National Aeronautics and Space Administration

HyTEC
Hybrid Thermally Efficient Core

SAE AeroTech Conference
NASA HyTEC Project Overview

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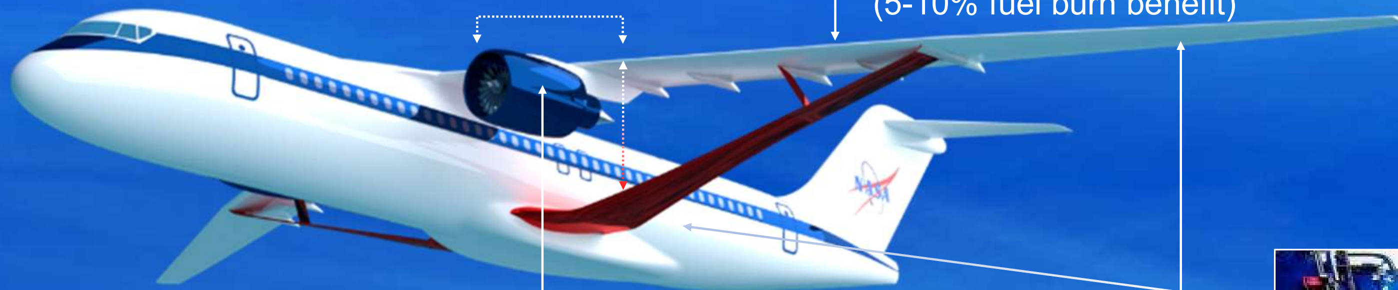
www.nasa.gov

Subsonic Airliner Technologies

Ensure U.S. industry is the first to establish the new “S Curve” for the next 50 years of airliners

Integrated Aircraft System Efficiency
Propulsion Airframe Integration Opportunity

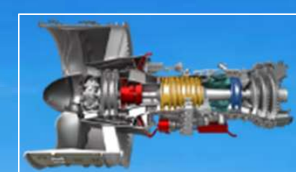
Aerodynamic Efficiency
Transonic Truss-Braced Wing
(5-10% fuel burn benefit)



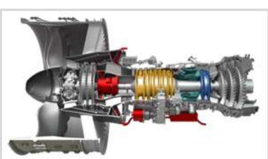
Weight
High-Rate Composites
(4-6x manufacturing increase)

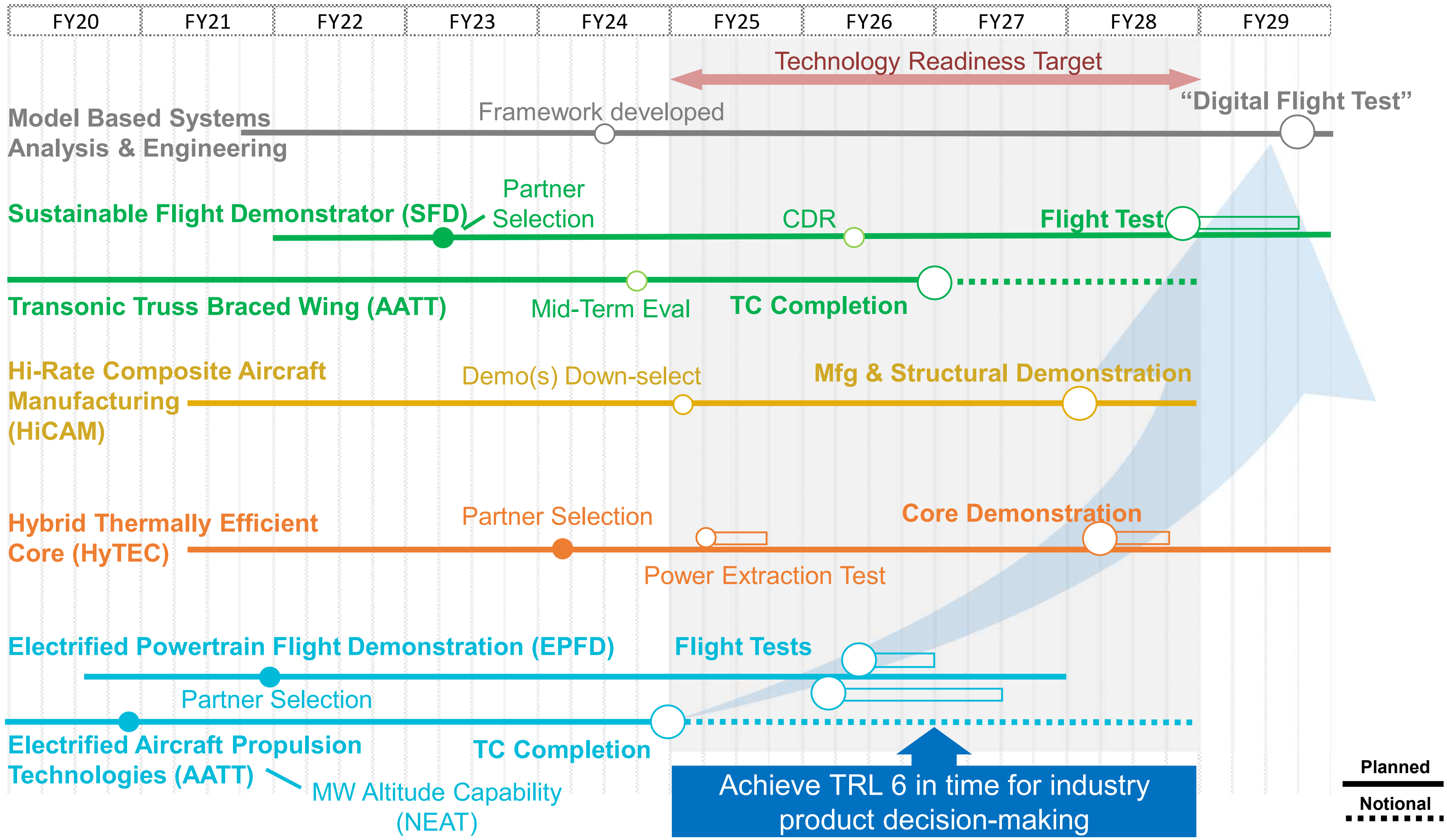
Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit

