National Aeronautics and Space Administration

Overview of NASA's Environmentally Responsible Aviation (ERA) Project

A NASA Aeronautics Project focused on midterm environmental goals

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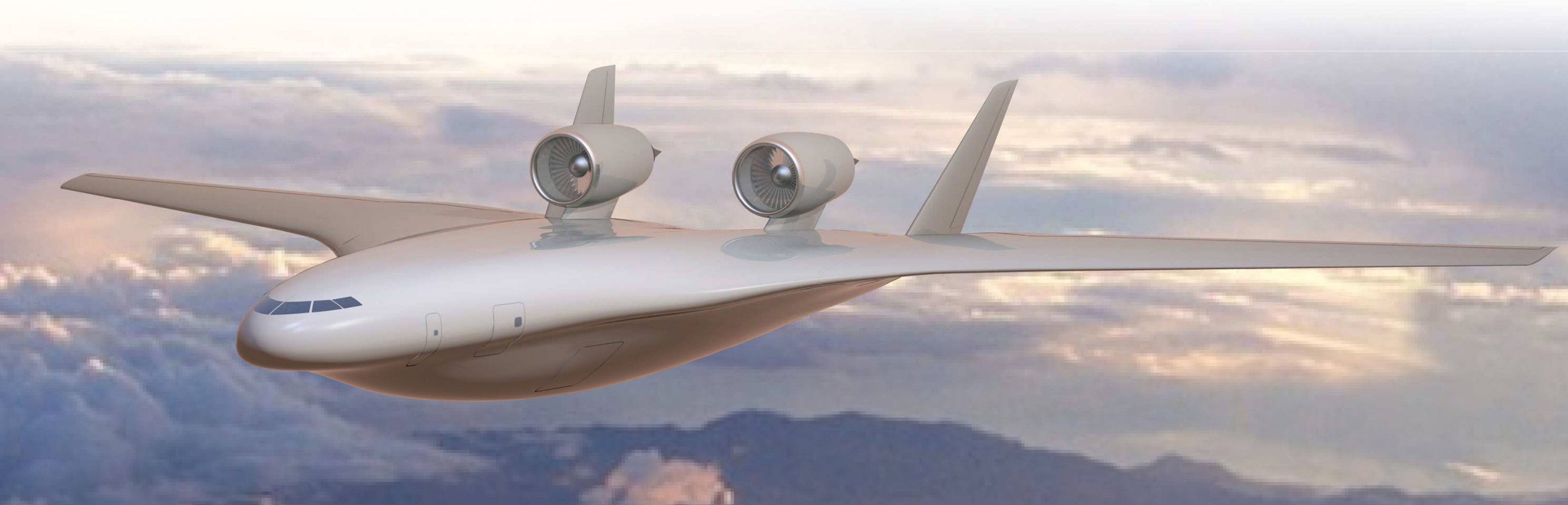

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www.nasa.gov

Why Green Aviation? – National Challenges Motivation for the ERA Project

Fuel Efficiency

•In 2008, U.S. major commercial carriers burned 19.6B gallons of jet fuel. DoD burned 4.6B gallons.

•At an average price of $3.00/gallon, fuel cost was $73B

Emissions

•40 of the top 50 U.S. airports are in non-attainment areas that do not meet EPA local air quality standards for particulate matter and ozone

•The fuel consumed by U.S. commercial carriers and DoD releases more than 250 million tons of CO_2 into the atmosphere each year

Noise

•Aircraft noise continues to be regarded as the most significant hindrance to NAS capacity growth.

•FAA's attempt to reconfigure New York airspace resulted in 14 lawsuits.

•Since 1980 FAA has invested over $5B in airport noise reduction programs

National Plan for Aeronautics R&D Context for the ERA Project

- Mobility, Security/Defense, Safety, Energy & Environment
  - Enable growth in Mobility/Aviation/Transportation
  - Dual use with Security/Defense
  - Safety and Cost Effectiveness are pervasive factors
- Specific and Quantifiable Energy and Environment goals
  - Energy Diversity
    - use of alternative fuels, not creation of alternative fuels
  - Energy Efficiency
  - Environmental Impact
    - reduction of impacts, not reducing scientific uncertainties of impacts

NASA Aeronautics Portfolio in FY2010
How the ERA Project Fits In

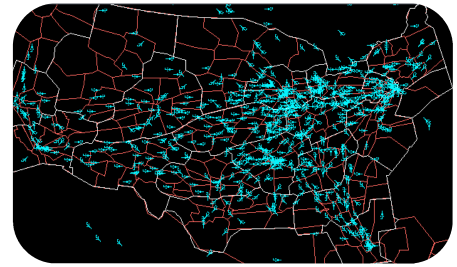


Fundamental Aeronautics Program

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

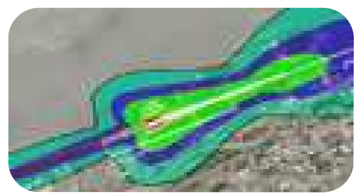
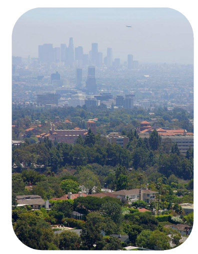
Integrated Systems Research Program

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

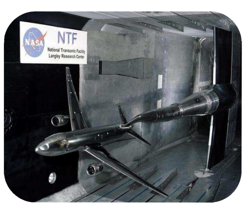
Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.


