and 9x15 (right) Wind Tunnels

	Adv UHB Turbofan	Adv Open Rotor
Fuel Burn re 1998 Reference Vehicle	-27%	-36%
Cumulative Noise Margin below Chapter 4	-24 dB	-13 dB

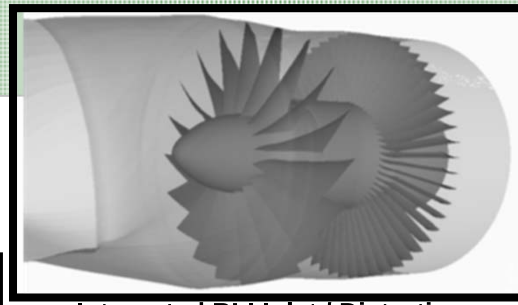
System Assessment Results - Fuel burn v. noise level

Fundamental & System-Level Research
BLI Inlet – Distortion-Tolerant Fan

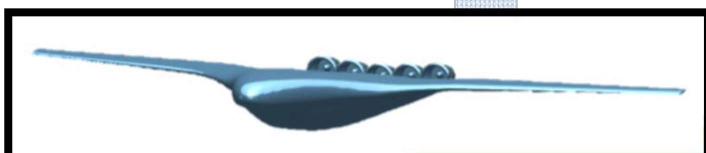
Objective: Determine feasibility and benefits of boundary layer ingesting (BLI) propulsion, and advance BLI technologies through experimental validation of a newly-designed integrated inlet, distortion-tolerant fan, and exit guide vane combination.

Significance: BLI propulsion could lead to substantial reduction in total aircraft fuel burn; Initial preparations for potential system-level research identified technology gaps and the need for additional fundamental research to increase TRL.

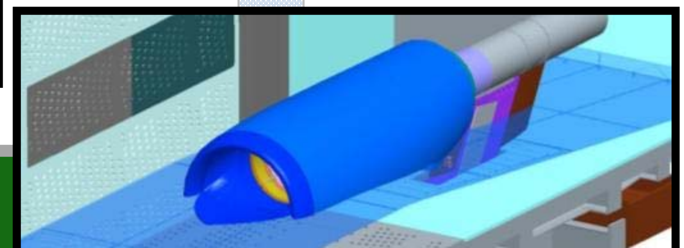
System Level Research



Integrated BLI Inlet / Distortion Tolerant Fan Design Complete FY13



Systems Study of “Clean Wing” N2A-EXTE HWB Aircraft with BLI Propulsion

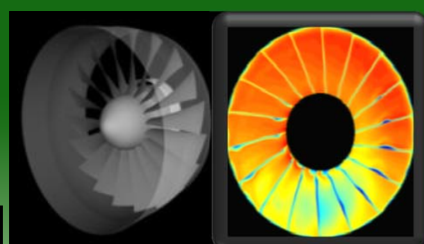


Experiment Fab Complete FY13

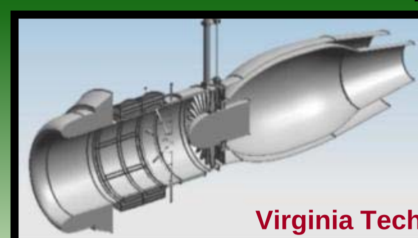
Phase I Tests Complete TRL 3, FY14

Phase II Tests FY15-16

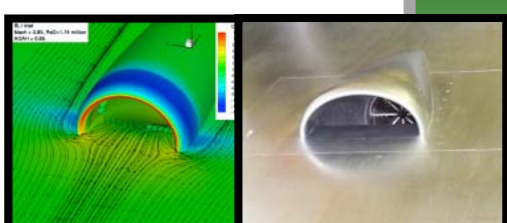
Fundamental Research



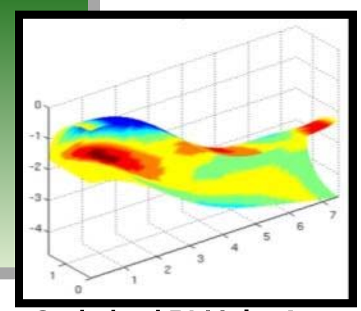
Full-Wheel G4 Pre-Baseline Distorted Inflow/Fan Analysis Complete TRL 1, FY11



Early JT15D Distortion (Screen) Impact Experiments Complete FY12



Prior NASA, industry, university and NRA Phase I studies, and inlet-only CFD/experimental research



Optimized BLI Inlet Aero Design Complete TRL 1.5, FY12

AAFEX-II Experiment Completed

CHALLENGE

Need to determine effects of synthetic alternative fuels on aircraft emissions

OBJECTIVE

Perform static aircraft engine testing using Hydrotreated Renewable Jet (HRJ) and other fuels to determine effects on engine performance and emissions. A second objective was to examine methodologies for particle sampling to assist the SAE –E-31 Aircraft Particle Measurement Subcommittee in developing a standard particle sampling technique.