Engine Efficiency
Small Core Gas Turbine
(5-10% fuel burn benefit)



Subsonic Airliners: Integrated Technology Development
Sustainable Flight National Partnership (SFNP)





Hybrid Thermally Efficient Core

HyTEC Hybrid Thermally Efficient Core

Goal:

- The Hybrid Thermally Efficient Core (HyTEC) Project will accelerate the development of the next generation small-core turbofan engine technologies with improvements in efficiency, durability, performance, hybridization, and sustainability in order to meet the next Entry into Service (EIS) single aisle aircraft expected in the 2030's.

Objectives:

- Achieve **5-10% fuel burn reduction** versus 2020 best in class
- Achieve **up to 20% power extraction** (4 times current state of the art) at altitude to optimize propulsion system performance and enable hybridization
- Demonstrate the effective and efficient operability of high blend **(>80%) Sustainable Aviation Fuels (SAFs)** in 2030s EIS combustors.

HyTEC Metrics

- Small core technologies aligned with future single-aisle propulsion products
- Target engine thrust of 25,000 – 35,000 lb_f

Key Performance Parameter (KPP)	Full Success Single Aisle ~2035 EIS
Engine Bypass Ratio	> 15
Engine Overall Pressure Ratio	> 50
HPC Exit Corrected Flow	< 3 lbm/s

Partner with industry to mature and demonstrate promising technologies.

Propulsion Efficiency through High Power Density Core

Small core:
- Low mass flow rate
- Keeping axial configuration of the High Pressure Compressor (HPC)
- Enables higher bypass ratio

Enabling technologies:
- High Pressure Turbine (HPT):
  - Aerodynamic improvements
  - Advanced materials to increase temp capability and reduce cooling requirements
- HPC aerodynamic and operability improvement
- Compact combustor optimization with SAF compatibility
- Electric hybridization