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.

ERA Project Framework

- Vision
  - ERA will expand the viable and well-informed trade space for vehicle design decisions enabling simultaneous realization of National noise, emissions, and performance goals
  - ERA will enable continued aviation growth while reducing or eliminating adverse effects on the environment
- Mission
  - Perform research to explore/assess the feasibility, benefits, interdependencies, and risks of vehicle concepts and enabling technologies identified as having potential to mitigate the impact of aviation on the environment
  - Transfer knowledge outward to the aeronautics community, and inward to NASA fundamental aeronautics projects.

NASA System Level Metrics

…. technology for dramatically improving noise, emissions, & performance

CORNERS OF THE TRADE SPACE	N+1 = 2015*** Technology Benefits Relative To a Single Aisle Reference Configuration	N+2 = 2020*** Technology Benefits Relative To a Large Twin Aisle Reference Configuration	N+3 = 2025*** Technology Benefits
Noise (cum below Stage 4)	-32 dB	-42 dB	-71 dB
LTO NO_x Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%**	-40%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

***Technology Readiness Level for key technologies = 4-6
** Additional gains may be possible through operational improvements
* Concepts that enable optimal use of runways at multiple airports within the metropolitan area

ERA Approach

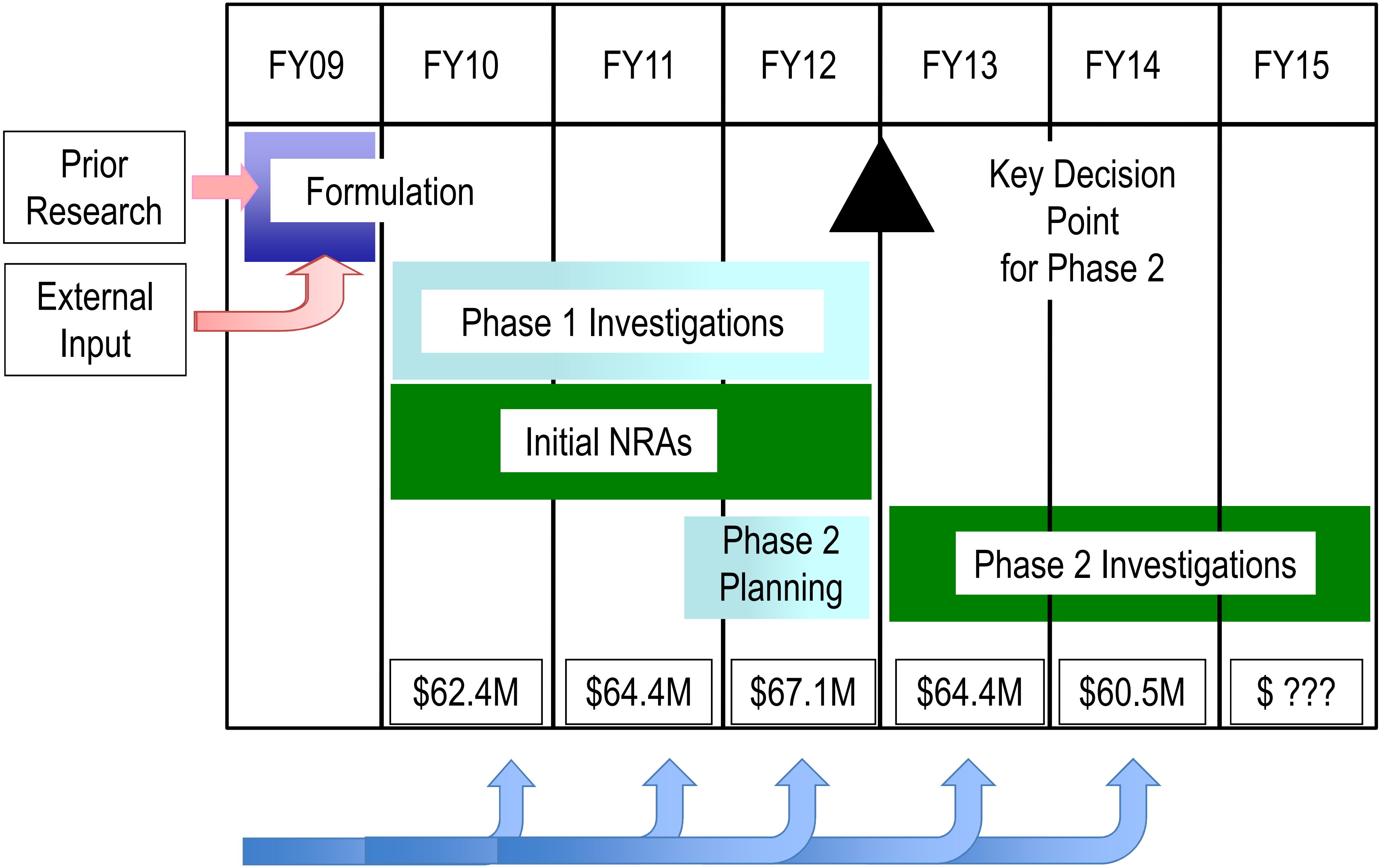
- *Focused on N+2 Timeframe – Fuel Burn, Noise, and NO_x System-level Metrics*
- *Focused on Advanced Multi-Discipline Based Concepts and Technologies*
- *Focused on Highly Integrated Engine/Airframe Configurations for Dramatic Improvements*

