National Aeronautics and Space Administration

HyTEC

Hybrid Thermally Efficient Core

Anthony Nerone, NASA Glenn Research Center
James Kenyon, NASA Headquarters
Ashlie Flegel, NASA Glenn Research Center Ian Park, NASA Glenn Research Center Ashlee Shaw, NASA Glenn Research Center

Industry Day
February 24, 2021

HyTEC Industry Day Agenda

10:00-10:05	Introduction
10:05-10:20	Advanced Air Vehicles Program Presentation
10:20-10:55	HyTEC Project and Draft NRA Overview
11:00-4:00	Industry One-on-one Meetings

Disclaimer

The purpose of this Industry Day and One-on-One Sessions is for clarification of the Draft NRA (DNRA) and applicable documents. The Government will NOT provide advice to potential Offerors on what to propose or what will elicit a favorable rating. NASA will not indulge in hypothetical questions (e.g. “if we propose this, how would NASA rate it?)

All information provided during Industry Day is notional. The Government anticipates a similar structure for the Final NRA; however it is subject to change.

Disclaimer, continued.

The Final NRA document when posted to BetaSAM is to official call for proposals, and the language in it dictates the terms of the procurement, regardless of what may have been posted in the DNRA or discussed during the Industry Day.

The announcement and any documents related to this procurement will be available over the Internet at www.beta.sam.gov. It is the Offeror's responsibility to monitor the website for the release of the announcement and any amendments (if any).

National Aeronautics and Space Administration

Framework for Sustainable Subsonic Transports

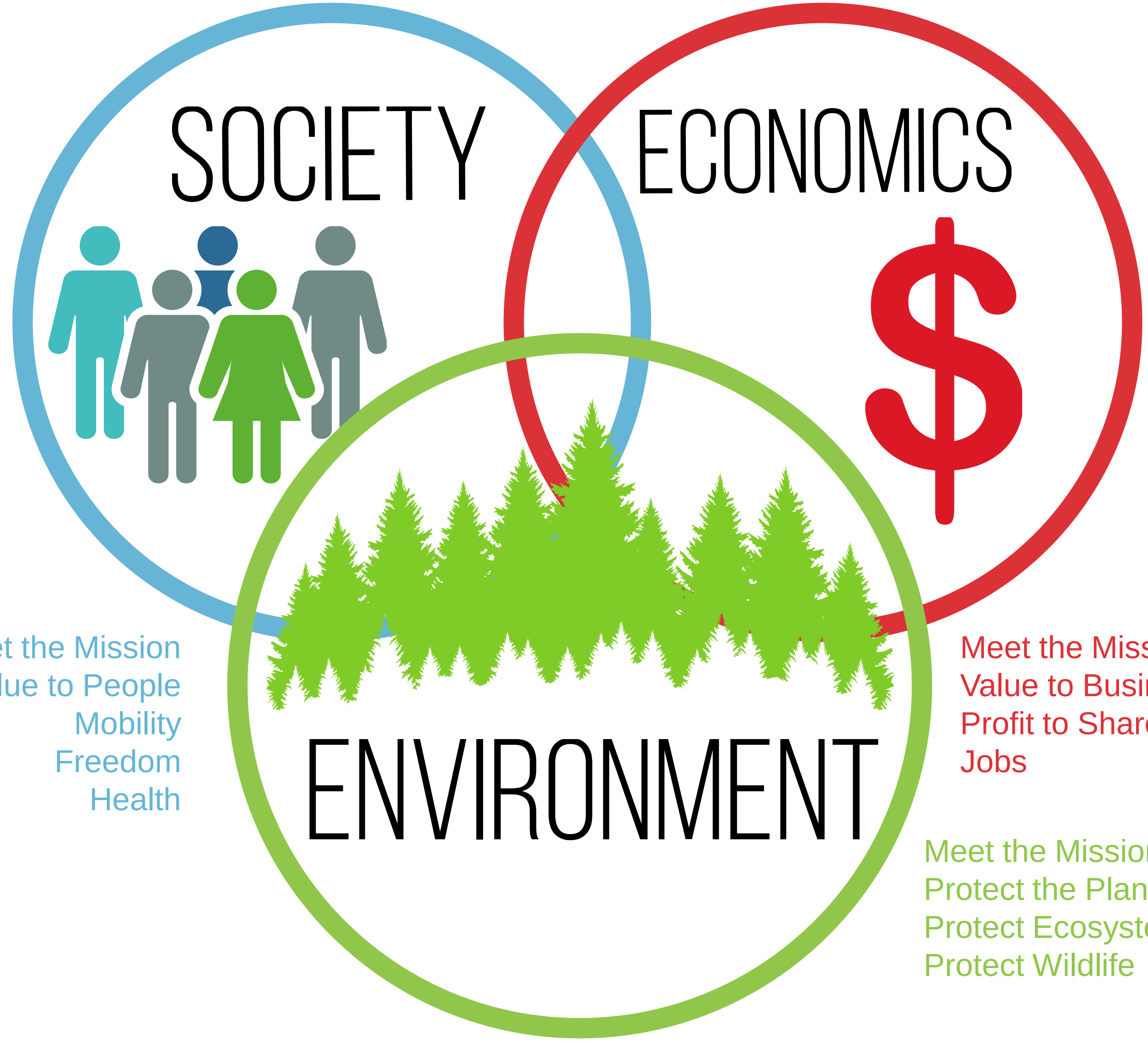
Jimmy Kenyon
Director, Advanced Air Vehicles Program
NASA

February 24, 2021

Sustainability – a Global View

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

- UN World Commission on Environment and Development



Meet the Mission
Value to People
Mobility
Freedom
Health

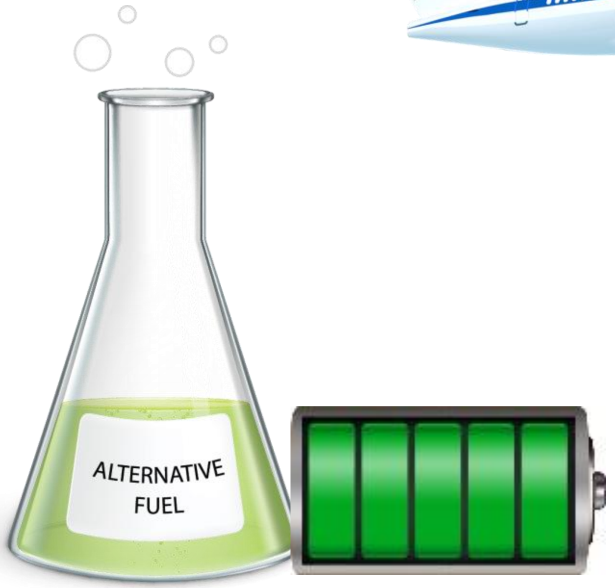
Meet the Mission
Value to Business
Profit to Shareholders
Jobs