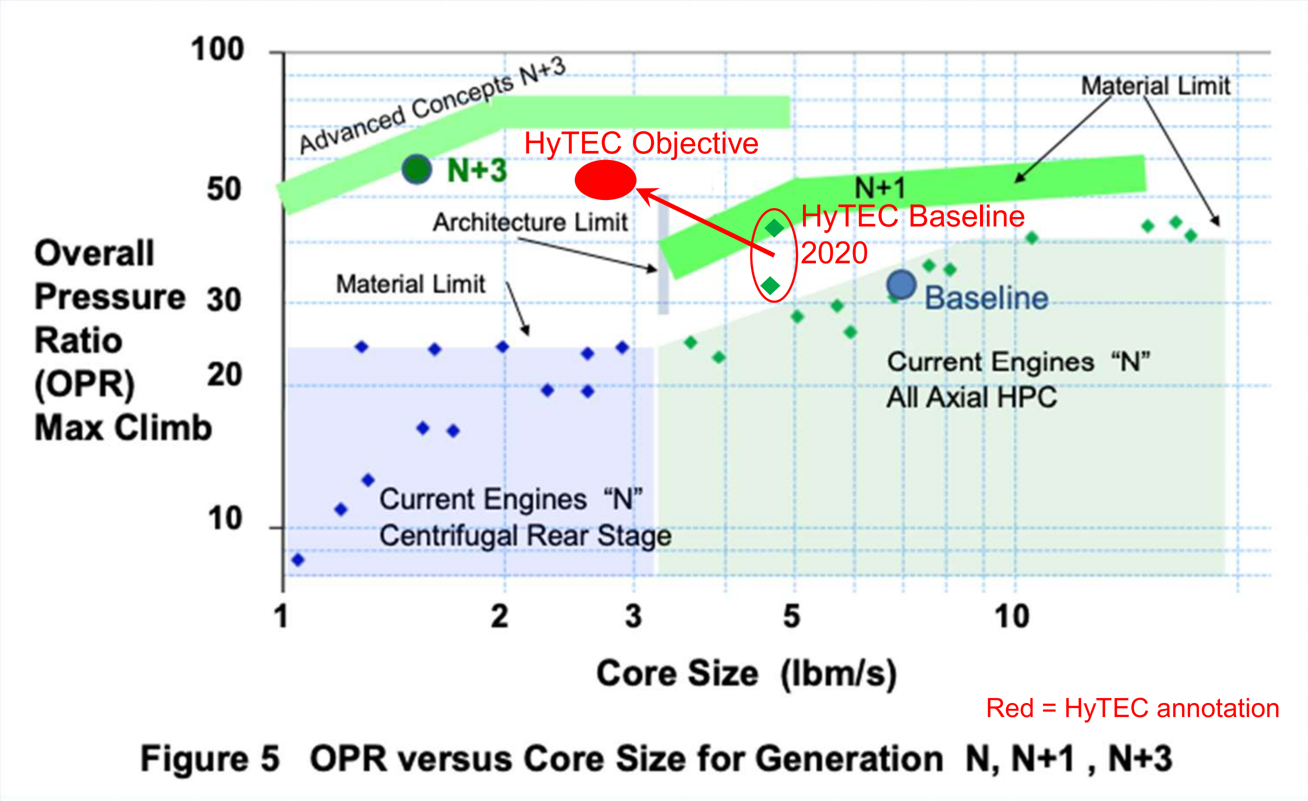


Figure 5 OPR versus Core Size for Generation N, N+1 , N+3

Ref. Lord, W.K. et al.: "Engine Architecture for High Efficiency at Small Core Size," AIAA 2015-00071. https://arc.aiaa.org/doi/10.2514/6.2015-0071

Develop technologies to overcome scaling barriers for compact core.

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 turbofan engine via ground and altitude testing
MOP-2	Develop and demonstrate via ground test an advanced high power density core
MOP-3	Raise the TRL level of high-power density core technologies to TRL 4-5 through component testing by 2024
MOP-4	**Raise the TRL level of high-power density core technologies to TRL 6 through ground testing by 2028**
MOP-5	Raise TRL of turbofan power extraction and insertion to TRL 5 through altitude ground testing by 2025
MOP-6	Raise the TRL of a small core combustor design to TRL 4-5 that provides reliable ignition and lean blowout performance when burning > 80% blend (by volume) SAF by 2025
MOP-7	**Raise TRL of turbofan power extraction and insertion to TRL 6 through integration into a core demonstration by 2028**
MOP-8	**Integrate a small core combustor design at TRL 6 that provides reliable ignition and lean blowout performance when burning > 80% blend (by volume) SAF by 2028**

BOLD: Specific to Core Demonstration Only

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 at altitude	20%	10%
KPP-6	HPC Exit Corrected Flow	< 3 lbm/s	< 3.5 lbm/s
KPP-7	Combustor operability using SAF is comparable to its performance using Jet-A/A-1fuel, as measured by lean blowout and ignition performance.	Combustor operability demonstrated with 100% SAF	Combustor operability demonstrated with >80% SAF
KPP-8	**Degree of hybridization measured by level of power extraction/insertion from the core.**	**10%**	**5%**

BOLD: Specific to Core Demonstration Only

HyTEC Phases

HyTEC Project is divided into two Phases of technology development:

Phase 1

- Address technology challenges through component or sub-system testing and mature a suite of small core technologies to TRL 4-5.
- Lays the groundwork for Phase 2 by maturing promising new technologies that meet HyTEC goals.

Phase 2

- Goal to integrate successful funded Phase 1 and potentially additional TRL 4-5 technologies into a functional high power density engine core demonstration at TRL 6.
- Accelerate technologies for inclusion into the next EIS single-aisle engines earlier to increase US competitiveness in the global market.

HyTEC Phase 1—Technology Development

Accelerate through component or sub-system testing and mature a suite of small core technologies to TRL 4-5.

