National Aeronautics and Space Administration

Propulsion Technologies for Future Commercial Aircraft

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Outline of Talk

- Introduction
- Future Challenges for Commercial Aviation
- NASA Aeronautics Research and Subsonic Transport Metrics
- Future Propulsion Technologies
  - NASA ERA Advance Vehicles Concepts (N+2)
  - NASA Fixed Wing Gen N+3 Advanced Vehicle Concept Studies
  - Towards Electric Propulsion
- Summary

NASA Aeronautics Programs

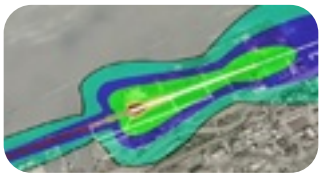


Fundamental Aeronautics Program

Conduct cutting-edge 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.

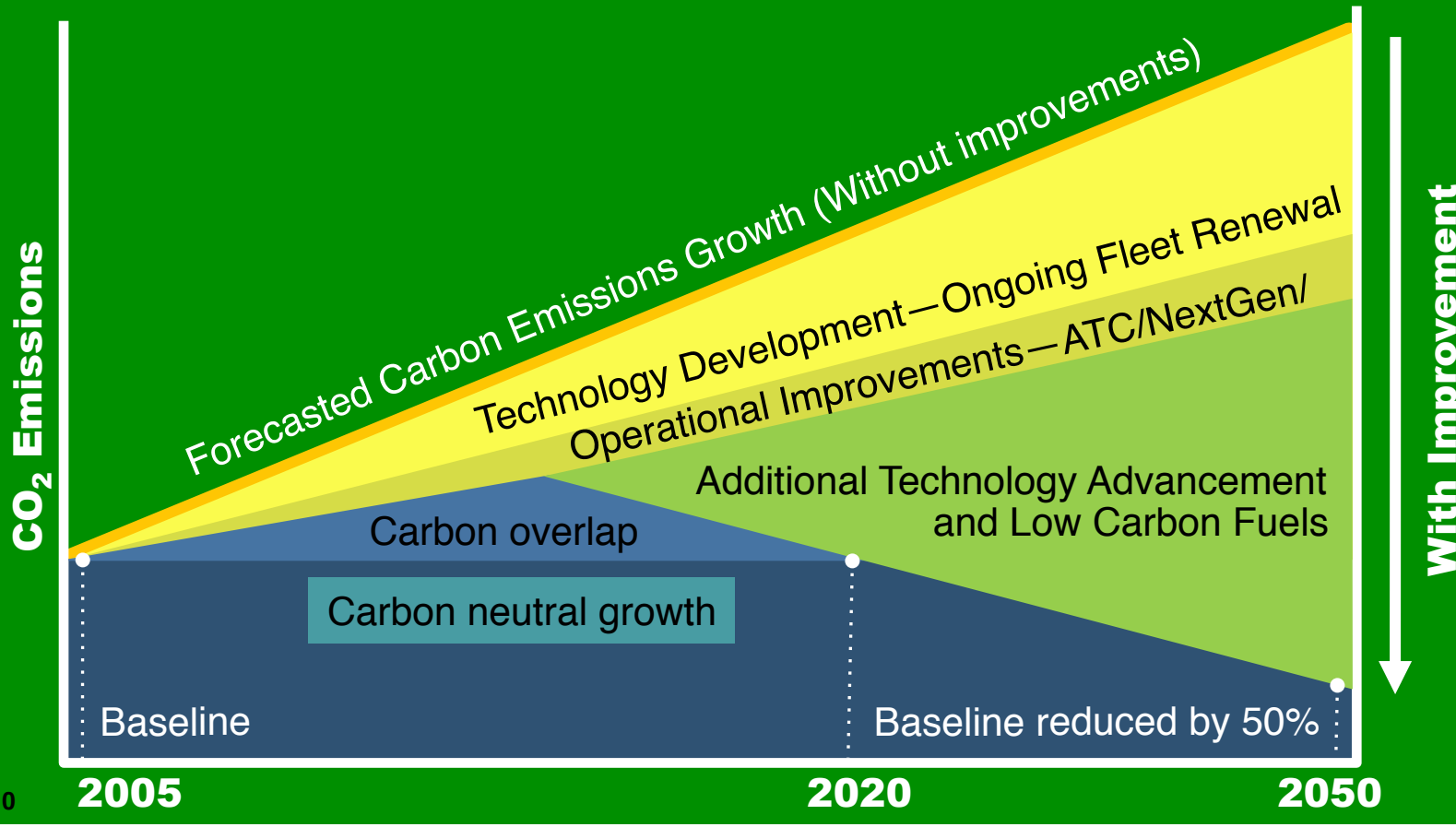



Aeronautics Test Program

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.