The Way Forward

- System research to bridge the gap between fundamental research (TRL 1-4) and product prototyping (TRL 7)
  - Identify vehicle concepts with the potential to simultaneously meet National goals for noise, emissions, and fuel burn in the N+2 timeframe
  - Understand the concept and technology <u>feasibility/risk</u> vs potential <u>benefits</u>
  - Understand the concept and technology <u>trades and interdependencies at high fidelity in relevant environments</u>
  - Determine safety implications of new technologies and configurations

- Technology investments guided by
  - matured in fundamental program and worthy of more in-depth evaluation at system level in relevant environment
  - systems analysis indicates most potential for contributing to simultaneous attainment of N+2 goals
  - identified through stakeholder input as having potential for contributing to simultaneous attainment of N+2 goals

ERA Project Flow
And Key Decision Point for Phase 2



Technical input from Fundamental Programs, NRAs, Industry, Academia, Other Gov't Agencies

Distinction between SFW and ERA

SFW

- Focus on tools, design codes, and MDAO
- Balancing toward foundational research
- Completion of N+1 focused work, working partnership with CLEEN
- High Lift Capability (CESTOL)
- Evolving N+3 focus with 4 external and 2 internal Advanced Concepts Study
- Wildcard is strong collaboration with Safety on F18, just now added to mix
- Characterization of Alternative Fuels for fuel flexible combustors

ERA

- All things laminar flow, except transition physics and transition prediction methods
- Advanced Architechture
  - All things X-48
  - All PRSEUS (pultruded rod stiffened efficient unitized structure)
  - HWB Noise Reduction Test in the 14x22
- Propulsion Concepts
  - Open Rotor isolated and integrated
  - UHB (geared and direct) isolated and integrated
- All things Boundary Layer Ingestion
- New low NOx and fuel flexible combustor NRA
- N+2 Advanced Concepts Study NRA

ERA Project
Phase 1 Investigations

Technology enablers - <u>broadly applicable</u>

- less visible than configuration features
- applicable to alternate and advanced conventional configurations
- Noise: continuous mold lines, increasing ducted BPR, boundary layer ingestion
- Emissions: fuel-flexible, low NOx combustion, reduced fuel burn technologies
- Fuel Burn: lightweight structure, reduced drag, and reduced SFC, open rotor

$$\text{Aircraft Range} = \frac{\text{Velocity}}{\text{TSFC}} \left(\frac{\text{Lift}}{\text{Drag}}\right) \ln\left(1 + \frac{W_{fuel}}{W_{PL} + W_{O}}\right)$$

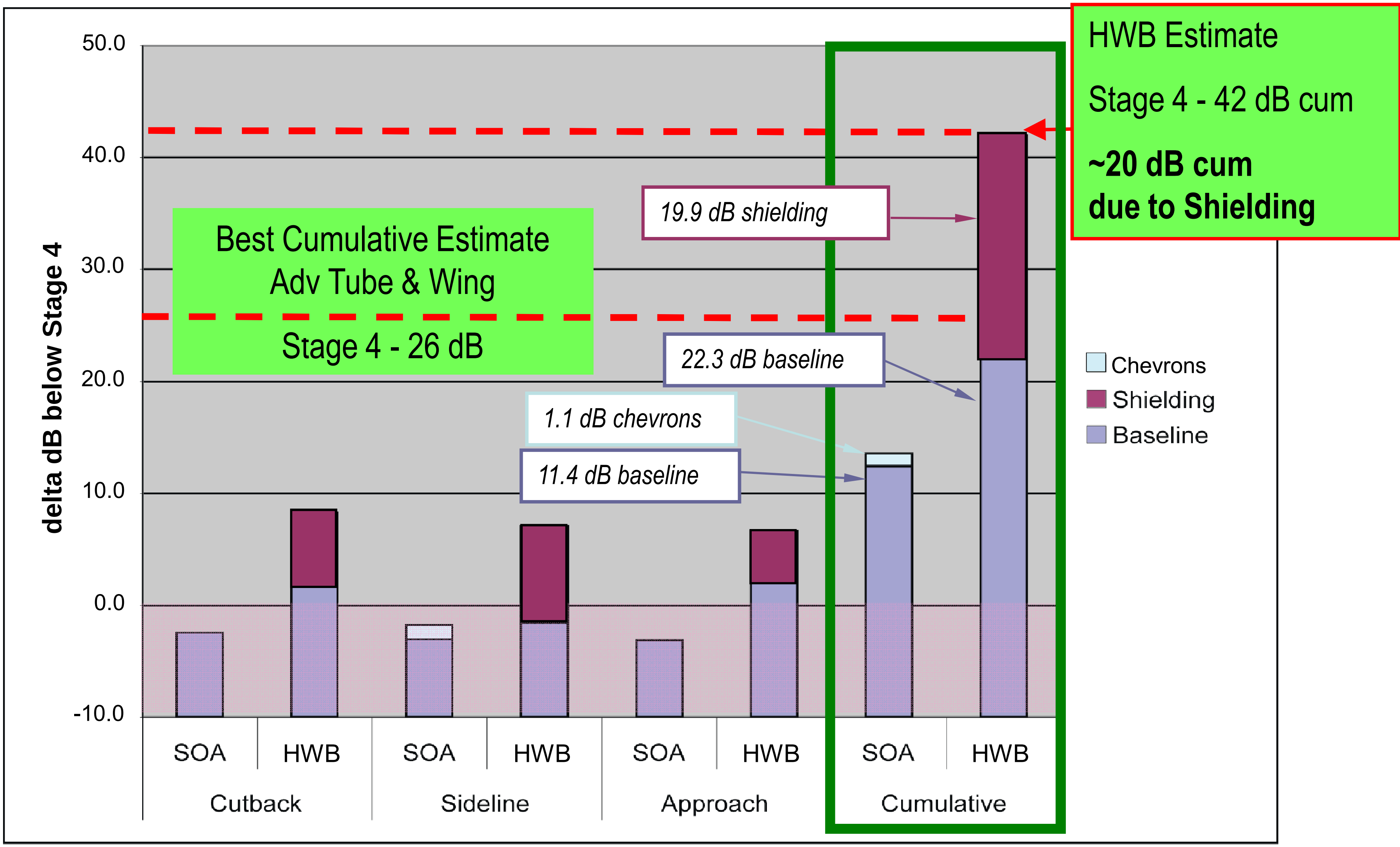
Engine Fuel Consumption (TSFC)