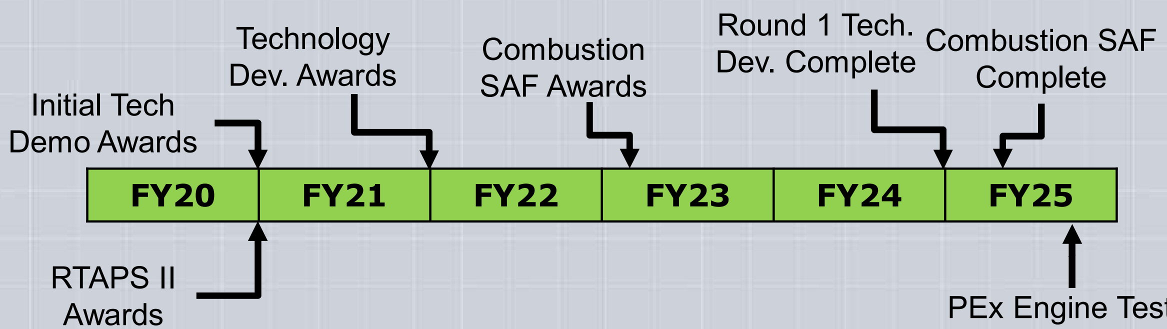
Objectives:

- Invest in aggressive, impactful small core turbofan technologies with development risk.
- Focus technologies on improvements in efficiency, durability, performance, hybridization, and sustainability.
- Assess impact of variable power extraction from low and high spools on turbofan performance, operability, and durability.

Approach:

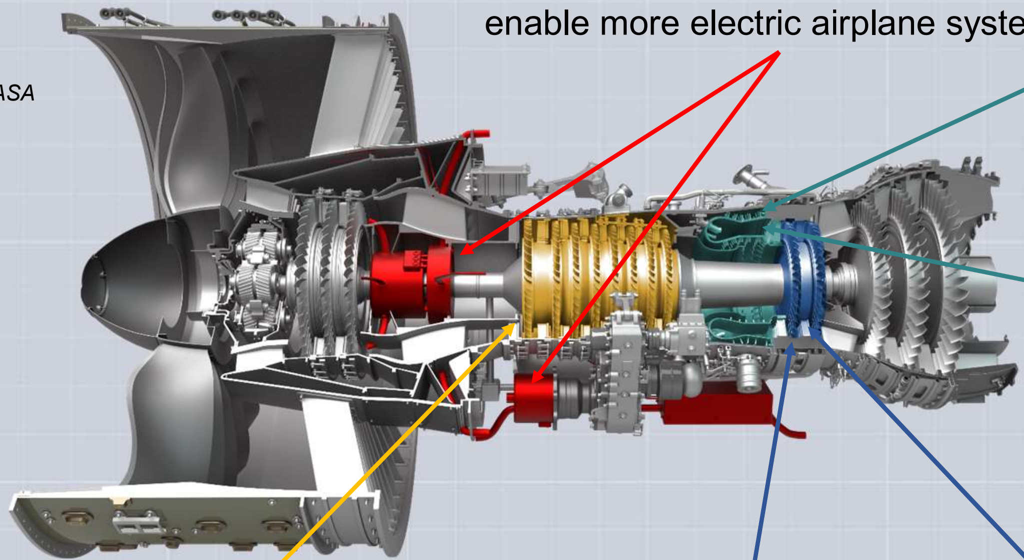
- Partner w/ industry and Government Agencies on technology development.
- Leverage prior NASA/industry small core and hybrid engine technology advances.
- Utilize NASA expertise and facilities to develop key small core technologies.

Milestones



HyTEC Phase 1 Technical Content

Phase 1 NRA Round 1 & Round 2



Turbofan Power Extraction
Dual Spool Power Extraction to enable more electric airplane systems

Combustion Technologies
- Sustainable aviation fuel compatibility
- Compact design for small core engines

Enhanced Combustor Materials
Ceramic matrix composite (CMC) liners for combustors to increase performance and durability.

High Pressure Turbine (HPT) Materials
- CMCs/Environmental Barrier Coatings (EBCs) for turbine components to increase temperatures and efficiency.

High Pressure Compressor (HPC)
Casing treatments and advanced designs to enable operability with optimized efficiency and performance.

Advanced HPT Aerodynamics
Enable more efficient turbine operation by developing advanced blade and cooling designs and aerodynamic features.