Meet the Mission
Protect the Planet
Protect Ecosystems
Protect Wildlife

3 Pillars to a More Sustainable Future

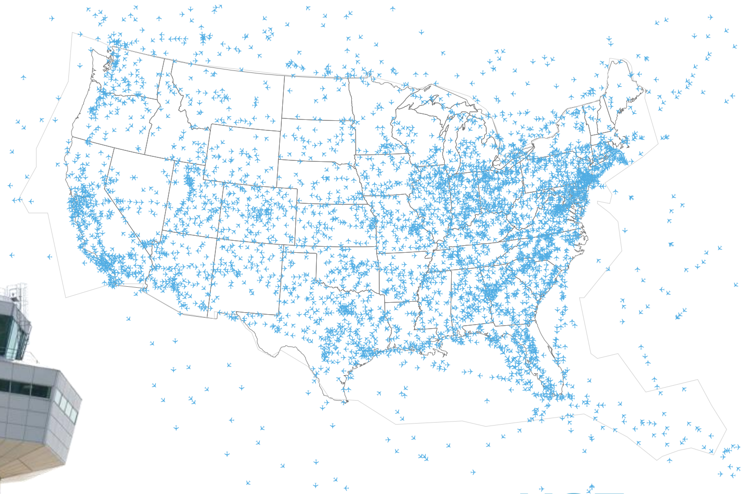
TECHNOLOGY

USE
LESS
ENERGY
by aircraft design



USE
CLEANER
ENERGY
full lifecycle

FUEL & ENERGY

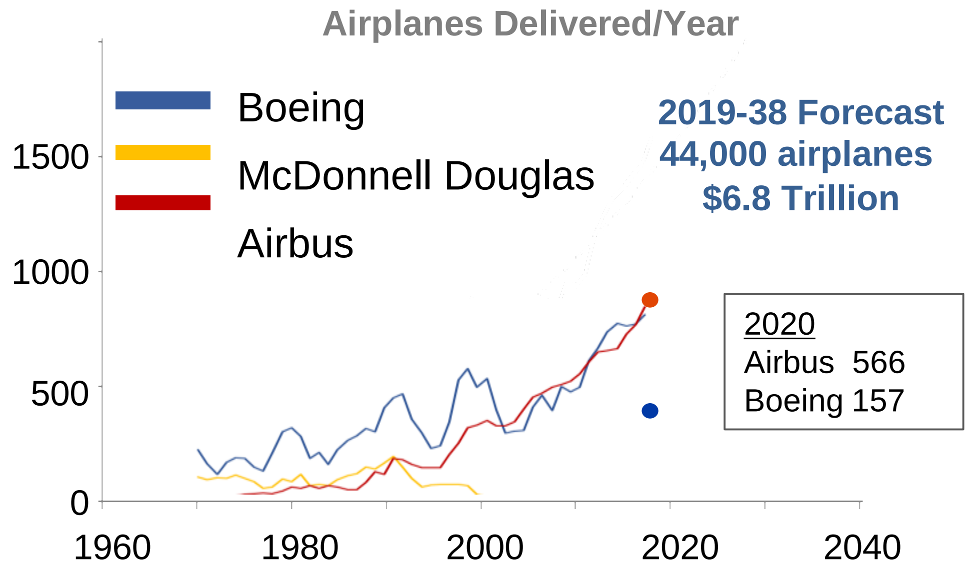


OPERATIONS

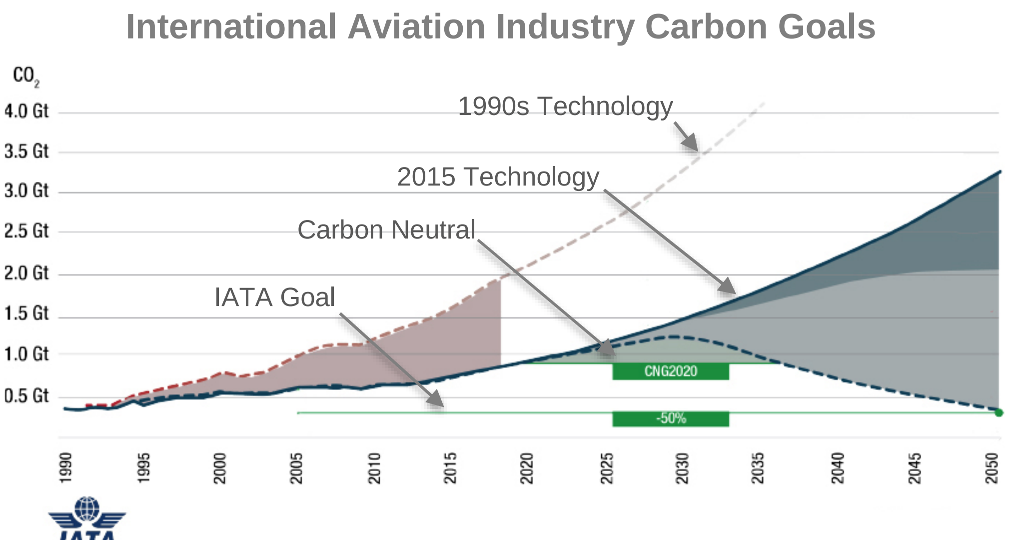
USE
LESS
ENERGY
by how you fly

Subsonic Transport Airplane Market

Global competition and environmental pressure expanding



Source data: Boeing



Source: IATA/ATAG

- European manufacturers reaching parity
- New competitors in key Asia-Pacific growth market
- *EU COVID-19 recovery investing heavily in commercial aerospace manufacturers*
- U.S. leadership at risk

- Market-based measures in place
- Community Noise and LTO NOx regulations
- New ICAO CO_2 and nvPM standards
- Social pressure growing, e.g., flight shaming
- U.S. industry must meet global standards

Ultra-efficient subsonic transport technologies address both needs and offer operating cost benefits to airlines

Subsonic Transport Technology Prioritization

NASA Aeronautics Vision
and Strategy Established

2008-2013

2014 - 2019

2020-2025

Subsonic Concept/Technology Studies
Electrified Aircraft Propulsion, Transonic Truss Braced Wing

Environmentally Responsible Aviation (ERA) Project

Flight Demonstrator Studies

Advanced Composites (ACP)

Next Step

Maturation and Integration of Four Key Technologies that will Create a New "S Curve" for Future Subsonic Transports