Aerodynamics (Lift/Drag)

Empty Weight (W_O)

ERA Project
Noise Reduction Goal

Includes estimate of maximum propulsion noise shielding

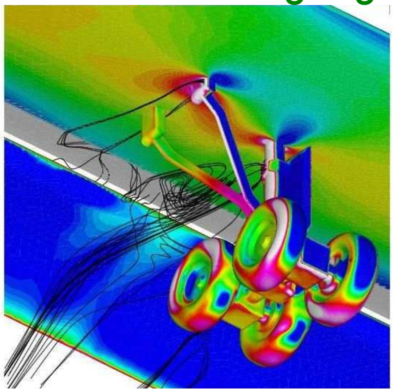


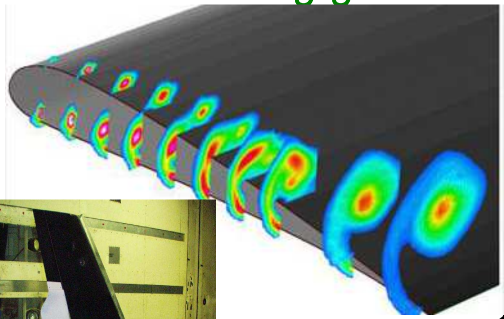
Thomas, Berton, et al

Addressing Noise Reduction

Airframe Noise

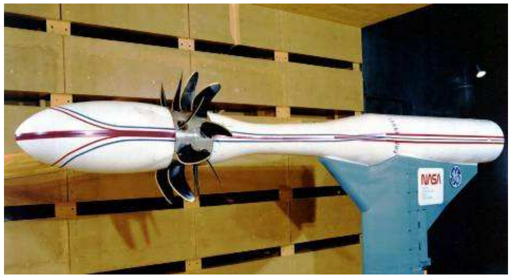
Addressing high-lift systems and landing gear