Phase 1 Technology Development Portfolio

Contract	Technology Area	Partner	ECD
NRA	High Pressure Compressor	GE Aviation	Q4 FY24
	High Pressure Turbine Advanced Aerodynamics	GE Aviation	Q2 FY24
	High Pressure Turbine Advanced Aerodynamics	Pratt & Whitney	Q1 FY25
	High Temperature Environmental Barrier Coatings	GE Aviation	Q2 FY24
	Ceramic Matrix Composite and EBCs	Pratt & Whitney	Q2 FY25
	Ceramic Matrix Composite Combustor Liner	GE Aviation	Complete
	Sustainable Aviation Fuel (SAF) Combustion Technologies (Round 2, awarded September 2022)	Pratt & Whitney	Q1 FY25
RTAPS II	Turbofan Engine Power Extraction Demonstration	GE Aviation	Q4 FY25
	Ceramic Matric Composite Turbine Blade Durability Enhancement	GE Aviation	Complete

Phase 1 Technology Development Portfolio

Advanced Materials Development: Testing at NASA GRC Facilities

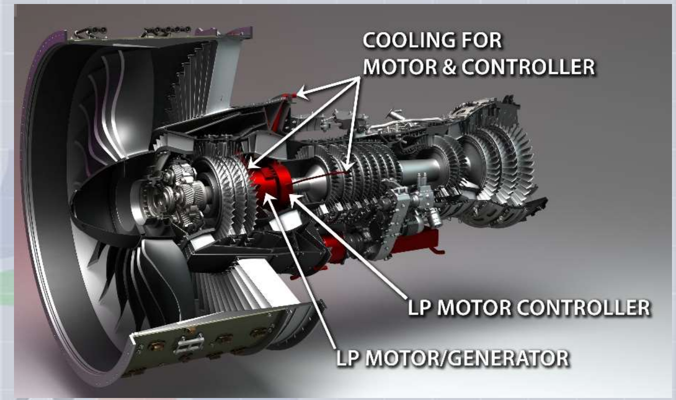
Dr. Michael Presby testing a NASA-developed, high-temperature environmental barrier coating (EBC) deposited on a ceramic matrix composite (CMC). The composite's environmental barrier coating surface temperature is 3,000 degrees Fahrenheit.

Dr. Bryan Harder describes hardware that will allow researchers to test an advanced CMC airfoil with an innovative EBC in a combustion environment. This test will be used to show the capability of these materials prior to a future engine core demonstration.

Phase 1 Technology Development Portfolio

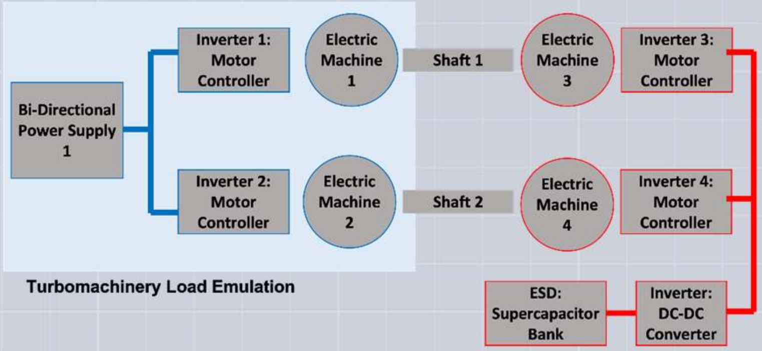
Turbofan Power Extraction (PEx): NASA and GE Aerospace are in partnership to mature a megawatt-class hybrid electric engine that advances technology for single-aisle aircraft.

NASA is conducting system analysis trade studies and controls hardware in the loop tests to advance technologies and to assess the performance impact of power extraction and insertion for commercial hybrid turbofans.



NASA Concept Hybrid Turbofan

Megawatt-Scale Controls Test



Kilowatt-Scale Controls Test with Energy Storage

HyTEC PEx Key Performance Parameter: 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 Systems Analysis

HyTEC has engaged the Systems Analysis team to assess the progress of the Phase 1 Technologies against HyTEC performance metrics.

Baseline models calibrated to public data

Baseline Engine:

- CFM LEAP 1B28

Engine cycle design:

- Numerical Propulsion Simulation System (NPSS)

Engine weight estimates:

- Weight Analysis of Turbine Engines (WATE++)

Parameter	Model Results
Takeoff thrust rating (lbf)	29,317
Bypass ratio	8.6
Overall pressure ratio (TOC)	44.6
Core Size (lbm/s)	4.23
TSFC (Cruise, lbm/h/lbf)	0.56

HyTEC Systems Analysis

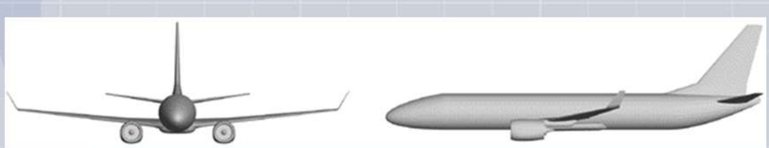
Baseline Models and Analysis Tools

Baseline Aircraft

- Boeing 737 MAX 8

Mission and sizing analysis:

- Flight Optimization System (FLOPS)