Major Challenges for Commercial Aviation

By 2050, substantially reduce emissions of carbon and oxides of nitrogen and contain objectionable noise within the airport boundary



Source: IATA, 2010

NASA Subsonic Transport System Level Metrics

Strategic Thrusts

1. Energy Efficiency

2. Environmental Compatibility

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-71 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines, N+2 values are referenced to a 777-200 with GE90 engines

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

‡ CO_2 emission benefits dependent on life-cycle CO_{2e} per MJ for fuel and/or energy source used

Research addressing revolutionary future goals with opportunities for near term impact

Fundamental Aeronautics Program
Integrated Systems Research Program

Fixed Wing Project

The Fixed Wing Project conducts research to improve prediction methods and technologies that will produce lower noise, lower emissions, and higher performing subsonic aircraft for the Next Generation Air Transportation System.

Environmentally Responsible Aircraft

The Integrated Systems Research Program (ISRP) focuses on maturing and integrating NextGen technologies into major vehicle/operational systems and subsystems that will address these national challenges.

Integrated Systems Research Program Overview

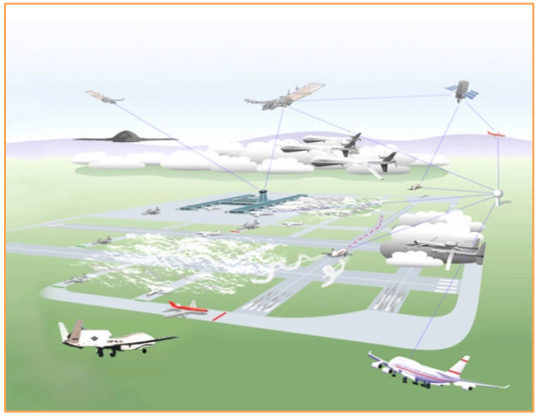
Program Goal:
Pursue innovative solutions to high priority aeronautical needs and accelerate implementation by the aviation community through integrated system level research on promising concepts and technologies, demonstrated in a relevant environment.

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

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Traceability from National R&D Plan to ERA Project Technical Challenges

National R&D Plan

Energy and Environment	Enhance Mobility	National Security

Lead development of vehicle concepts that enable simultaneous reduction of fuel burn, noise and emissions

-75% LTO & -70% Cruise NOx Emissions below CAEP6	-42dB below Stage 4 Community Noise	-50% Aircraft Fuel/ Energy Consumption

Technical Focus Areas

Accelerate technology maturation through integrated system research

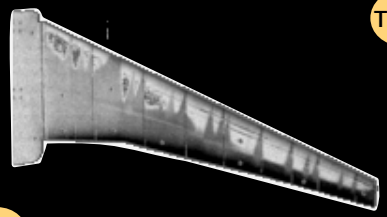
Innovative Flow Control Concepts for Drag Reduction	Advanced Composites for Weight Reduction	Advanced UHB Engines for SFC & Noise Reduction	Advanced Combustors for LTO Oxides of Ni reductions	Airframe & Engine Integration for Community Noise Reduction

ERA Phase 1 Investigations

ERA Phase I Investigations

Reduce Mission Fuel Burn and Community Noise

TFA1 DRAG REDUCTION - Via Laminar Flow

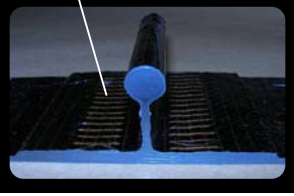


TFA3 SFC/NOISE REDUCTION

Advanced Cores and Development of Integration of Advanced UHB Engines

TFA2 WEIGHT REDUCTION

PRSEUS – Pultruded Rod Stitched Efficient Unitized Structure



ERA Phase I Investigations

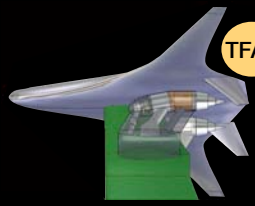
Reduce Mission Fuel Burn and Community Noise