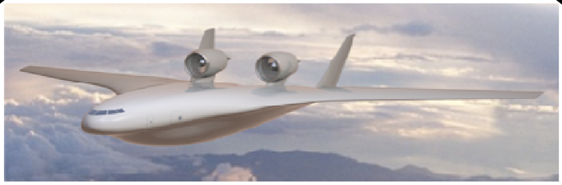
Propulsion Noise

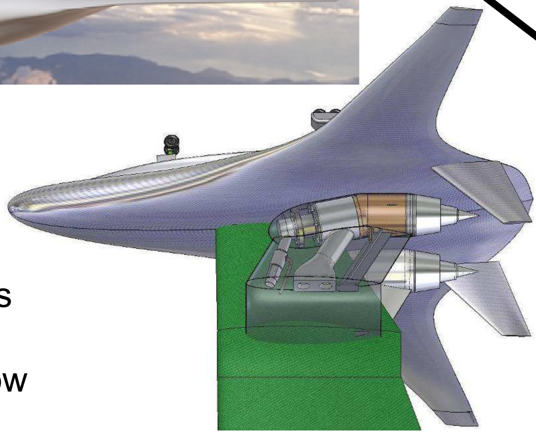
Addressing fan, core, and jet noise



Open Rotor

UHB Turbofans





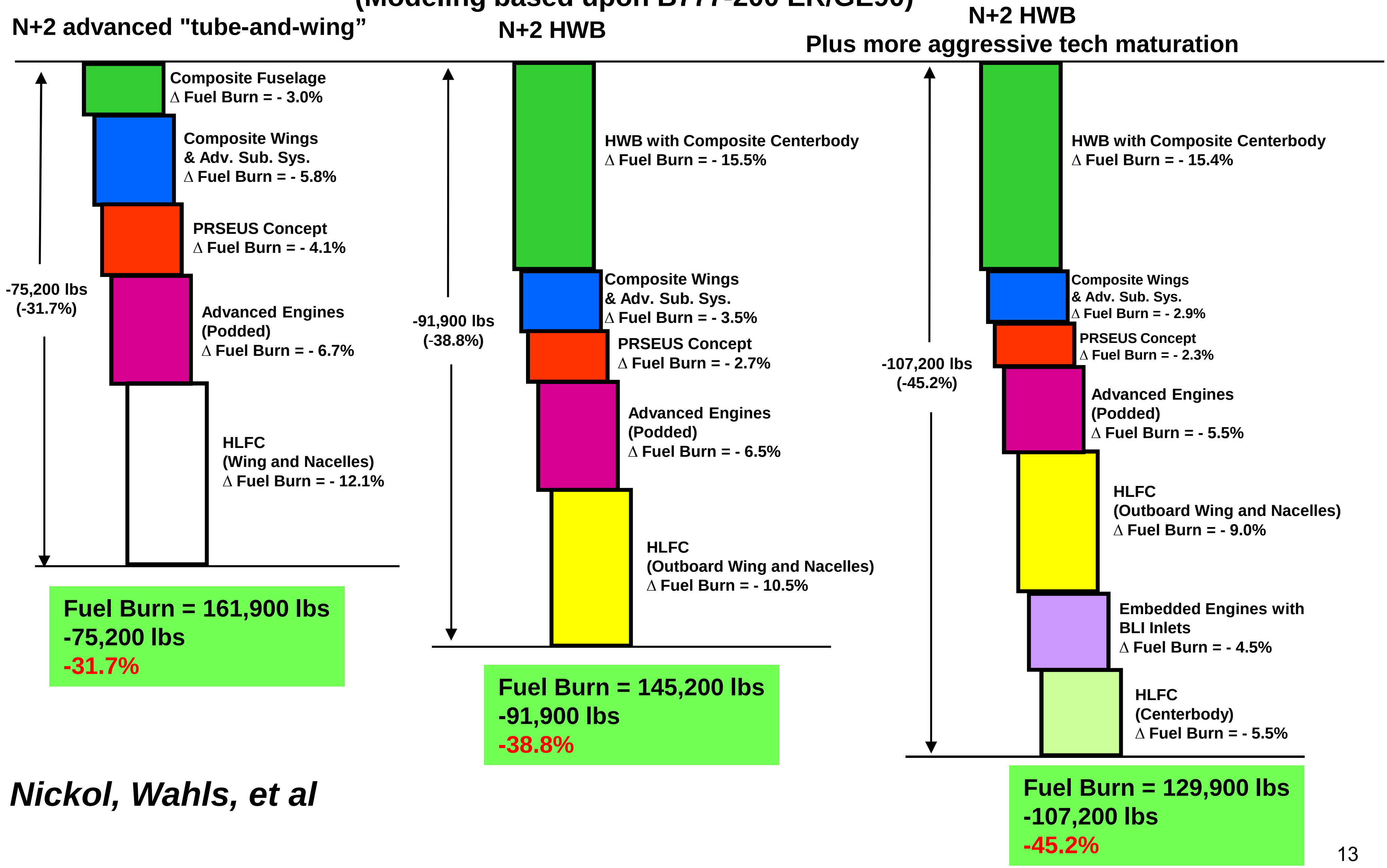
- Twin High Bypass Ratio Jet Simulators
- Simplified Fan Noise Simulator
- Instrumentation and Processing for Low Noise Levels

Propulsion Airframe Aeroacoustics

Addressing airframe/propulsion interaction - shielding

ERA Project
Fuel Burn (and CO_2) Reduction Goal

Technology Benefits Relative to Large Twin Aisle
(Modeling based upon B777-200 ER/GE90)



Nickol, Wahls, et al

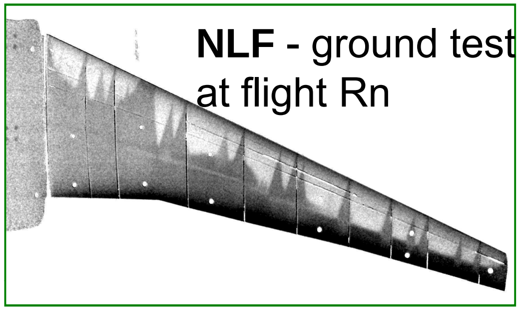
Addressing Fuel Burn (CO_2 Emissions)

DRAG REDUCTION via Laminar Flow

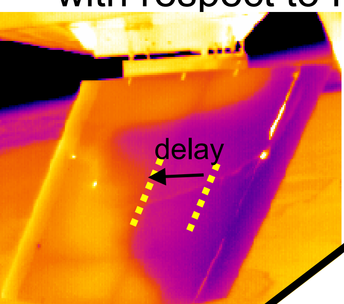
Addressing concepts & barriers
to achieving practical laminar flow on transport a/c