FAA CLEEN I

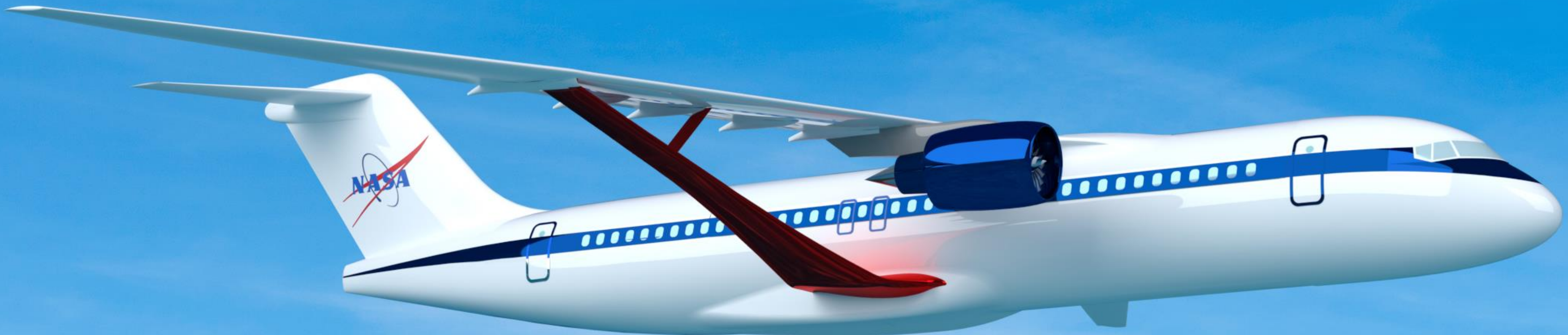
FAA CLEEN II

FAA CLEEN III

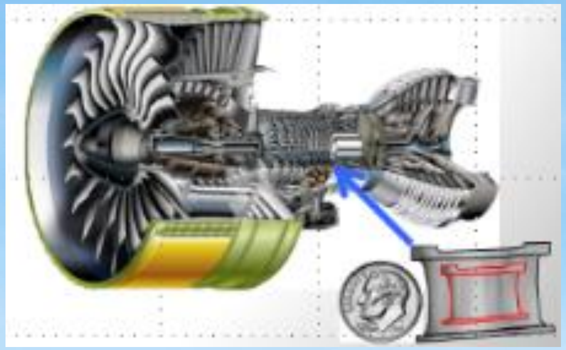
ARMD Subsonic Transport Strategy Based on over a Decade of Research, Concept and Technology Development, and NASA-Industry Partnership

Subsonic Transport Strategy

Ensure U.S. industry is the first to establish the new "S Curve" for the next 50 years of transports