TFA5 AIRFRAME NOISE

High-lift Systems and Landing Gear

TFA5 PROPULSION NOISE

Fan, Core and Jet Noise



TFA5 PROPULSION AIRFRAME AEROACUSTICS

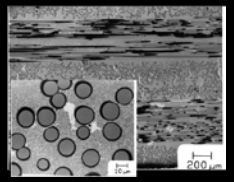
Airframe/Propulsion Interaction & Shielding

ERA Phase I Investigations

Reduce LTO and Cruise NOX

TFA4 CMC COMBUSTOR LINER

For higher engine temps



SIC CMC Concepts

CMC combustor liner

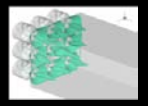
TFA4 INSTABILITY CONTROL

Suppress combustor instabilities

High Temperature SiC electronics circuits and dynamic pressure sensors

Fuel Modulation for high frequency fuel delivery systems

TFA4 LOW NOX, FUEL FLEXIBLE DESIGN/TEST



Innovative Injector Concept

ASCR Combustion Rig

Environmentally Responsible Aviation
Advanced Vehicle Concepts

- Task 1 - Define / Development Future Scenario
- Task 2 - Develop a conceptual design of a 2025 EIS subsonic transport – passenger and/or cargo
- Task 3 - Develop associated tech maturation plans
- Task 4 - FY 2013 – 2015 Critical Technology Demonstrations
- Task 5 - Conceptual Design of a Subscale Testbed Vehicle

The NASA Fixed Wing Project

Explore and Develop Tools, Technologies, and Concepts for Improved Energy Efficiency and Environmental Compatibility for Sustained Growth of Commercial Aviation

Objectives

- Prediction and analysis tools for reduced uncertainty
- Concepts and technologies for dramatic improvements in noise, emissions and performance

Relevance

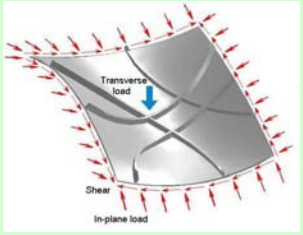
- Address daunting energy and environmental challenges for aviation
- Enable growth in mobility/aviation/transportation
- Subsonic air transportation vital to our economy and quality of life

Evolution of Subsonic Transports

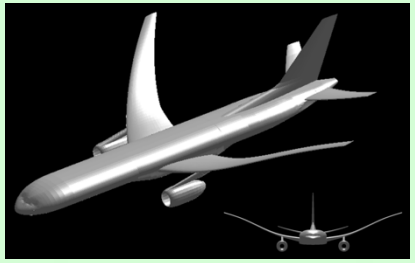
Fixed Wing Project Research Themes

based on Goal-Driven Advanced Concept Studies

Goals *Metrics (N+3)*	*Noise* *Stage 4 – 71 dB cum*	*Emissions (LTO)* *CAEP6 – 80%*	*Emissions (cruise)* *2005 best – 80%*	*Energy Consumption* *2005 best – 60%*
Goal-Driven Advanced Concepts *(N+3)*				 