AAFEX-II Test Team

APPROACH

Utilize the NASA DC-8 aircraft at the Dryden Operational Facility in Palmdale, CA to perform emissions testing using various alternative fuels and a JP-8 reference fuel and obtain gaseous, solid, and aerosol samples for analysis at 1, 30, and 150 meters downstream of the aircraft engine exhaust.

RESULTS

Over 30 hours of engine testing conducted.

Participants from NASA LaRC, DFRC, and GRC, AFRL, AEDC, MST, NAVY AESO, EPA, P&W, GE, RR, UTRC, PSU, as well as several particle instrument measurement companies.

Gaseous & particulate emissions obtained for neat HRJ, HRJ/JP-8 blend, JP-8, F-T low sulfur, & F-T high sulfur fuels. Data obtained from E-31 Particle sampling probes that will be utilized for application to particle measurement standard.

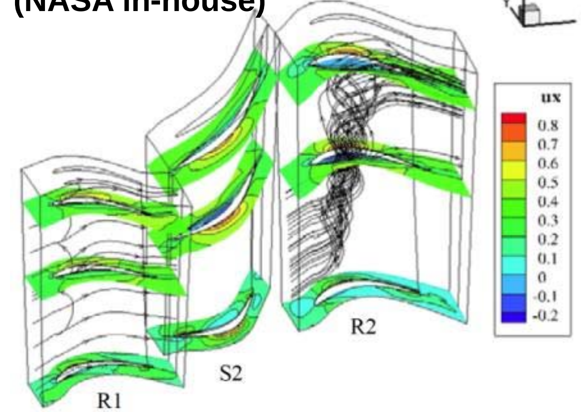
SIGNIFICANCE

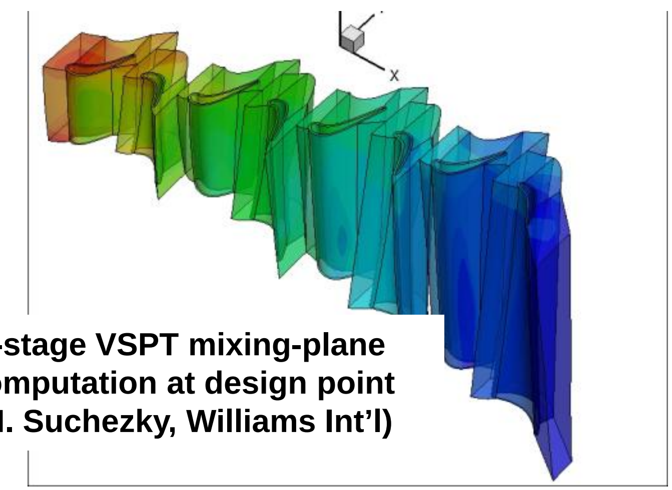
Results will be used for to determine effects of several alternative fuels and fuel sulfur on engine performance & emissions. Particle sampling methodology experiments will directly support SAE E-31 subcommittee development of a standard for particulate sampling.

Variable-Speed Power Turbine (VSPT)

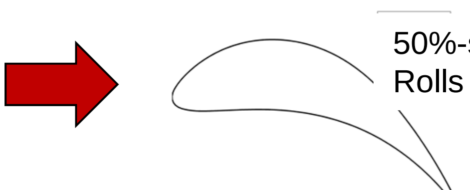
- Conceptual & 3-D blade design/analysis (in-house) completed
- Rolls-Royce and Williams Int. contracts for blade design & analysis completed
- Down-selected Walters-Leylek transition model for RANS tools
- GRC Transonic Linear Cascade Facility (CW22 test cell) selected and modified for VSPT component test; testing of incidence-tolerant blade set complete
- Rotordynamics evaluation complete
- Collaboration with Army Aviation Applied Technology Directorate (AATD); exploring applicability to FATE-class engines

Embedded 1.5-stages of VSPT at takeoff (NASA in-house)





4-stage VSPT mixing-plane computation at design point (M. Suchezky, Williams Int'l)



Incidence-tolerant blading
First entry in CW-22

Significance: New innovative concept to enable efficient, wide-range turbine operation.