Transonic Truss-Braced Wing
5-10% fuel burn benefit

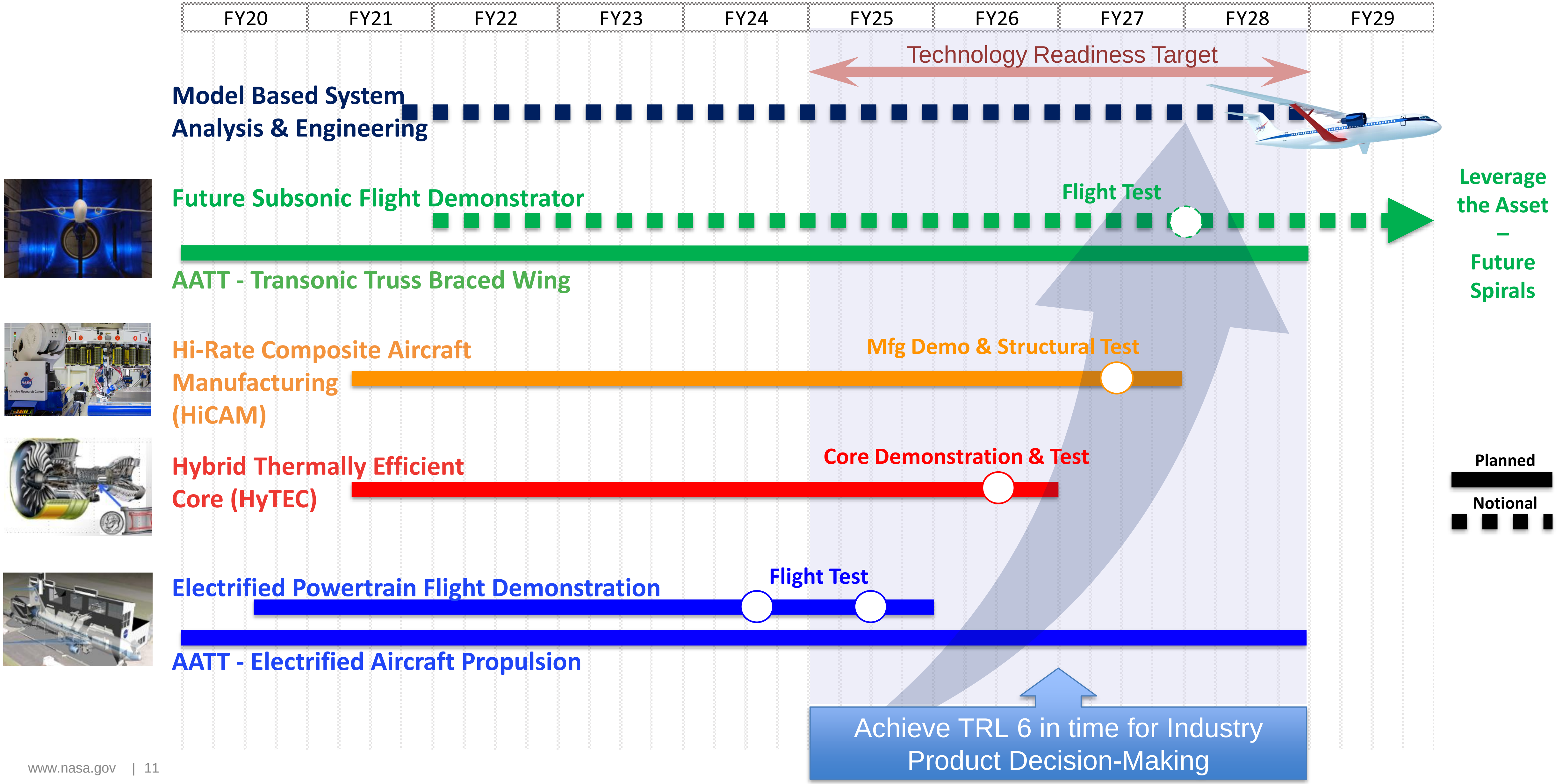


Small Core Gas Turbine
5-10% fuel burn benefit

Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit

High-Rate Composite Manufacturing
4x-6x manufacturing rate increase

Next Gen Transports: Integrated Technology Development

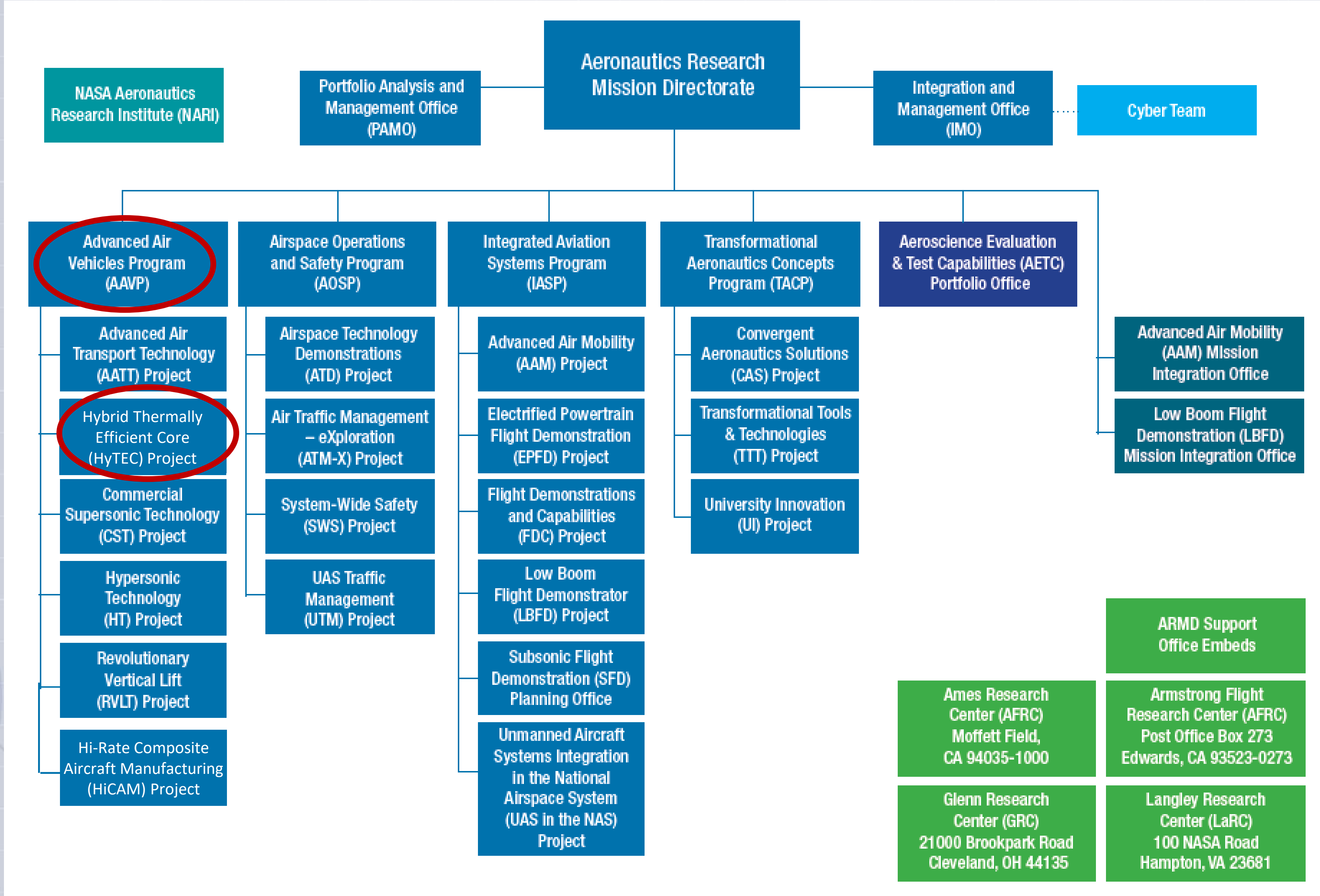


HyTEC

Hybrid Thermally Efficient Core

Industry Day

Tony Nerone, Project Manager
NASA
February 24, 2021


NASA Aeronautics Research Institute (NARI)
Portfolio Analysis and Management Office (PAMO)
Aeronautics Research Mission Directorate
Integration and Management Office (IMO)
Cyber Team
Advanced Air Vehicles Program (AAVP)
Airspace Operations and Safety Program (AOSP)
Integrated Aviation Systems Program (IASP)
Transformational Aeronautics Concepts Program (TACP)
Aeroscience Evaluation & Test Capabilities (AETC) Portfolio Office
Advanced Air Transport Technology (AATT) Project
Hybrid Thermally Efficient Core (HyTEC) Project
Commercial Supersonic Technology (CST) Project
Hypersonic Technology (HT) Project
Revolutionary Vertical Lift (RVLT) Project
Hi-Rate Composite Aircraft Manufacturing (HiCAM) Project
Airspace Technology Demonstrations (ATD) Project
Air Traffic Management – eXploration (ATM-X) Project
System-Wide Safety (SWS) Project
UAS Traffic Management (UTM) Project
Advanced Air Mobility (AAM) Project
Electrified Powertrain Flight Demonstration (EPFD) Project
Flight Demonstrations and Capabilities (FDC) Project
Low Boom Flight Demonstrator (LBFD) Project
Subsonic Flight Demonstration (SFD) Planning Office
Unmanned Aircraft Systems Integration in the National Airspace System (UAS in the NAS) Project
Convergent Aeronautics Solutions (CAS) Project
Transformational Tools & Technologies (TTT) Project
University Innovation (UI) Project
Advanced Air Mobility (AAM) Mission Integration Office
Low Boom Flight Demonstration (LBFD) Mission Integration Office
ARMD Support Office Embeds
Ames Research Center (AFRC) Moffett Field, CA 94035-1000
Armstrong Flight Research Center (AFRC) Post Office Box 273 Edwards, CA 93523-0273
Glenn Research Center (GRC) 21000 Brookpark Road Cleveland, OH 44135
Langley Research Center (LaRC) 100 NASA Road Hampton, VA 23681

HyTEC Project Organization

Hybrid Thermally Efficient Core (HyTEC) Project Structure

Project Manager
Tony Nerone

Deputy Project Manager
TBD

Chief Engineer
Ada Narvaez-Legeza (acting)

Lead Systems Engineer
Michael Alexander

Technical Advisors

AATT SA&I Liaison	*Jeff Chapman*
Turbine Engine Tech	*Ken Suder*
Aeropropulsion	*Mark Turner*

Project Planning and Control Team

Business Manager	Sheena Fussell
Resource Analyst	*Meredith Irwin*
Scheduler	*April Albert*
Risk Manager	*Kelli Peterson*
Project Coordinator	*Denise Stefula*
Config. and Data Mgr.	*Barbara Kimbell*