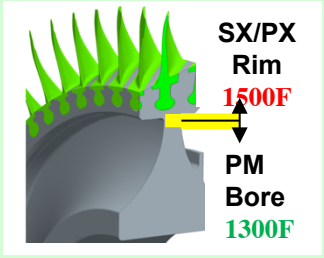


Lighter-weight Lower Drag Fuselage

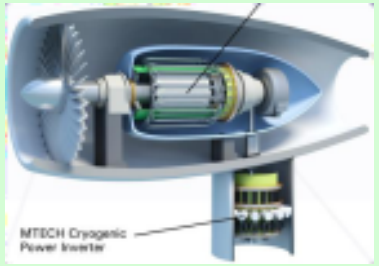


Higher Aspect Ratio Optimal Wing

Quieter Low-Speed Performance

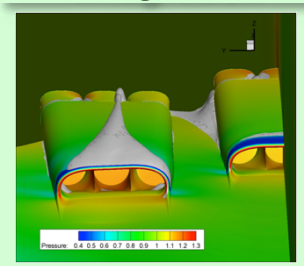


Cleaner, Compact Higher BPR Propulsion

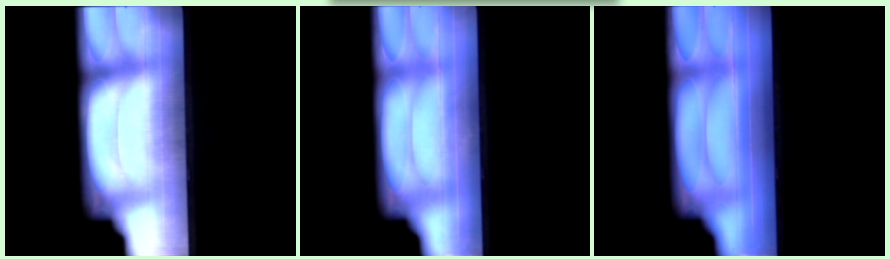


Hybrid Gas-Electric Propulsion

Unconventional Propulsion Airframe Integration



Alternative Fuel Emissions



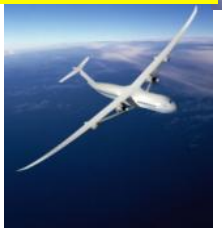
Systems Analysis and Integration

Research Themes

Gen N+3 Propulsion Technologies

NASA Gen N+3 Advanced Vehicle Concept Studies
Summary

Boeing, GE, GA Tech



Advanced concept studies for commercial subsonic transport aircraft for 2030-35 EIS

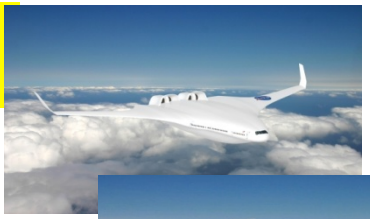
NG, RR, Tufts, Sensis, Spirit

Trends:

- Tailored/Multifunctional Structures
- High AR/Active Structural Control
- **Highly Integrated Propulsion Systems**
- **Ultra-high BPR (20+ w/ small cores)**
- **Alternative fuels and emerging hybrid electric concepts**
- Noise reduction by component, configuration, and operations improvements

GE, Cessna, GA Tech

MIT, Aurora, P&W, Aerodyne



NASA, VA Tech, GT

NASA

Advances required on multiple fronts…

Northrop Grumman/Rolls Royce SELECT

Three-Shaft Turbofan
- High BPR (~18) = propulsive efficiency
- High OPR (~50) = thermal efficiency
- Low noise
- Low weight

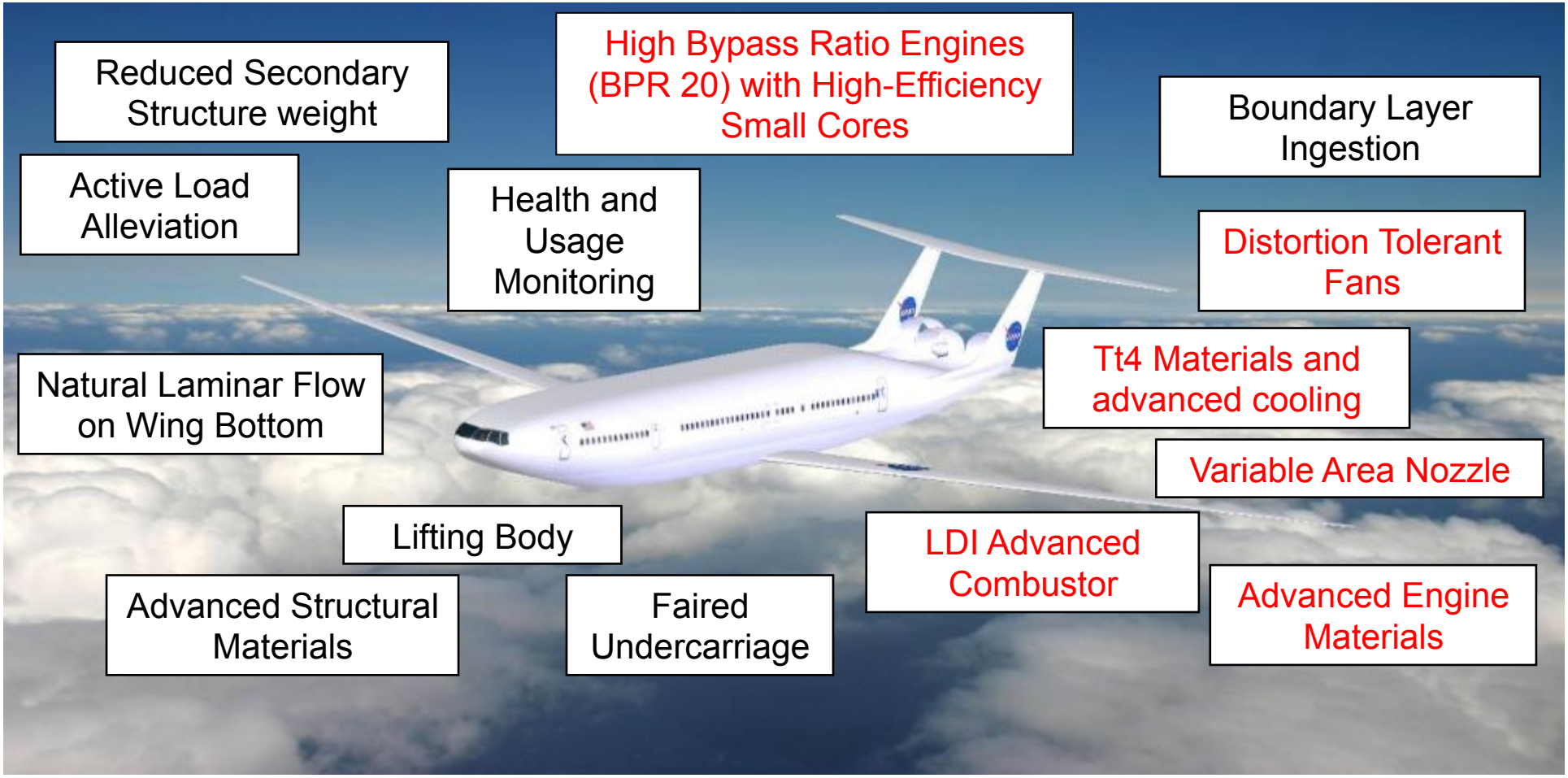
Technology Suite
Three-shaft Turbofan Engine
Ultra-High Bypass Ratio of ~18
CMC Turbine Blades
Lean-Burn CMC Combustor
Intercooled Compressor Stages
Swept Fan Outlet Guide Vanes
Fan Blade Sweep Design
Lightweight Fan/Fan Cowl
Compressor Flow Control
Active Compressor Clearance Control
Variable Geometry Nozzles