Design and Assessment of Low Noise Nozzles

Challenge

Develop tools and technologies for future supersonic cruise aircraft that have acceptable noise for airport community operations

Objective

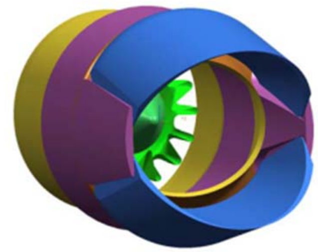
Validate acoustic performance of low noise nozzle concepts for supersonic airliners that could enter service in the 2025 timeframe (N+2 designs)

Accomplishment

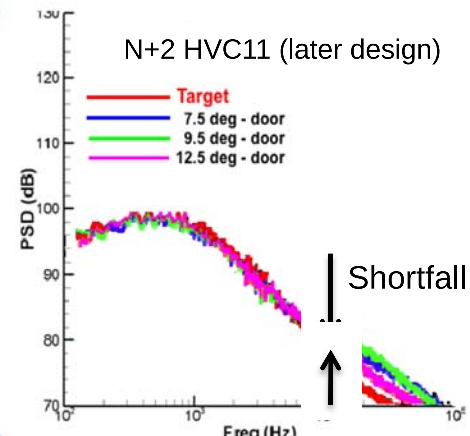
Under the N+2 Supersonic Systems Level Validation Study, contract partners GE and Rolls Royce N.A. designed noise reduction nozzles that work with advanced, 3-stream Variable Cycle Engine concepts to greatly reduce jet noise. A NASA GRC facility was modified, adding a third flow stream to an existing test rig to enable testing of the new nozzle designs. Testing measured nozzle acoustic characteristics using conventional test techniques and applied new advanced diagnostic capabilities such as phased array microphones and Particle Image Velocimetry (PIV).

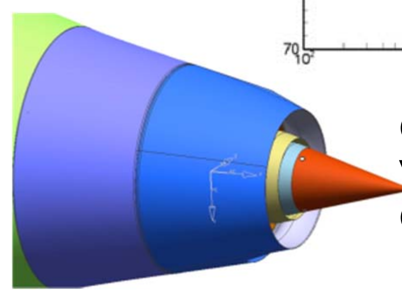
Significance

Advanced diagnostic data was used to identify internal nozzle flow characteristics that were responsible for neither concept meeting acoustic performance goals. Armed with this new knowledge, researchers are confident that further design improvement, particularly incorporating advanced CFD techniques, will result in the achieving the desired noise levels.