HLFC - revisit crossflow expt
- understand system weight

NLF - ground test at flight Rn



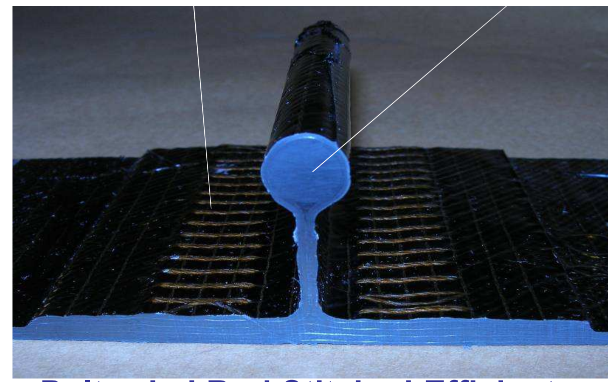
DRE - exploring the limits with respect to Rn



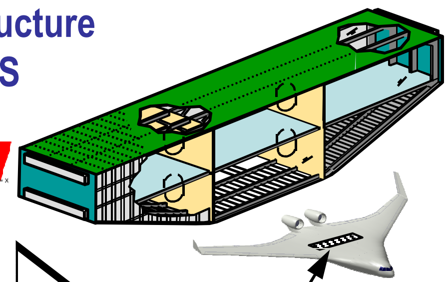
WEIGHT REDUCTION via Advanced Structures

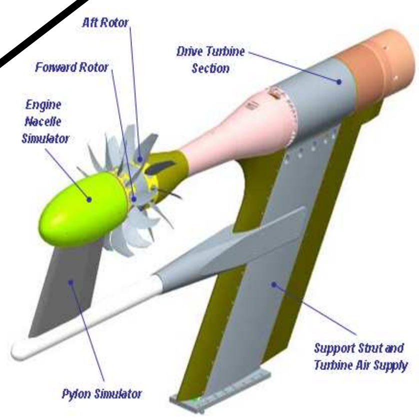
Moving from "safe-life" to "fail-safe" design
with a lightweight composite structure