- Open rotor had best sea level static fuel consumption
- Open rotor potential noise not quantified in time to be included

NASA-CR-2010-216798

MIT/Pratt & Whitney D Series

Novel configuration plus suite of airframe and propulsion technologies, and operations modifications



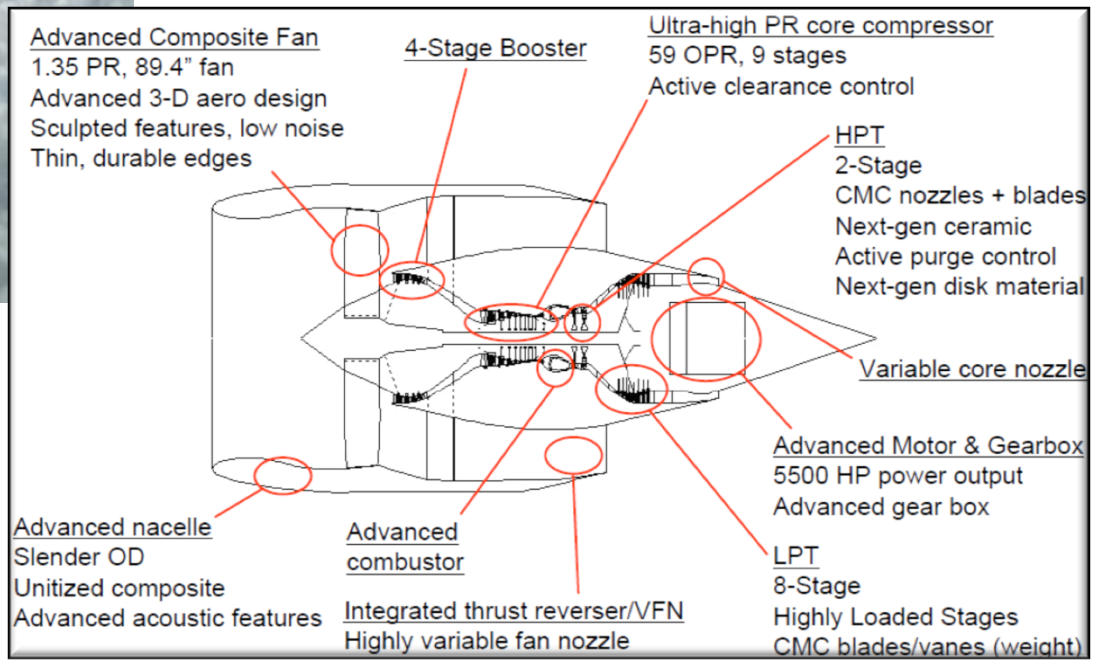
NASA-CR-2010-216794 Vol. 1 & 2

Massachusetts Institute of Technology · Aurora Flight Sciences · Pratt & Whitney, A United Technologies Company

