GE VERNOVA

High Temperature Additive Architecture for 65% Efficiency

DE-FE0031611

GE Gas Power

PI: Richard DiCintio

PM: Carlos Miranda

Key Contributors: Ben Lacy, Srikanth Kottilingam, Brad VanTassel, Evan Dozier, Tim Moricca

Conference presenter

Scott Johnson

FECM / NETL Spring R&D Project Review Meeting

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GE-NETL Partnership Leads to Record Performance

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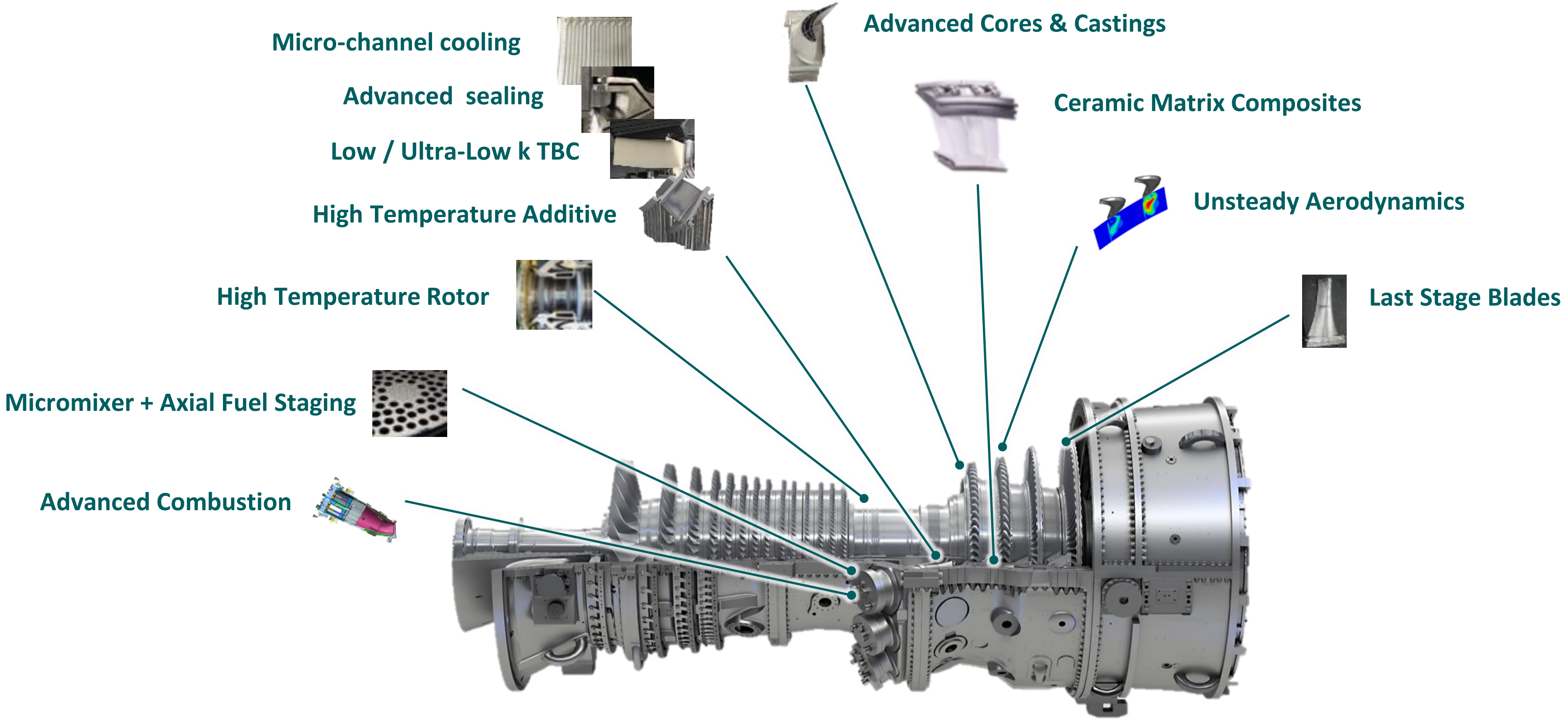

57% to 64%+ Combined Cycle Efficiency in 15 years!