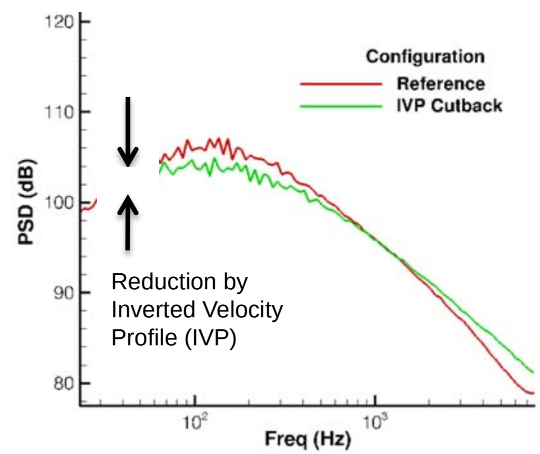


RRLW Mixer-Ejector Concept





GE Inverted Velocity Profile Concept



1st Generation Off-Nominal Engine Operation Sensing

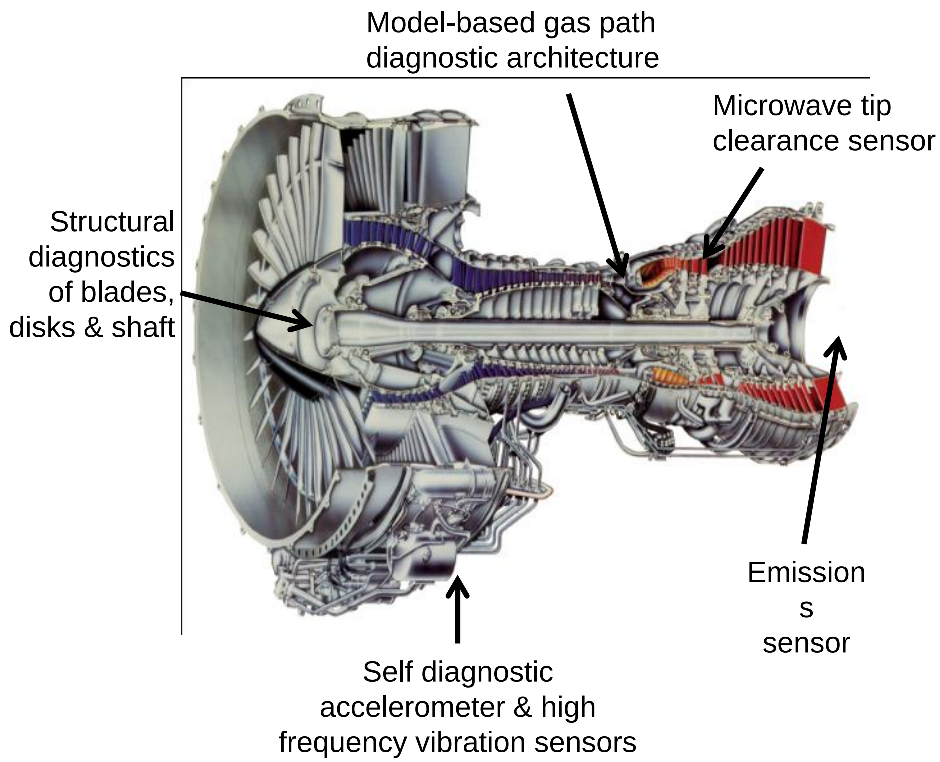
Problem
- Ability to diagnose engine faults & off-nominal operation between inspections

Objective
- Correlate engine sensors and diagnostics with engine fault conditions.

Approach
- Enhanced Engine Detection and Diagnostics enable improved understanding of engine health state & end of life degradation, with improved real-time failure prediction and prognosis.
- Vehicle Integrated Propulsion Research (VIPR) series of tests demonstrates a range of new and developing technologies and correlates their response as an engine is tested to degraded failure.
- Partners: Pratt & Whitney, USAF, FAA

Results
- In VIPR-1 test, diagnostic and sensor systems respond as desired to induced fault conditions.

Significance
- VIPR is maturing high temperature engine sensor systems that directly monitor engine reliability and anticipate potential critical failures.



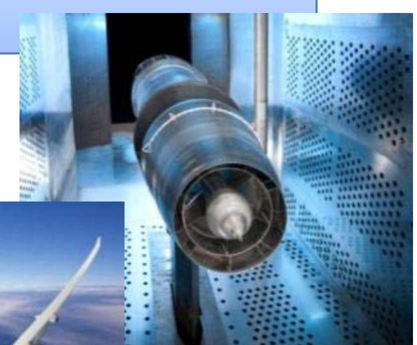
NASA Aeronautics' Priorities

Accelerate implementation and **enhance** the capabilities of NextGen

Innovate to close critical gaps in both ATM and vehicles to achieve the full potential of NextGen

Lead the country with a vision and revolutionary capabilities for the Nation's future aviation system

NASA Aeronautics is making tangible and compelling impact today in all three priorities



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Advanced Inlet Design for Supersonic Aircraft

Challenge

Develop tools and technologies for future supersonic cruise aircraft that achieve high levels of cruise efficiency while creating little or no sonic boom disturbance on the ground.

Objective

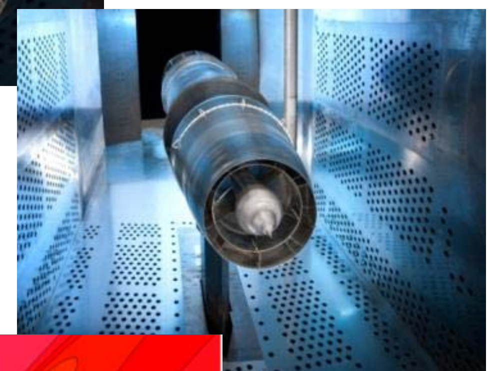
Validate effectiveness of a new technology (Micro Flow Control devices), incorporated in an advanced inlet concept, to improve performance and flow quality in low-boom supersonic inlets.