Boeing/General Electric SUGAR "Volt"

Subsonic Ultra Green Aircraft Research (SUGAR)

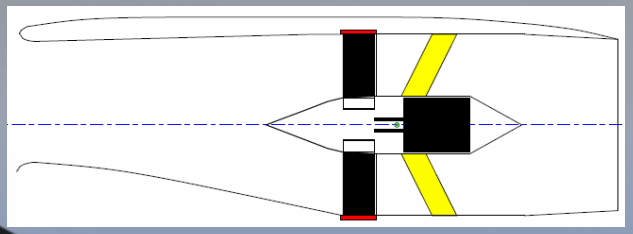
High Aspect Ratio Truss Braced Wing
Hybrid Electric (Batteries) Propulsion Systems



NASA-CR-2011-216847

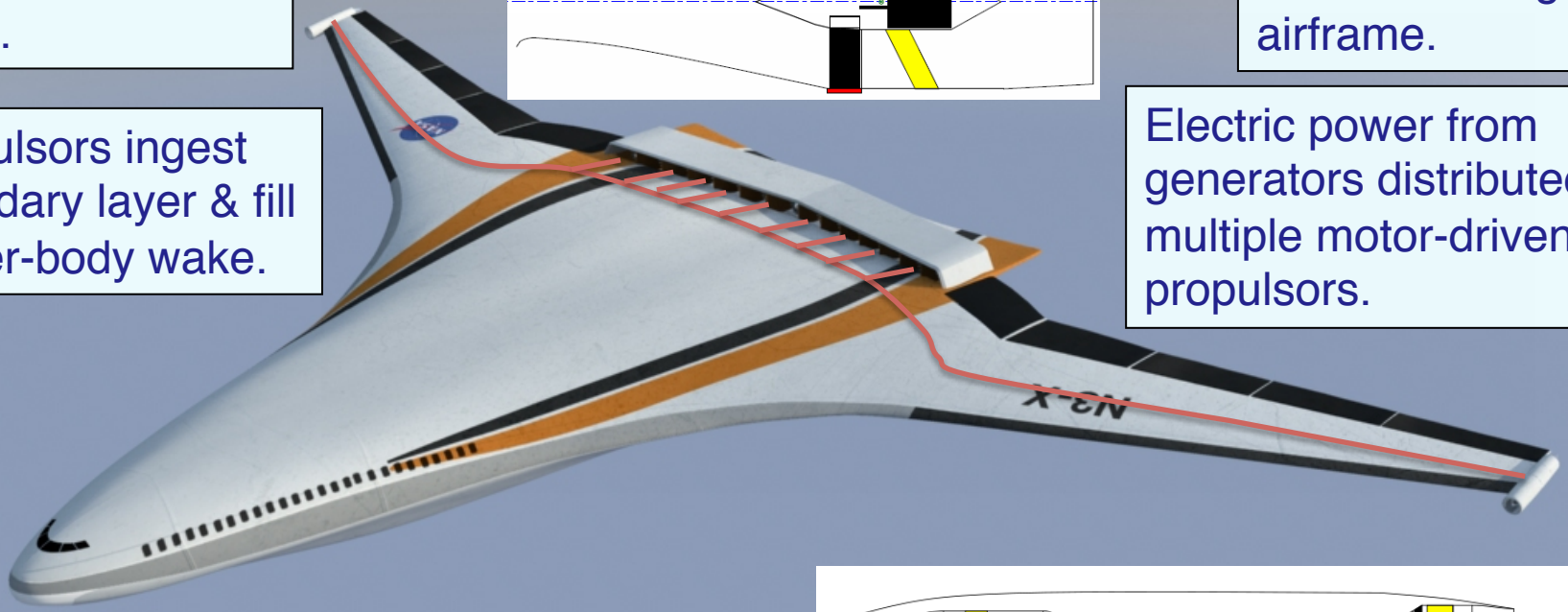
NASA Turboelectric Distributed Propulsion

Low velocity core exhaust reduces noise.