Stitches Rod

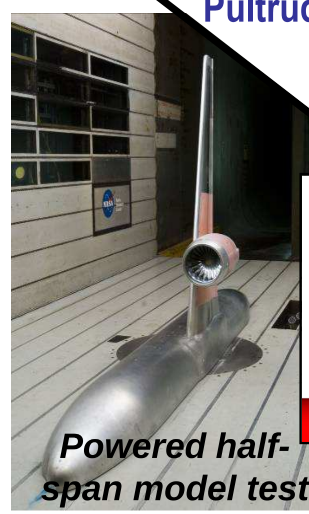


Pultruded Rod Stitched Efficient
Unitized Structure
PRSEUS

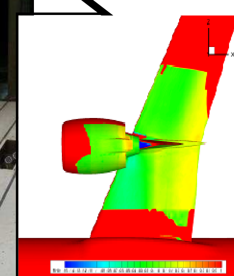




Open Rotor Propulsion Rig



Powered half-span model test

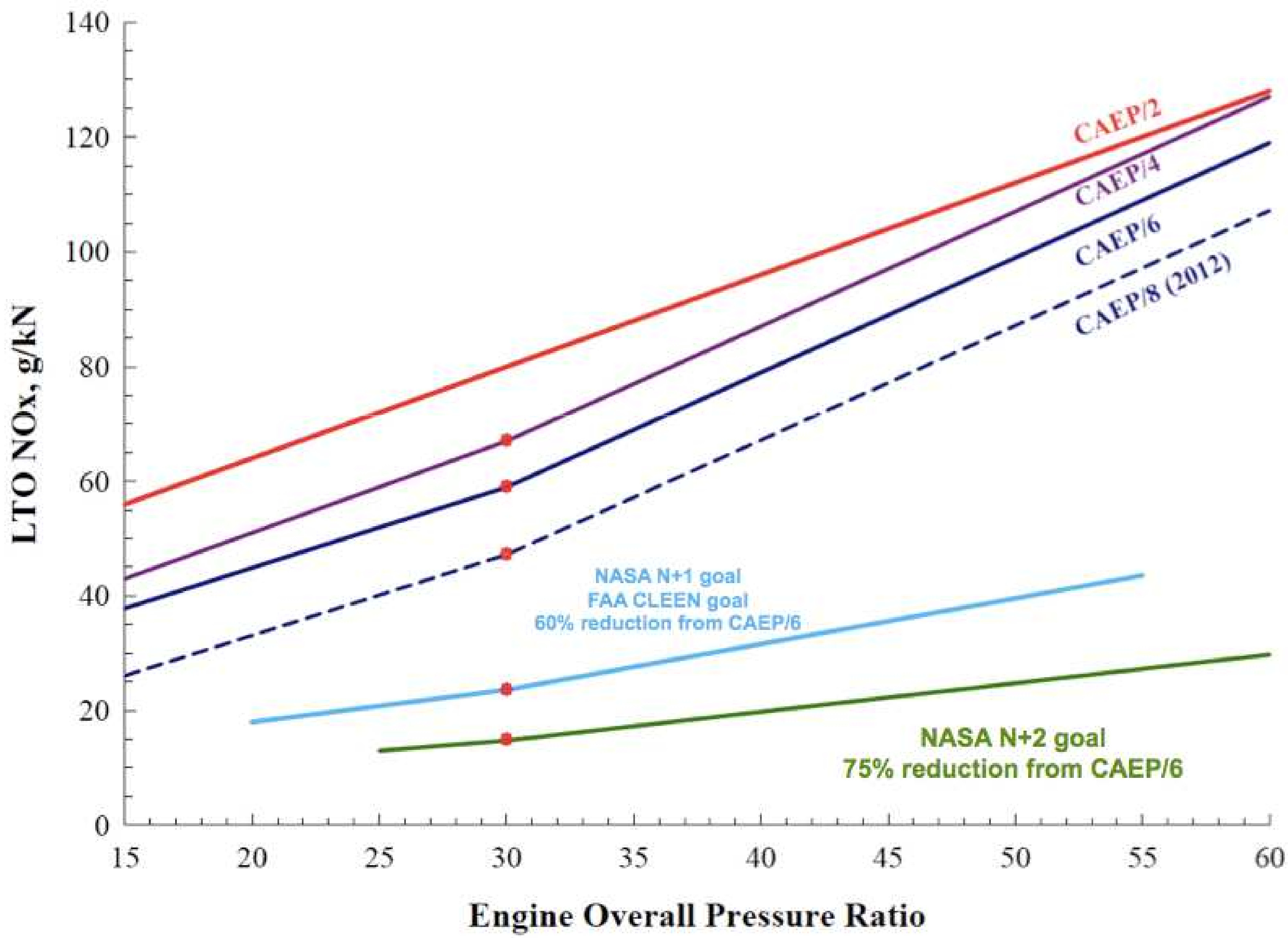


PSP Results

SFC REDUCTION via UHB

Addressing multidisciplinary challenges from subcomponent to installation
to achieve ultra-high by-pass ratio

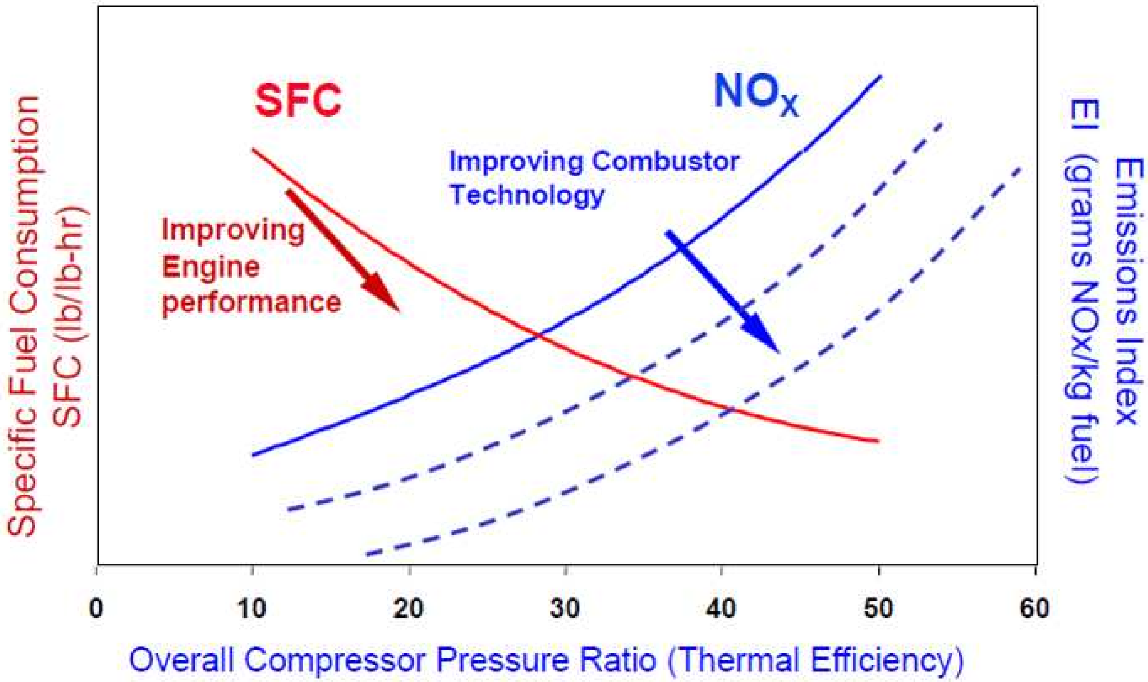
Addressing N+2 LTO NO_x Reduction Goal



Addressing Reduced LTO NO_x Emissions

Low NOx combustor concepts for high OPR environment

Increase thermal efficiency without increasing NOx emissions



NASA Injector Concepts

- Partial Pre-Mixed
- Lean Direct Multi-Injection

Enabling Technology

- lightweight CMC liners
- advanced instability controls

- Improved fuel-air mixing to minimize hot spots that create additional NOx
- Lightweight liners to handle higher temperatures associated with higher OPR
- Fuel flexibility to accommodate emerging alternative fuels
- Coordinating with DoD Programs