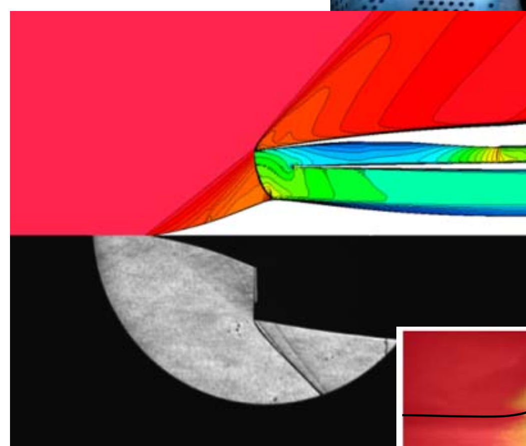
Milestone Accomplishments

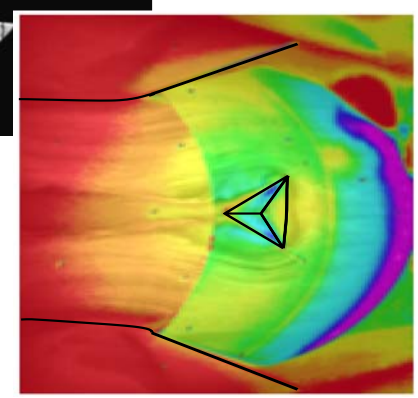
Research effectively combined the capabilities of the NASA team with NRA and collaborative partners to complete an extensive parametric design study; fabricate a complex test model and conduct an extensive and efficient test program in GRC 8x6 Wind Tunnel. Initial design effort relied extensively on the application of sophisticated CFD analysis to establish the effectiveness of the flow control devices. Wind tunnel tests provided an extensive validation database through the use of advanced imaging techniques.

Significance

New design tools and approaches for supersonic propulsion inlets developed and proven. Advanced flow control devices demonstrated to improve inlet performance and reduce complexity. These new capabilities are critical to enable future design of efficient, quiet supersonic airliners.

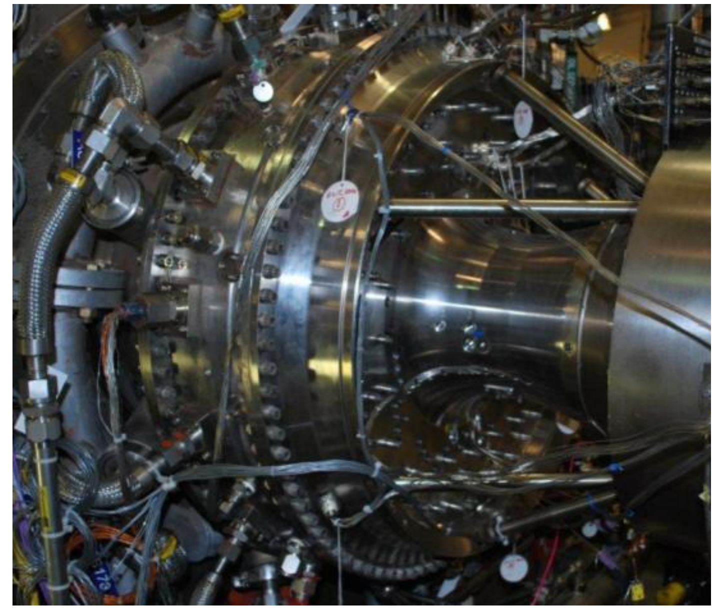


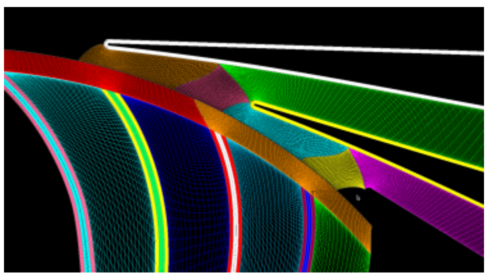


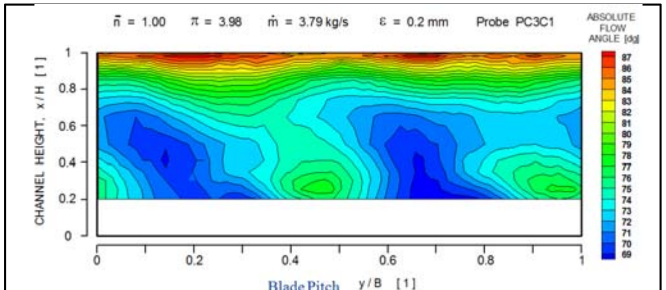


High Efficiency Centrifugal Compressor (HECC)

- Pre-test grid-generation and URANS CFD (CC3 reference compressor & HECC) completed; post-test CFD on-going
- High-response p_0-probe developed
- Completed detailed mapping of HECC compressor in CE-18. Data collected at corrected speed lines between 55% and 104%, at multiple impeller-to-shroud tip-gap settings.







Flow Angle from High-Response p_0 Probe Data

Significance: Knowledge gain will advance the SOA compressor technology to enable new lighter weight/high efficiency compressor needed to power the next generation of variable speed rotors.

(cost-shared effort with UTRC)