Acquisition Team

Contracting Officers	*Ashlee Shaw*
	Ian Park

Small Core Technology Subproject
SPM: *Kim Pham*
SE: *Nathan Williams*

Advanced Core Demonstration Subproject
SPM: *TBD*
SE: *TBD*

High Pressure Compressor (HPC)
Technical Lead/Contract TM
Sameer Kulkarni

High Pressure Turbine (HPT)
Technical Lead/Contract TM
Craig Smith

Turbofan Power Extraction (PEx)
Technical Lead/Contract TM
Joe Connolly

Combustor Technologies
Technical Lead/Contract TM
TBD

Core System Technologies
Technical Lead/Contract TM
TBD

NRA Timeline

- ✓ **February 10, 2021: Draft NRA Released**
- ✓ **February 24, 2021: Industry Day**

March 12, 2021: Draft NRA Closes

April 5, 2021: Final NRA Released

May 20, 2021: Proposals Due

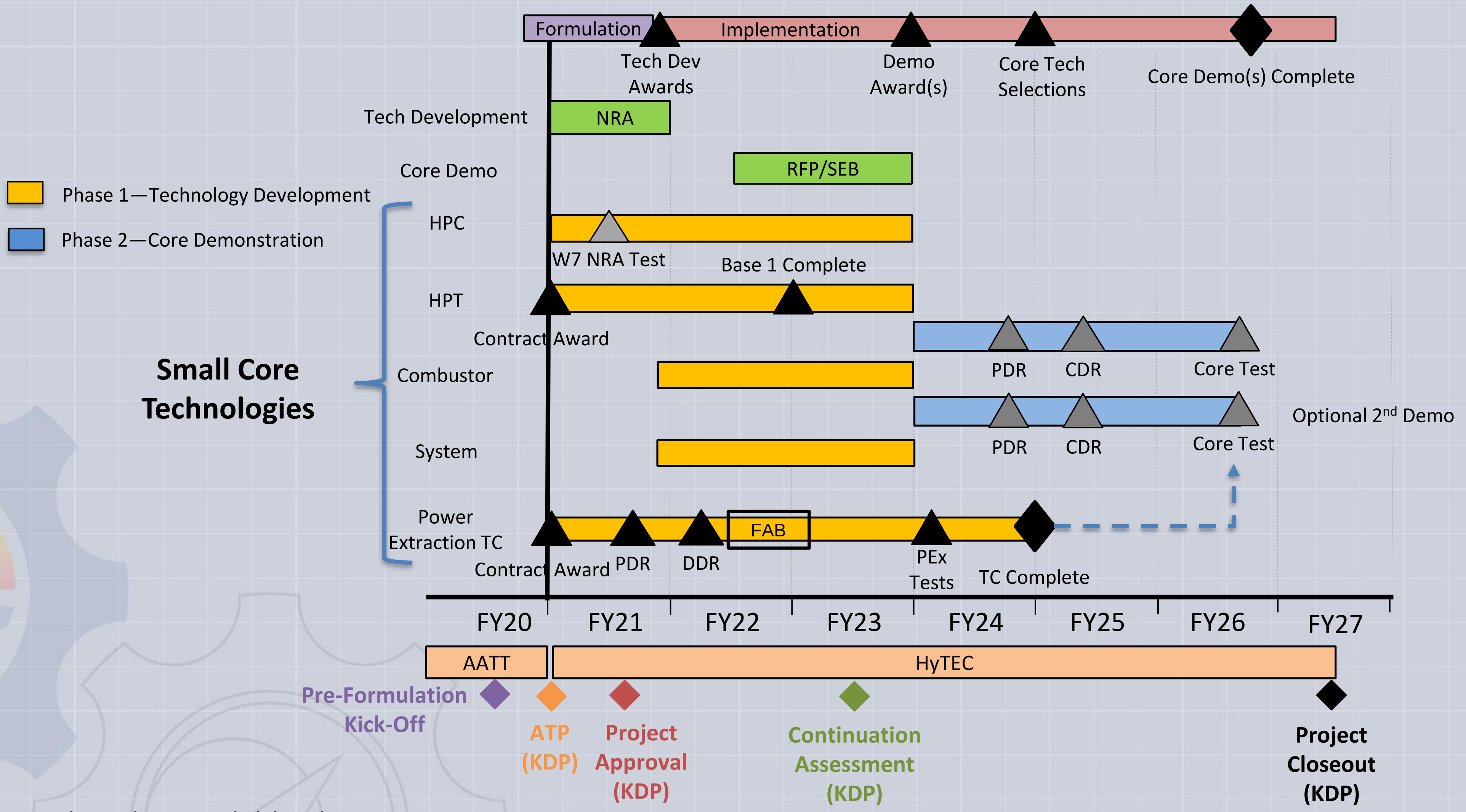
HyTEC Project

Overall Project Goals

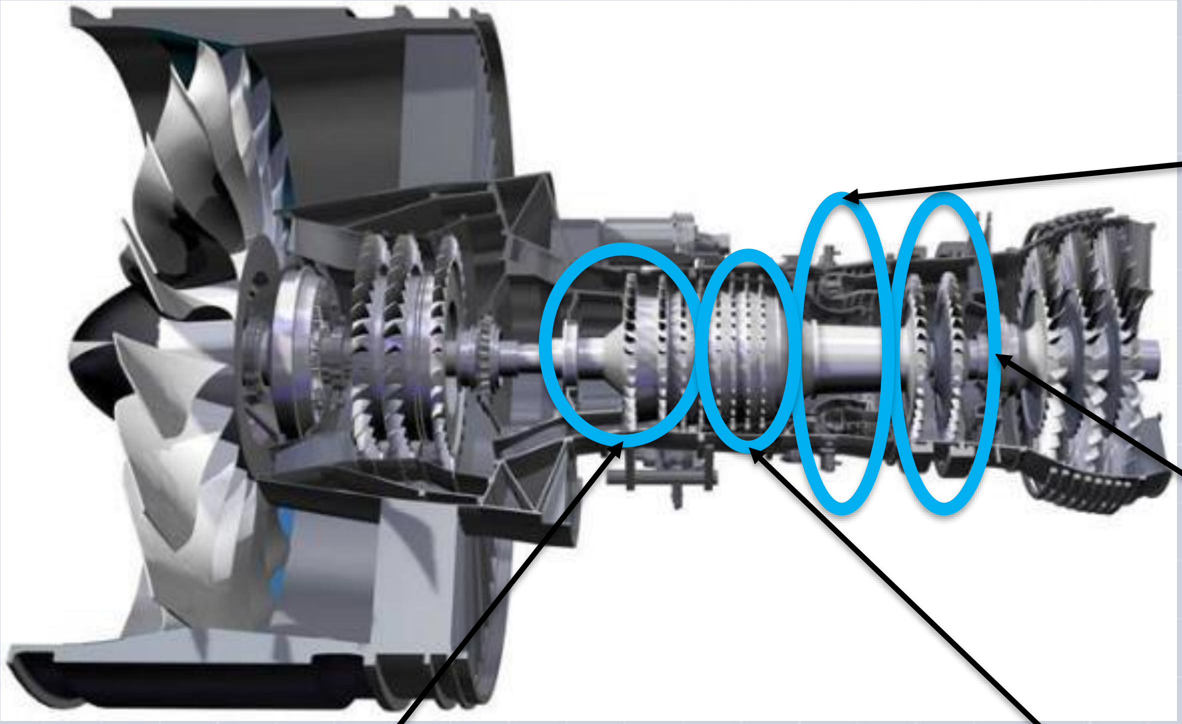
- **Demonstrate increased thermal efficiency with integrated high-power density-core engine technologies achieving a 5% to 10% fuel burn benefit, versus 2020 best in class, for early 2030s EIS single-aisle aircraft.**
- **Achieve up to 20% power extraction at altitude from a modern commercial turbofan engine with the thrust, efficiency, operability, and durability to enable the benefits of electrified aircraft propulsion at a vehicle level.**

