An Approach to Evaluating the Impact of Small-core Turbofan Technologies on Engine and Aircraft Performance

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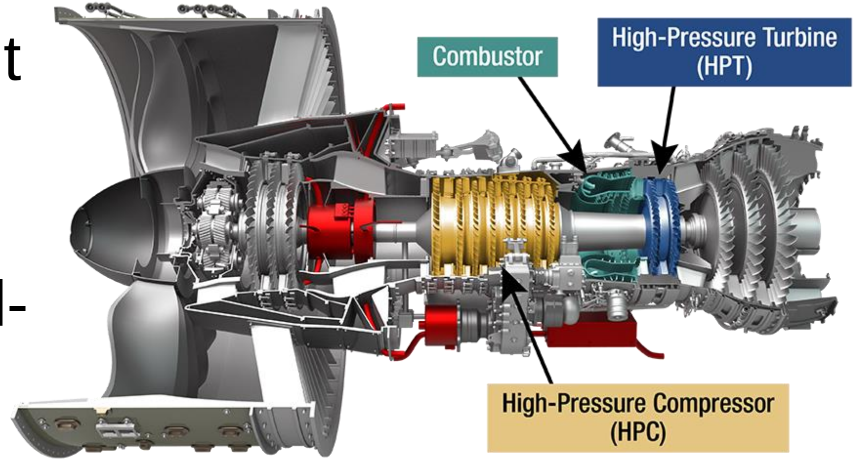
Introduction

- HyTEC: Hybrid Thermally Efficient Core
- Objective: Demonstrate a method for forecasting the impact of small-core technologies on HyTEC Key Performance Parameters (KPPs)
  - KPP1 - Reduced fuel burn 5-10%
  - KPP2 - Engine BPR 12 - 15
  - KPP3 - Engine OPR 45 - 50
  - KPP6 - HPC exit corrected mass flow (core size) 3 - 3.5 lbm/s



Cross-section of a turbofan engine with core components highlighted.
Credit: NASA

Approach Outline

- Develop current-technology propulsion and aircraft models and baseline the KPPs
- Integrate small-core technologies into the baseline propulsion model by altering design parameters
- Assess sensitivity of KPP to design parameter changes
- Develop a notional "vision" system
- Integrate vision propulsion systems and baseline aircraft
- Quantify the impact of technologies on the KPPs

Baseline Models and Analysis Tools

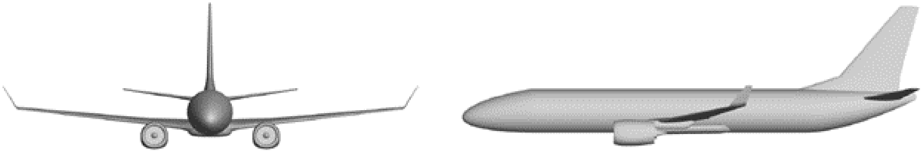
- Baseline models calibrated to public data
- Baseline Engine:
  - CFM LEAP 1B28
- Engine cycle design:
  - Numerical Propulsion Simulation System (NPSS)
- Engine weight estimates:
  - Weight Analysis of Turbine Engines (WATE++)

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

Baseline Models and Analysis Tools

- Baseline Aircraft
  - Boeing 737 MAX 8
- Mission and sizing analysis:
  - Flight Optimization System (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