Agenda

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- Impact of Additive at GE
- Industrial Gas Turbine Terminology
- Phase I Objectives
- Phase II Key Technology Activities
- Phase II Validation Testing
- Phase II Next Steps

Impact of Additive at GE

Performance

- Removes traditional mfg. constraints
- Enables "near surface" cooling & cooling air reduction

Speed to Market

- Model to part directly
- Quick prototypes
- ~18-month cycle

Cost

- Eliminate casting tooling
- Metal only where needed
- Reduction of component counts

Improved Processing Sciences

More Capable Alloys

Advanced Product Designs

Advanced Manufacturing Works – Greenville, SC

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Merging design and manufacturing technology to deliver better products

Additive

- >25,000 parts shipped
- 1st GT parts produced/fielded

Ceramics

- 1st fielded CMCs
- Thermal coatings

Process optimization

- Automation/Digital
- HGP Special Processes
- Reduced cost and lead time

Industrial Gas Turbine Terminology

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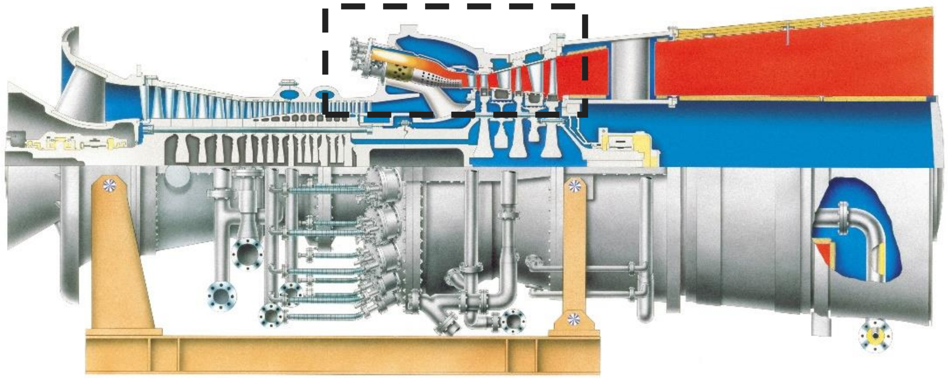
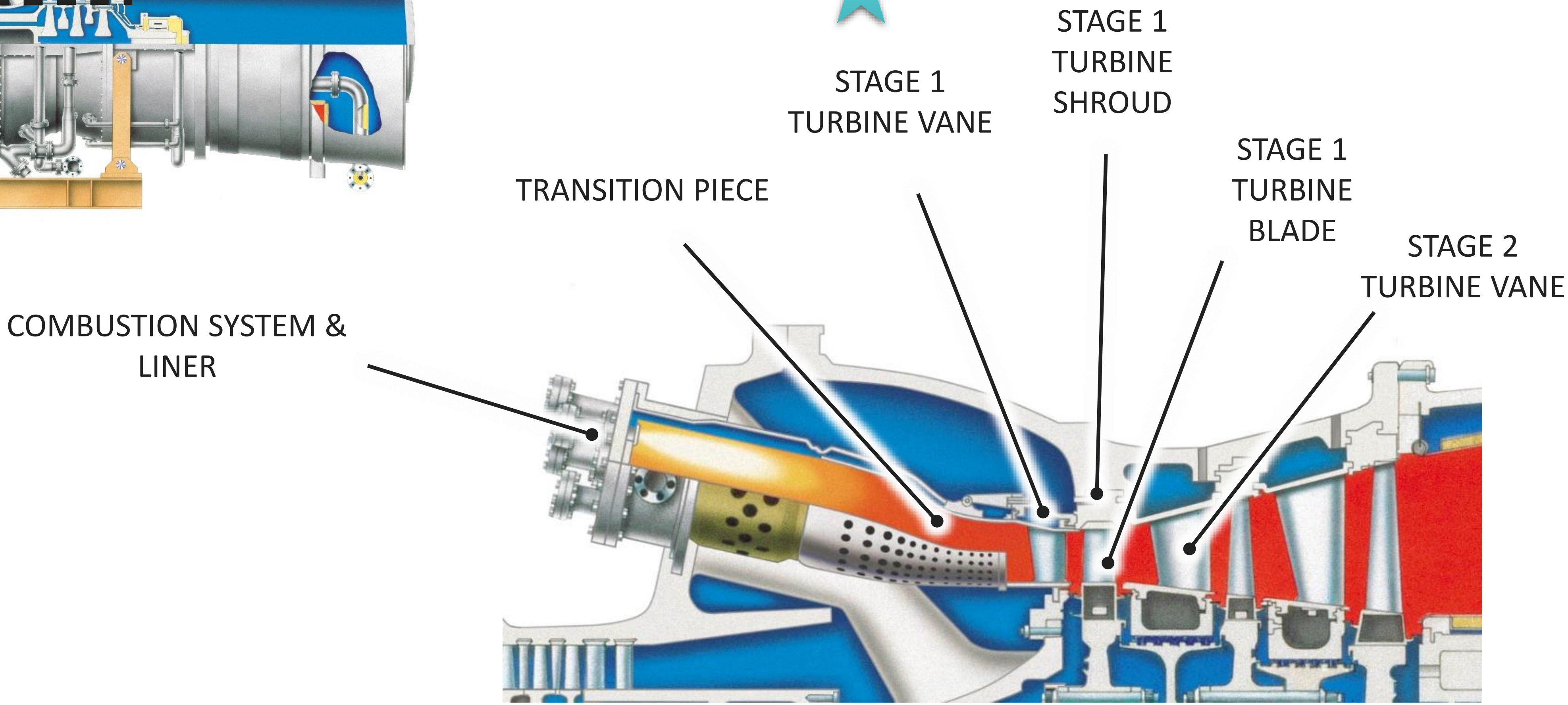
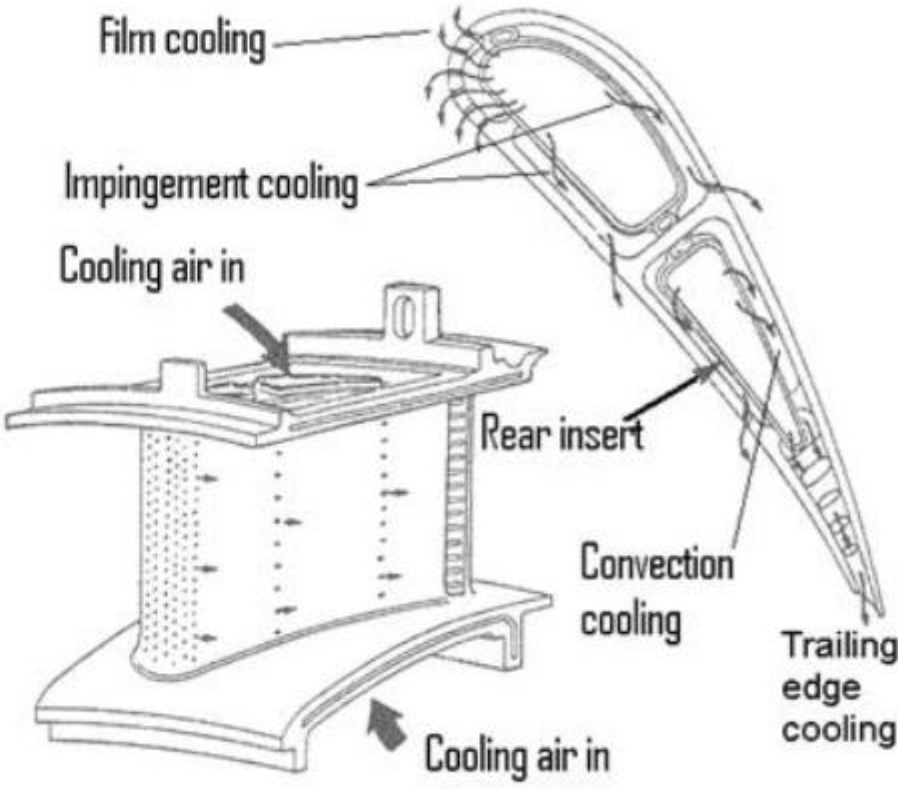