HyTEC Preliminary Schedule Overview

Formulation/Implementation Schedule:



HyTEC NRA Technical Content: Phase I NRA



Combustor

Advanced materials:
- Small core combustor liner with improved performance such as reduced cooling requirements, reduced weight, and longer life

HPT

Advanced Aerodynamics:
- Geometry effects, secondary and cooling flow management, reduced airfoil and tip thermal loading, and optimum tip features

High Temperature CMC Blades and Vanes:
- CMC/EBC system offering temperature or performance capability beyond the current state of the art

HPC

Front Block Aerodynamic Optimization:
- Casing treatments, advanced airfoil shapes, and other advanced HPC technologies.

HPC

Rear Block Aerodynamic Optimization:
- Casing treatments, advancing airfoil shapes, and other advanced HPC technologies.

HyTEC Technical Performance Metrics

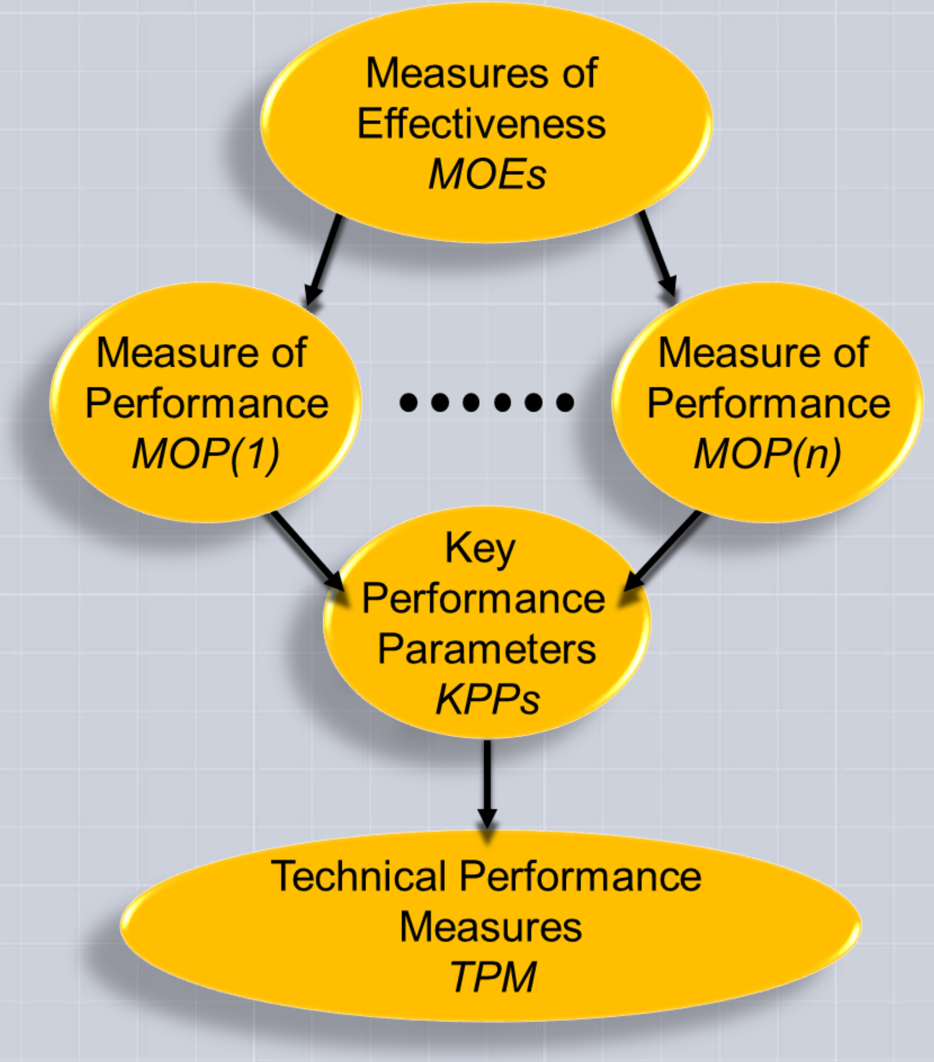
From NRP 7123.1C: NASA Systems Engineering Processes and Requirements

MOEs (Goals, Mission Outcomes) - used by stakeholders to judge their satisfaction with the delivered product

MOP (Objectives, System Outputs) - quantitative measure, that when met, helps ensure an MOE will be satisfied

KPP (Success Criteria)- capabilities or characteristics most essential for mission success - (High Priority)

TPM - a set of KPPs monitored (current best estimate) to confirm progress and ID deficiencies that might impact meeting a system requirement



Measures of Effectiveness (MOE)

The HyTEC MOEs will be used to establish the HyTEC stakeholder’s expectations and HyTEC’s goals.

MOE #	Measure of Effectiveness (MOE)
MOE-1	Define a viable path that identifies key high power density core technologies needed to accelerate U.S. Industry product that is enhanced by government participation.
MOE -2	Establish a turbofan engine with a high power density core that addresses the next generation single-aisle for EIS in the 2035 timeframe.
MOE-3	Demonstrate increased power extraction at altitude from a modern commercial turbofan engine with the thrust, efficiency, operability, and durability to enable the benefits of electrified aircraft propulsion at a vehicle level.

Measures of Performance (MOP)

The MOPs defines the objectives HyTEC seeks to achieve through the technology development and hybrid thermally efficient core ground demonstration.

MOP #	Measure of Performance (MOP)
MOP-1	Execute dual spool power extraction on a SOA turbofan engine via ground and altitude testing
MOP-2	Develop and demonstrate via ground test an advanced high power density core engine
MOP-3	Raise the TRL level of high power density core technologies to TRL 4-5 through component testing by 2023
MOP-4	Raise the TRL level of high power density core technologies to TRL 6 through ground testing by 2026
MOP-5	Raise TRL of turbofan power extraction and insertion to TRL 5 through altitude ground testing by 2024

Key Performance Parameter (KPP)

The KPPs define the success criteria of the HyTEC technology development and core ground demonstration.