OpenVSP render of the reference aircraft used to define the geometric inputs to FLOPS

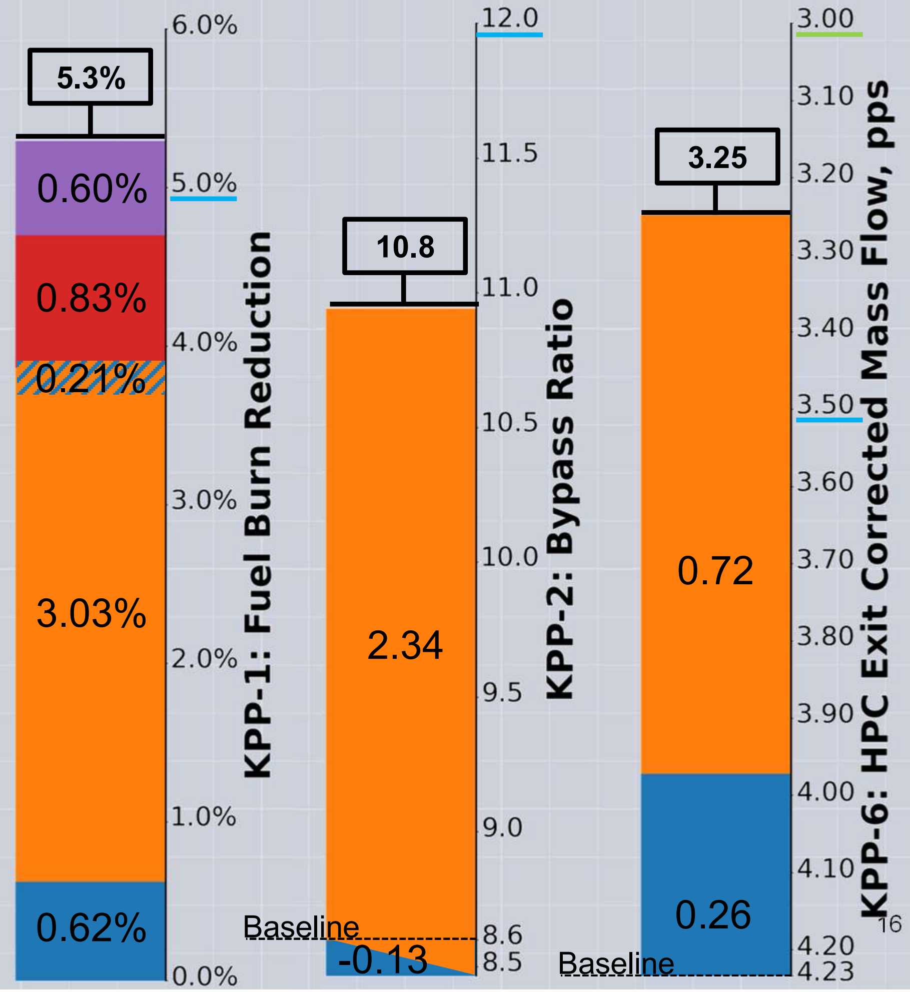
Parameter	Model Results
Max Design TOGW (lb)	182,200
Max Payload (lb)	46,040
Cruise Mach	0.78
Economic Range (NM)	1000
Economic Range Block Fuel (lb)	9,664

HyTEC Systems Analysis—Forecasted KPP Impact

HyTEC Full Success

HyTEC Min Success

Modified LEAP-1B28 like NPSS Model	
HPC Advanced Loading	• OPR: +10% → 49.0 (TOC)
HPC Advanced Casing Treatment	• $\eta_{Poly,HPC}$: +0 pnts
HPT Advanced Materials	• $T_{41,max}$: +215 F • $T_{metal,HPT}$: +300 F
HPT Advanced Cooling	• HPT TCA: -38% • η_{HPT}: +1.53 pnts
HPT Aerodynamic Improvements	• η_{HPT}: +0.5 pnts
Re-engine B737 MAX 8 like FLOPS Model	
Aircraft sizing and mission analysis	• Vision engine deck used
Aircraft sizing and mission analysis with reduced engine weight	• Vision engine deck used • 440 lbs engine weight reduction applied



HyTEC Phase 2—Core Ground Demonstration

Integrate key small core technologies into a full engine core to demonstrate a functional high power-density small core at TRL 6.