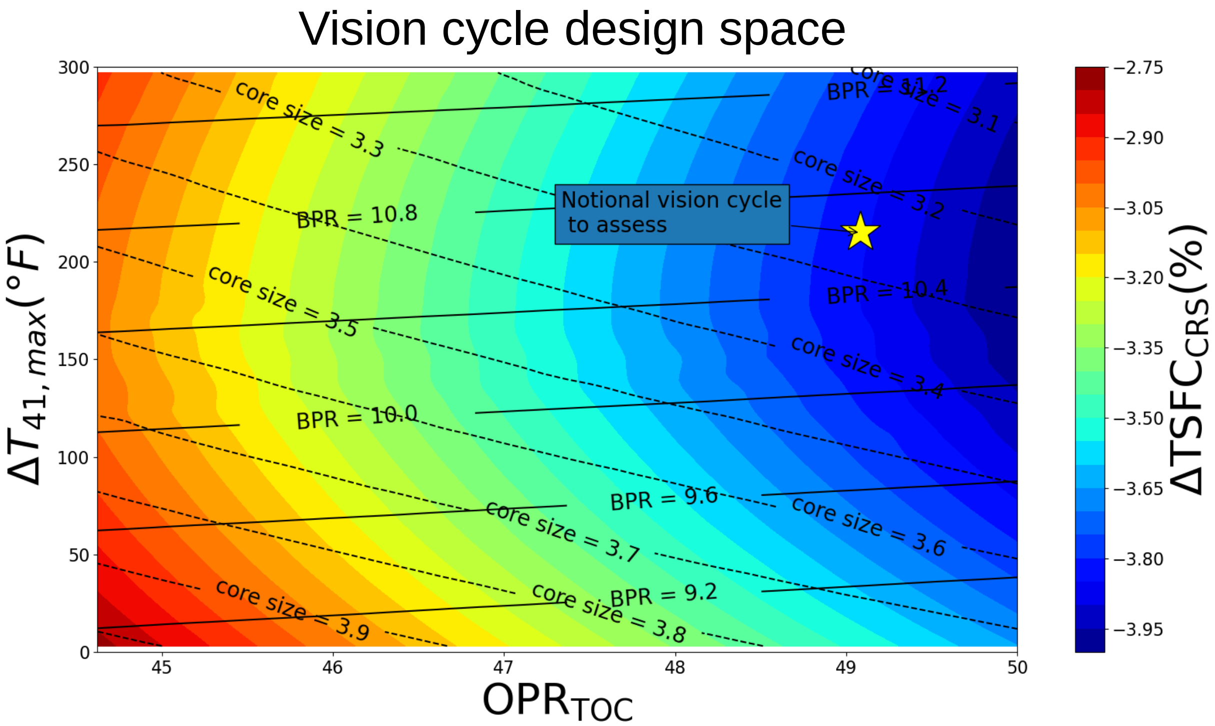


OpenVSP render of the reference aircraft used to define the geometric inputs to FLOPS

Technology Integration

Component	Technology	Cycle Parameters	Aeromechanical Parameters
High Pressure Compressor	Advanced design	HPC pressure ratio	Stage loading
	Casing Treatment	HPC polytropic efficiency ($\eta_{poly,HPC}$)	-
Combustor	Advanced materials	-	Material density
High Pressure Turbine	Advanced aerodynamics	Adiabatic efficiency (η_{HPT})	Stage loading
	Advanced materials	HPT blade 1 inlet temp ($T_{41,max}$)	Material density
		HPT material temp ($T_{metal,HPT}$)	
		Turbine cooling air (TCA) $TCA = f(T_{41,max}, T_{metal,HPT})$	
		Efficiency $\Delta\eta_{HPT} = f(\Delta TCA)$	

KPP Sensitivities / Vision Cycle Design Space

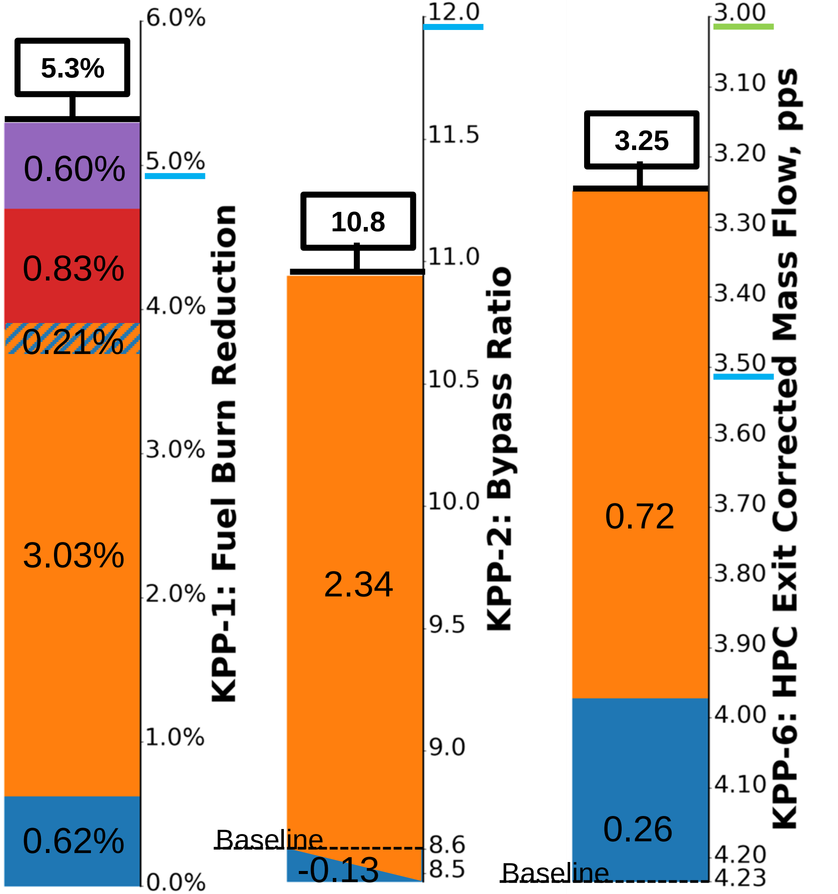


- Assumptions
  - Max OPR = 50
  - $\Delta T_{41,max}$: 0°F - 300°F
  - 300°F HPT material temperature improvement
  - $TCA = f(T_{41,max}, T_{metal,HPT})$
  - HPT efficiency improvements
    - +0.5% from advanced aerodynamics
    - +0.04% per 1% reduction in HPT TCA

Notional Vision Cycle & 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



Summary and Conclusions

- Demonstrated an approach to examining the impact of small-core technologies on turbofan performance and aircraft fuel burn.
- The approach involves integrating small-core advancements into current technology systems models
- Results indicate that comprehensive core development is likely needed to meet HyTEC KPPs
- Future research could expand the scope of this study by investigating a broader spectrum of advanced technologies and their integration with novel engine and aircraft designs.

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