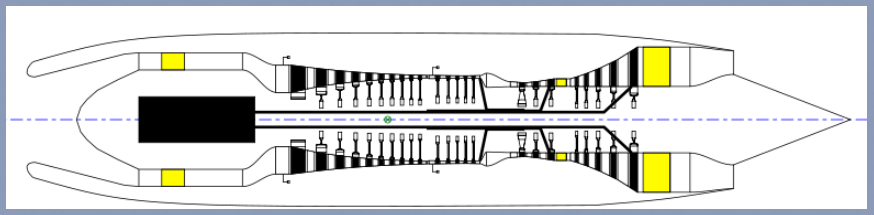


Forward and aft fan noise shielding by airframe.

Propulsors ingest boundary layer & fill center-body wake.



Electric power from generators distributed to multiple motor-driven propulsors.

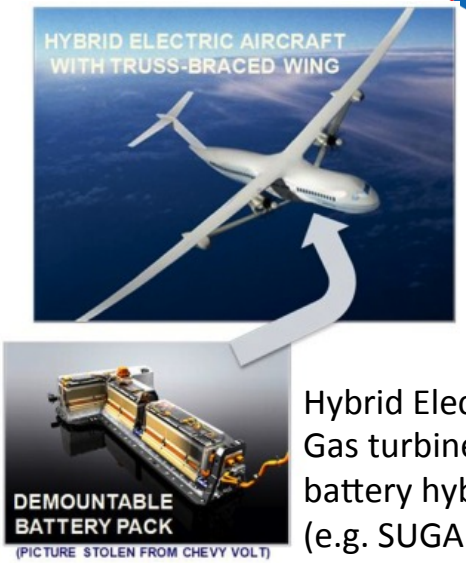


Many small fans give a large total fan area and very high effective bypass ratio

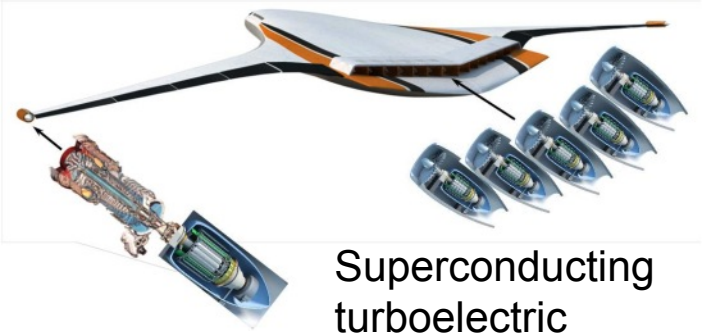
Large efficient engines with freestream inlets drive superconducting generators.

Toward Large Electric Aircraft Propulsion

- Hybrid-electric and turboelectric aircraft offer cleaner skies and fuel savings
- Hybrid electrics use battery power for short-range cruise, fuel and turbine engine for long-range
- Battery-powered cruise emits little or no CO_2 and water vapor on short flights (Boeing SUGAR Volt study)
- Turboelectric distributed propulsion offers up to 20% fuel savings on Blended Wing Body aircraft
- Distributed and/or more-electric propulsion critical to meeting NASA N+3 fuel burn, noise, and emissions metrics



Hybrid Electric Gas turbine – battery hybrid (e.g. SUGAR Volt)



Superconducting turboelectric distributed propulsion

Summary

- NASA's ARMD research Portfolio includes System Level technologies targeted at the N+2 timeframe and Fundamental Research targeted at the N+3 timeframe.

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FAP/Fixed Wing

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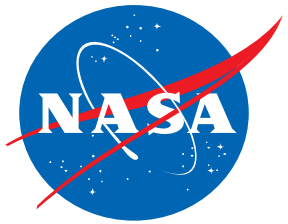
ERA Technical Focus Areas:

- **Innovative Flow Control Concepts for Drag reduction**
- **Advanced Composites for Weight reduction**
- **Advanced UHB Engine Designs for Specific Fuel Consumption and Noise reduction**
- **Advanced Combustor Designs for Oxides of Nitrogen Reduction**
- **Airframe and Engine Integration Concepts for Community Noise and Fuel Burn Reduction**


NASA