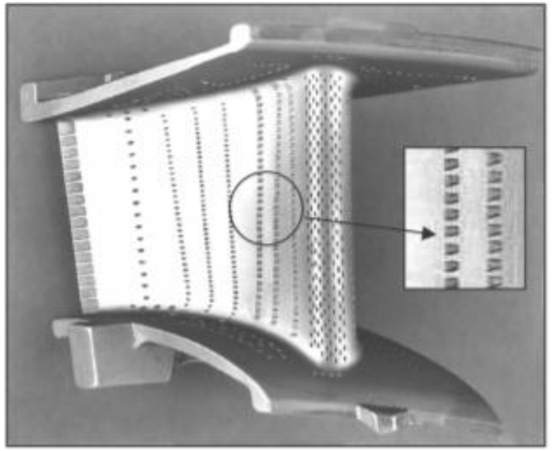


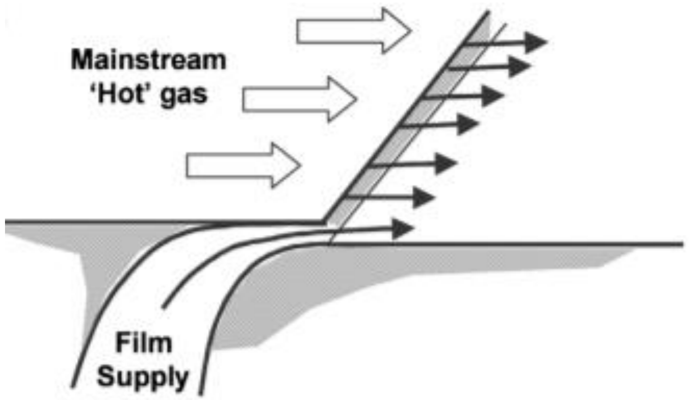
Turbine Vane Conventional Cooling Fundamentals

Internal Cooling Flow Circuit



Surface/External Film Cooling





Project Objectives & Technical Approach

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Overall Objective

Develop a feasible conceptual design for advanced additive turbine inlet components that enable 65% CC efficiency through analytical methods and feature print trials.

Technical Approach

Phase 1 – Discovery (July 2018 – Jan 2020)

- Generate advanced wall architecture and airfoil concepts enabled by additive manufacturing
- Identify and evaluate additive methods and materials that enable desired geometry through coupon print trials
- Downselect a primary concept and additive method/material plus a backup to carry forward into potential Phase II project
- Develop test plan for Phase II execution

Phase 2 – Demonstration (Jan 2020 – Sept 2024)

- Generate high efficiency component design, enabled by additive manufacturing, using state-of-the-art tools and methods.
- Demonstrate manufacturing readiness level for additive manufacturing modalities through extensive print trials and post print inspection.
- Validate individual wall architecture and cooling concepts with laboratory environment testing.
- Demonstrate technology readiness level for component design at representative gas turbine conditions in combustion validation rig.