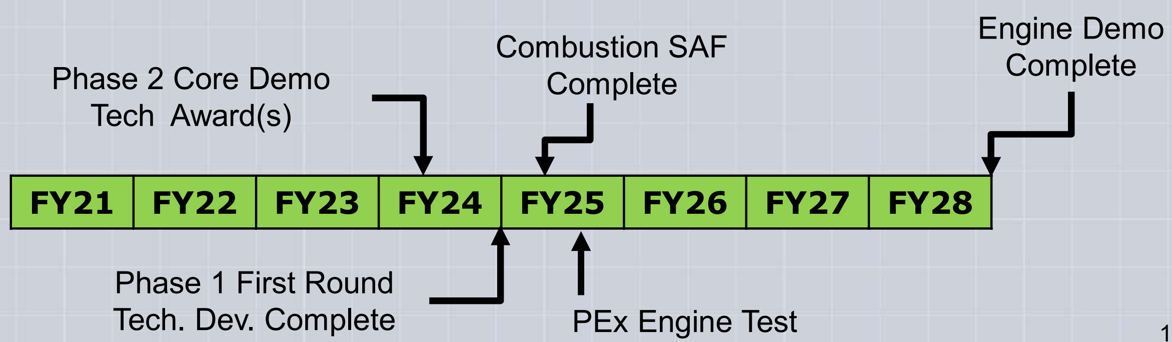
Objectives:

- Integrate technologies that enable reduced engine core size and advanced vehicle architectures.
- Integrate power extraction with small core for integrated demo if feasible.
- Demonstrate technologies achieve a 5-10% fuel burn benefit versus 2020 best in class.

Approach:

- Leverage technologies matured to TRL 4-5 from Phase 1 (not limited to HyTEC Phase 1 contracts).
- Partner w/ industry and Government Agencies for ground test of small turbine engine core technologies, with hybridization potential.

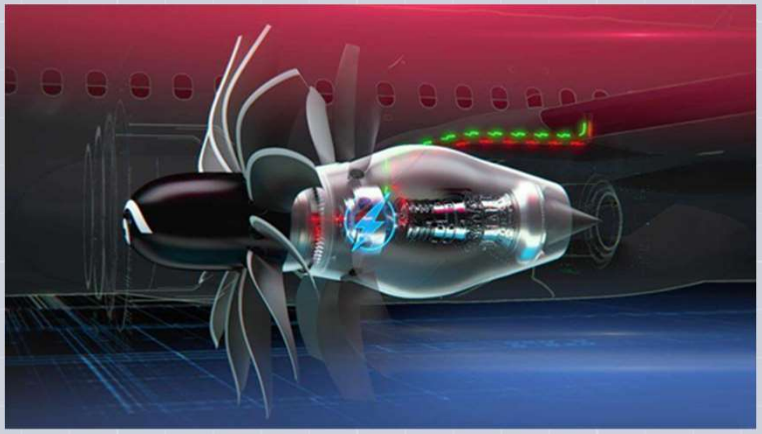
Milestones



HyTEC Phase 2 Contract Award

Phase 2 Engine Core Demonstration Contract

- NASA selected GE Aerospace of Cincinnati for HyTEC's Phase 2 Integrated Core Technology Demonstration.
- Cost-share contract with a maximum government value of approximately $68.1 million and a 50% minimum GE Aerospace cost share.
- Five-year performance period that began Feb. 15, 2024.

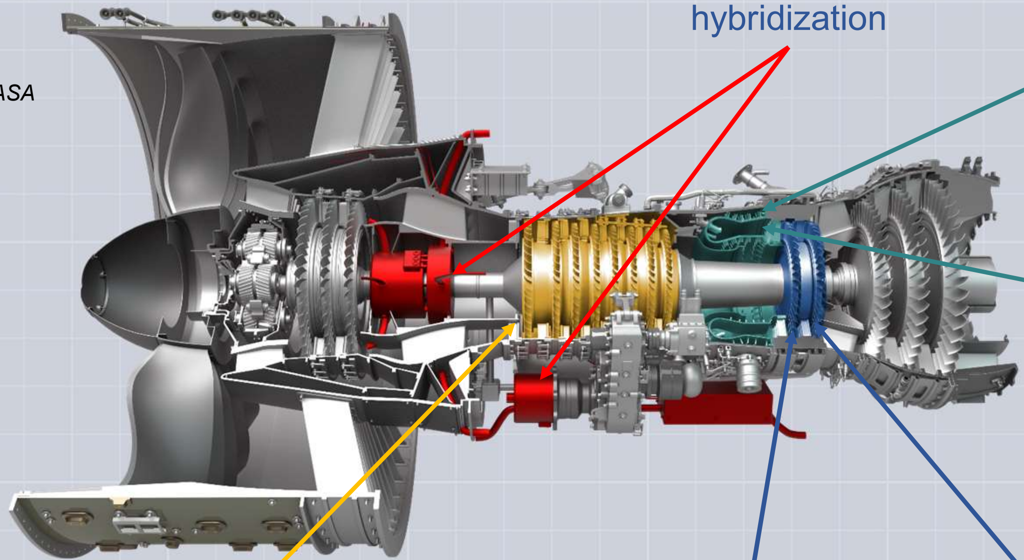


GE RISE Engine Concept

To meet the goal of HyTEC Phase 2, GE Aerospace will integrate Phase 1 technologies into an engine core to perform a compact, high-power density core ground demonstration by the end of 2028.