ERA Project Flow
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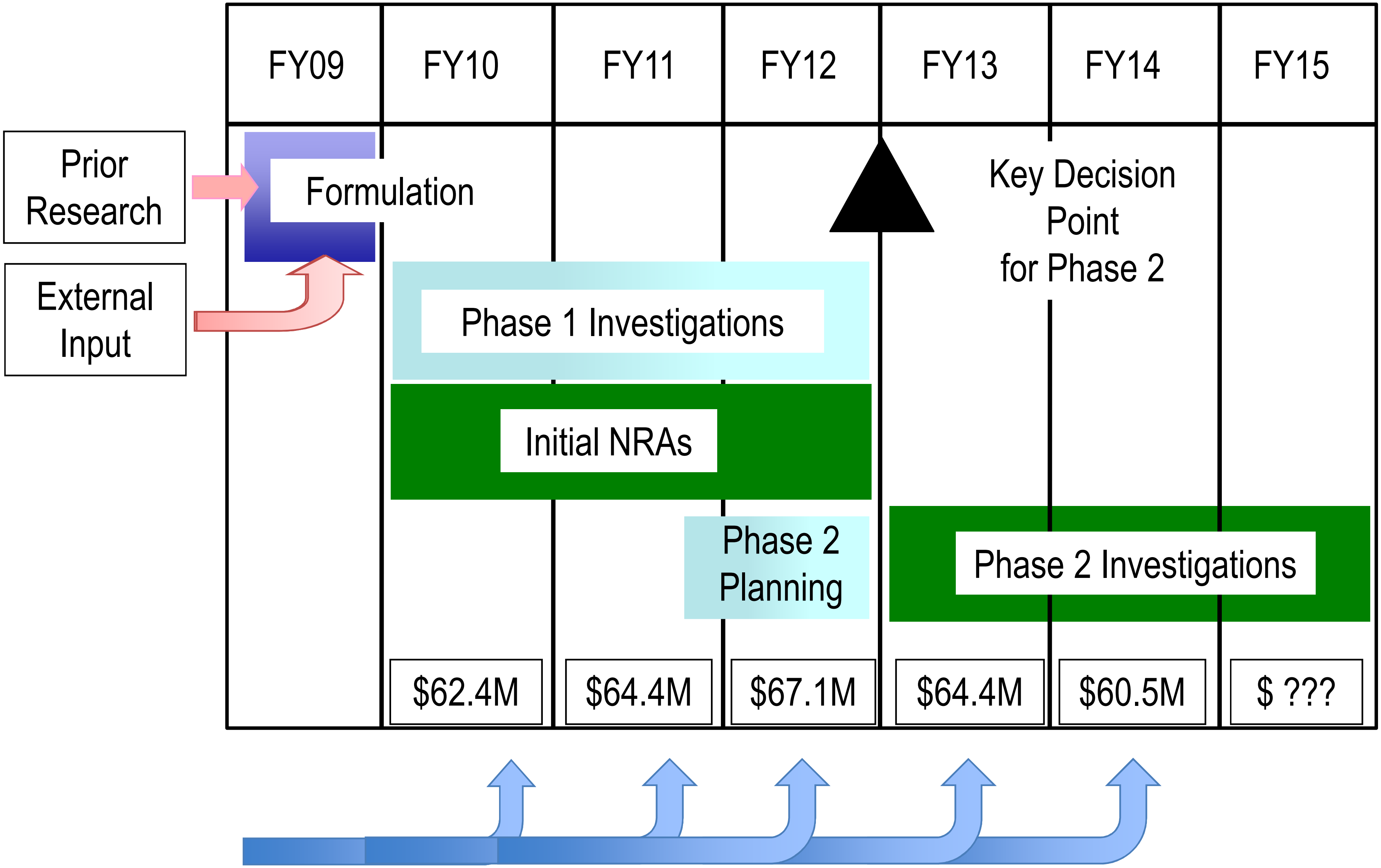

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ERA Project - Initial NRAs
Broad-based input to the ERA Project

- Topic 1 - N+2 Advanced Vehicle Concepts – Bidders conference Feb. 11
  - **Concept development and technology roadmaps**
  - **Scope key system Investigations to inform Phase 2 decisions**

- Topic 2 - Low NOx Combustors – Selections Made
  - **Concept development and technology roadmaps**
  - **Initial flametube experiments**
  - **Inform Phase 2 decisions**

- Topic 3 - Quick-Start System Research Investigations – Bidders conference Feb. 11
  - **Complementary to Phase 1 investigations**
  - **Early technical progress/results toward ERA goals**
  - **Inform Phase 2 decisions**

Summary

- Explore/demonstrate the feasibility, benefits, and risks of vehicle concepts and enabling technologies identified to have potential to mitigate the impact of aviation on the environment

- Expand viable and well-informed trade space for vehicle design decisions enabling simultaneous realization of National noise, emissions, and performance goals; identify challenges for foundational research

- Simultaneous attainment of N+2 goals will require alternative configurations w/ advanced technology; technologies will be broadly applicable and tradable

NASA