KPP#	Key Performance Parameter (KPP)	Full Success Single Aisle ~2035 EIS	Min. Success Single Aisle ~2035 EIS
KPP-1	Fuel burn reduction attributed to the high power density core of the original equipment manufacturer’s (OEM) vision turbofan engine	10%	5%
KPP-2	Engine Bypass Ratio	> 15	> 12
KPP-3	Engine Overall Pressure Ratio	> 50	> 45
KPP-4	Durability, measured in operating hours between major refurbishment	Exceed SOA by 5%	Meet SOA of baseline
KPP-5	Degree of hybridization measured by level of power extraction from the turbofan engine	20%	10%
KPP-6	HPC Exit Corrected Flow	< 3 lbm/s	< 3.5 lbm/s

Technical Performance Measures (TPM)

This will be developed once we award the contracts.

Per the NRA:

> **Technical Performance Measures (TPMs) are a set of performance measures that will monitor progress and identify deficiencies that may jeopardize meeting the MOPs.**
>
> **The Offeror is expected to define the TPM's for each technology proposed, the TPM(s) shall be identified and an estimate of the technology's contribution to the appropriate KPP's shall be provided.**

Key Requirements in NRA

These are elements contained in Draft NRA that are critical to HyTEC.

Per the NRA:

- **NRA focus on Phase 1 Technologies with TRL 4-5 goal by 2023**
- **NASA intends to invest in aggressive, impactful technologies**
- **Must show clear path to TRL 6 by 2026**
  - Path for technology integration into a system level engine core demo, and eventual product
- **Clear contribution to KPP's and other performance metrics**
- **Must be within technology areas listed in NRA**

Programmatic Consideration

- **HyTEC is seeking a minimum 50/50 cost share**
  - Includes in-kind contributions
  - NASA facility in-kind shall be accounted for in the proposals

- **HyTEC plans to invest NASA share of ~$7M per year total on the NRA contracts**

Highlights

- NASA intends to use the Offerors proposed work plan as the SOW in section C of the contract.
- Using the NRA process allows us to chose parts of the Offerors proposed work plan to award in several technology areas.
- Intended to be a 50/50 cost share. Cost share is being used as an evaluation factor.
- Per NFS 1835.016-71(d)(4), Competitive range determinations shall not be made, and final proposal revisions shall not be requested.

Black Out Period

Communications allowed:

- Industry Day including One-On-Ones
- Responses to questions that are sent to the COs/HyTEC email address
  - These questions and answers are subject to be posted on BETA.SAM for public knowledge.

Once the final NRA has been posted, NASA will formally publish the Blackout Period Notice.

HyTEC Evaluation Criteria

Each proposal will be evaluated by a NASA panel. Criteria B-D and its sub-elements below will be evaluated and given a numerical score between 4-10.

A. Past Experience (Acceptable/ Unacceptable)

B. Relevance, Potential for Implementation, and Impact (40%)
- Relevance to NASA goals and efficiency benefits—25%
- Technology readiness level—25%
- Path to small core/ future product—25%
- Impact and benefits—25%

C. Technical Approach and Capabilities (30%)
- Overall approach—65%
- NASA contributions—25%
- Team qualifications—10%

D. Proposed Work Plan (30%)
- Overall work plan—35%
- Technology assessment—25%
- Cost share—25%
- Intellectual property—10%
- Documentation—5%

Evaluation Score and Rating Definitions

Score	Ratings	Definition
10	Exceptional	See NRA for Details
8-9	Good	
6-7	Fair	
4-5	Poor	

HyTEC Evaluation Criteria

Overall Evaluation

The evaluation panel will consider technical merit to be significantly more important than proposed price. The best value selection decision will be made with these considerations:

- A numerical scoring system will be used to identify strengths, weaknesses, deficiencies and risks and determine the overall technical merit of the proposal.
- If there are significant differences in technical merit among competing proposals, a more expensive proposal may be selected for award, one where value of the selected proposal is deemed to be worth the price differential.
- Conversely, as technical scores become closer, differences in cost/price increases importance. Total evaluated price will be the determining factor for award where all proposals are considered equal from a technical merit standpoint.

HyTEC Phase 2 Transition

Approach to Engine Core Demonstration

Goal to carry successful technologies from Phase 1 into Phase 2:

- HyTEC intends to continue to cost share the technologies in Phase 1 that have met the goals for performance, and TRL 4-5
- Goal is to show these technologies mature to TRL 6 by conducting integrated system core ground demonstrations
- NASA will cost share the technologies carried forward from Phase 1, NOT the entire core demonstration
- Funded technologies must be aggressive, impactful, and make significant contribution to HyTEC project goals

NASA

HyTEC Small Core Demo

Goal: Demonstrate increased thermal efficiency with integrated high power-density core engine technologies achieving a 5-10% fuel burn benefit versus 2020 best in class for early 2030s entry into service (EIS) single-aisle aircraft

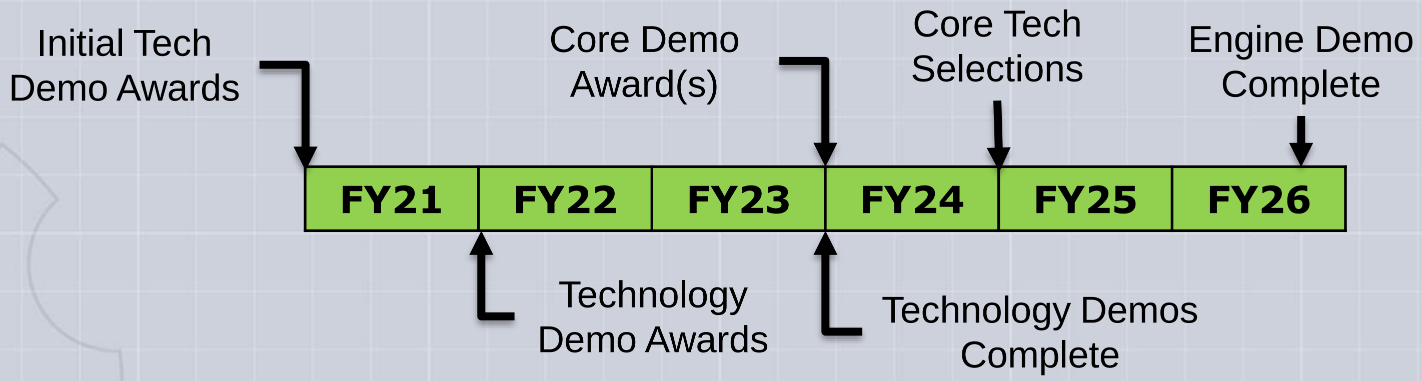
Objectives:

- Reduce engine core size, increase thermal efficiency, and facilitate hybridization
- Accelerate technologies needed for reduced engine core size that enable advanced vehicle architectures
- Characterize and validate the design trade space for conventional and hybrid engines

Approach:

- Partner w/ industry and Government Agencies for ground test of small turbine engine core technologies, with hybridization potential
- Leverage prior NASA/industry small core and hybrid engine technology advances (TRL~4)
- Utilize NASA expertise and facilities to develop key technologies for small turbine engine cores

Potential Milestones



Turbofan Power Extraction Technical Challenge

Goal:

Achieve up to 20% power extraction at altitude from a modern commercial turbofan engine with the thrust, efficiency, operability, and durability to enable the benefits of electrified aircraft propulsion at a vehicle level.