HyTEC Phase 2 Technologies

➢ Blue technologies were awarded to GE Aerospace.



Credits: NASA

Turbofan Power Extraction
Power extraction to enable hybridization

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Advanced HPT Aerodynamics
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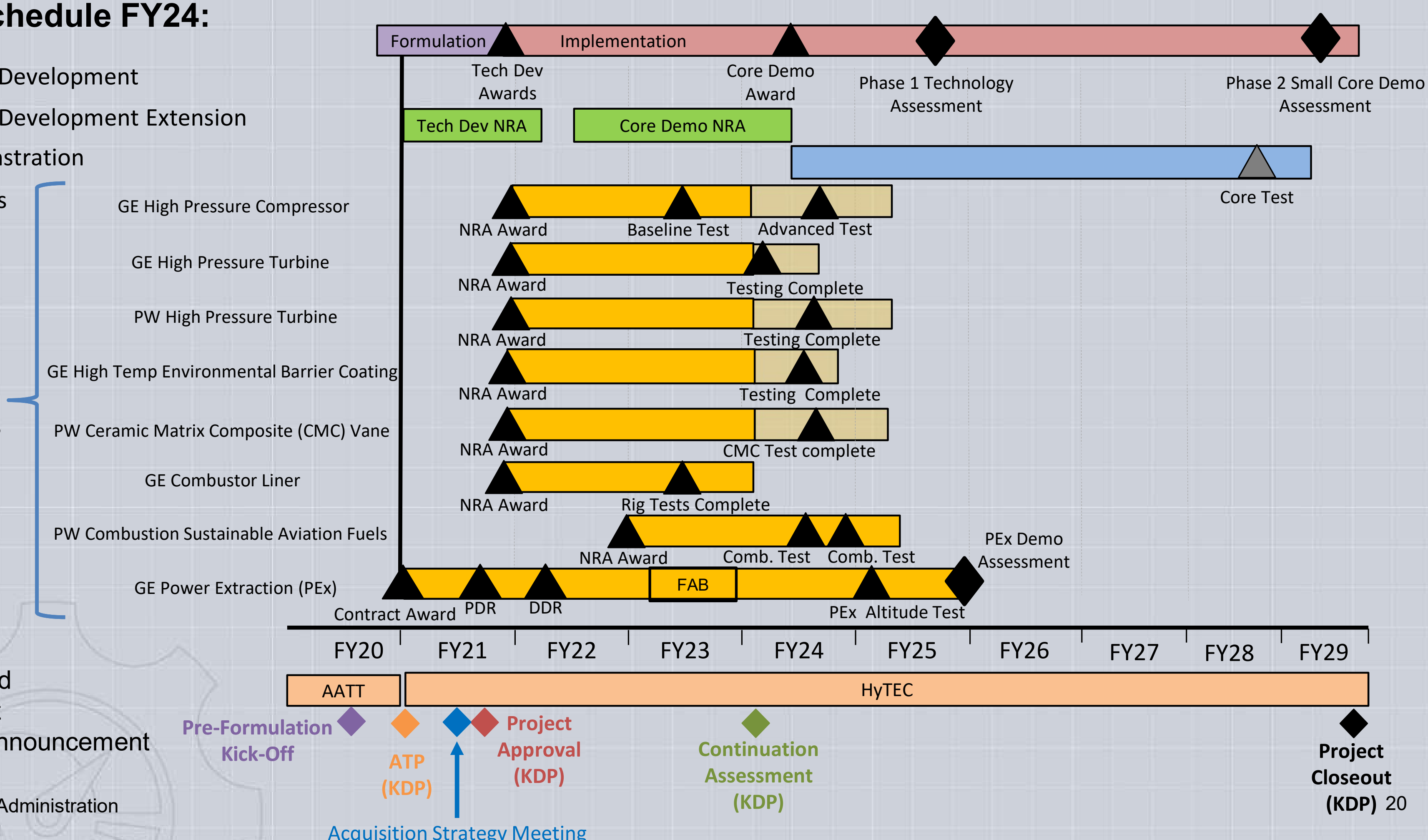
HyTEC Project Overview

Current Project Schedule FY24:

- Phase 1—Technology Development
- Phase 1—Technology Development Extension
- Phase 2—Core Demonstration
- Procurement Activities
- Level 2 Milestone
- Level 1 Milestone



ATP – Authority to Proceed
KDP – Key Decision Point
NRA – NASA Research Announcement

NASA