- 20% power extraction is 4 times the current most electrified aircraft (787)

Approach:

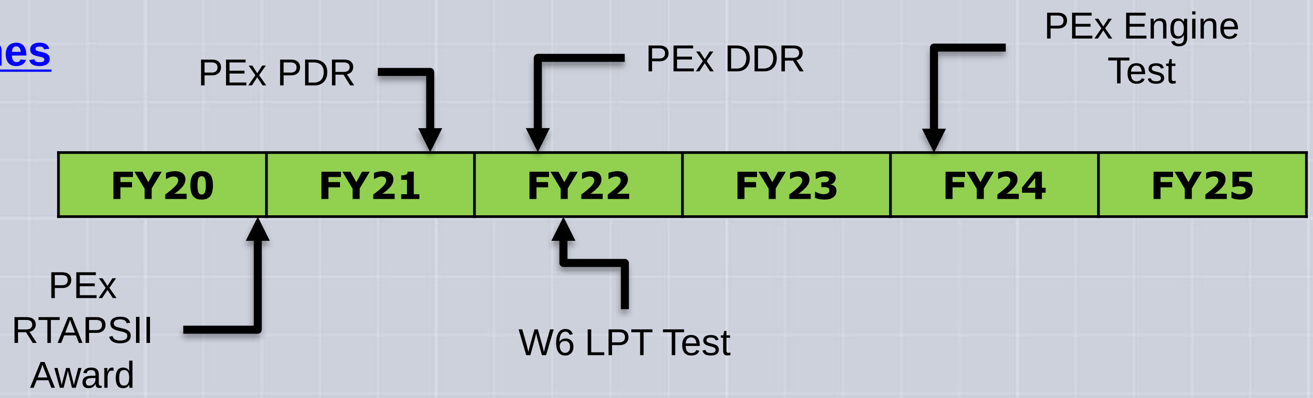
- Demonstrate and evaluate power extraction on a commercial turbofan engine
- Low Pressure Turbine (LPT) Tests, Controls HIL Test, NEAT Controls Test, Power Extraction Engine System Test
- Assess impact of variable power extraction from low and high spools on turbofan performance, operability, and durability
- Develop system model, turbofan model, controls concept, and representative system
- Partner w/industry for power extraction engine test

Potential Integration:

- *Integrate power extraction with small core for integrated demo if feasible*

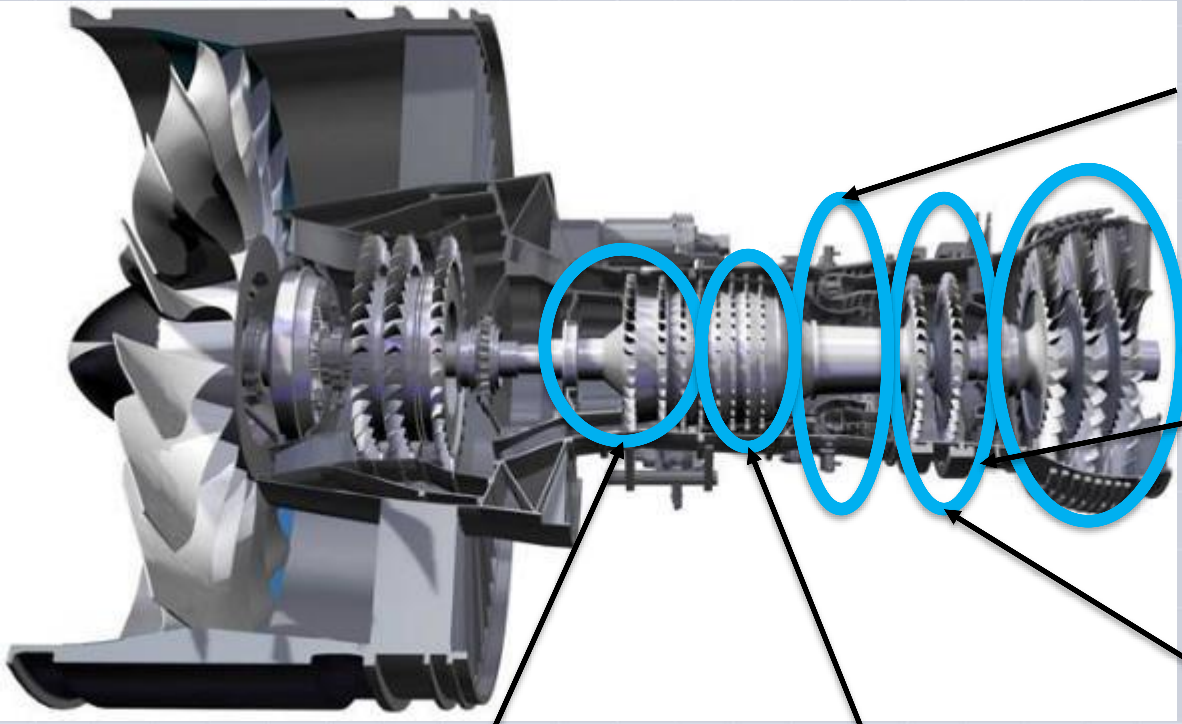
Significant Milestones

LPT – Low Pressure Turbine
HIL – Hardware in the Loop
NEAT – NASA Electric Aircraft Testbed
PEx – Power Extraction
W6 – Core Turbine Facility



HyTEC Technical Content

- Content contained in Phase 1 NRA



Combustor
- Advanced Cooling Strategies
- Ultra Compact Combustor
- Advanced materials

HPT & LPT
- Power Extraction for more electric airplane systems

HPT
- CMC Turbine Blade Development
- Advanced Cooling Strategies
- Advanced Aero Technologies
- Advanced Materials and Coating

HPC
- Rear Block Technologies: Stator Performance and Stability at higher pressure ratios

HPC
- Front Block Technologies: Compressor operability, performance characterization, and aeromechanics
- Advanced Casing Treatments

System Level
- Advanced Thermal Management

Small Core Alignment

Technologies developed under HyTEC shall have a direct path to a future product, which is assumed to have the following characteristics:

- ~180 passengers,
- minimum range of 1500nm
- requiring 25000 – 35000 lbf. of thrust