Program Objectives: Phase I – Discovery

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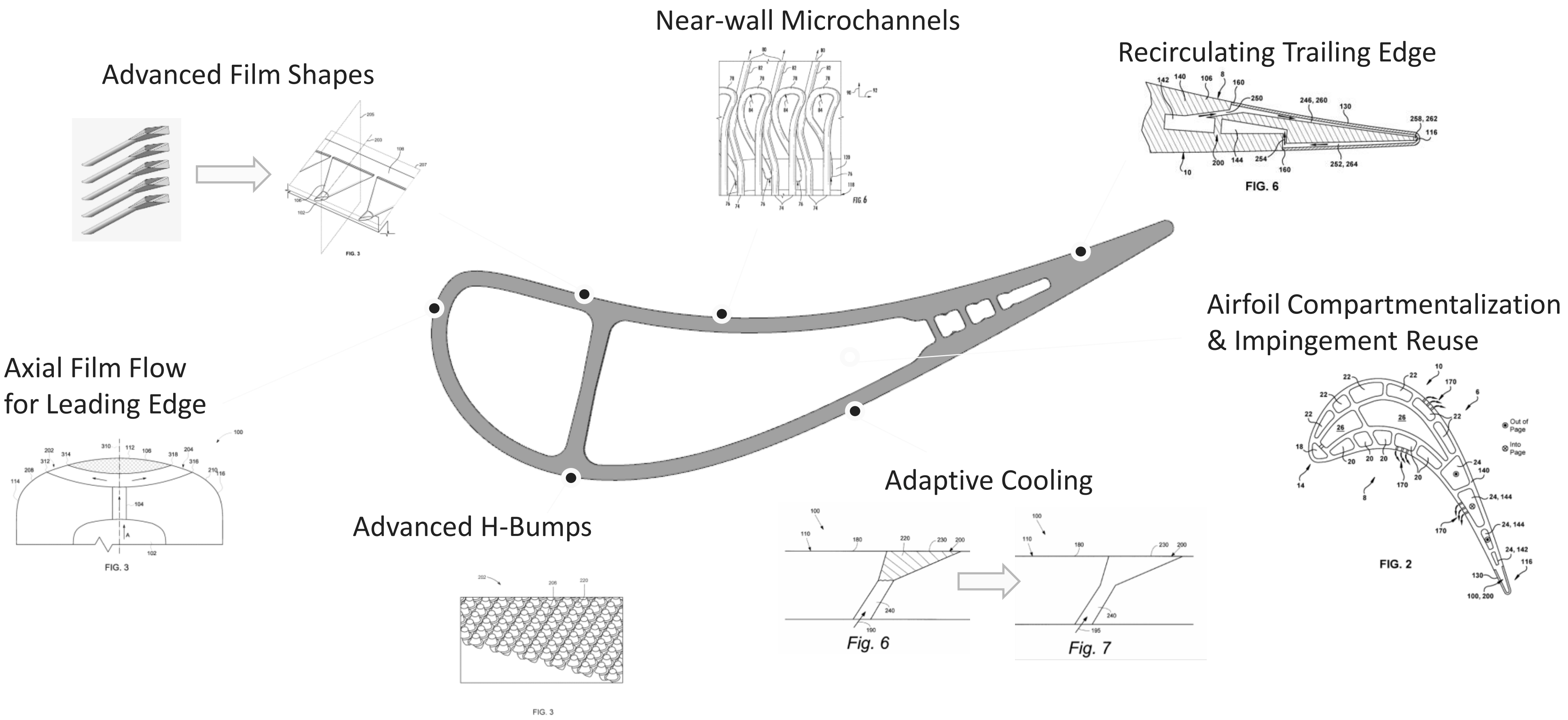
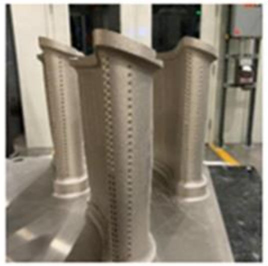
Conceptual Design & Feasibility



Program focus: high-temperature alloys, new additive modalities, geometry enabled by additive, and manufacturing capability

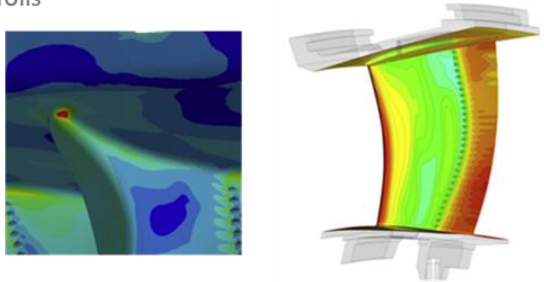
Phase II Key Technology Activities

Additively Printed Features



Additively Printed Airfoils

Additively Printed End walls



Detailed Design – Heat Transfer and Structural

Cooling Technology
Initial scope of thermal correlations for additive cooling features.

Wall Architecture Technology Bench Testing
Correlations of model to printed feature size for different additive modalities.
Flow testing of cooling features, total and by feature.

Additive Process Capability and Control
Powder removal on production viable designs.
Repeatability demonstration/ dimensional control.

Additive Material Properties
Properties for several modalities.

Detailed Design
Heat transfer and structural mechanical.

All activities listed above are complete

Phase II Validation Testing

Test Cell
Vernova Advanced Research
Niskayuna NY

Testing Summary

Tested over 3 days, ~20 fired hours.
No test issues, all key instrumentation preserved.

Testing Envelope

Gas: 2700°F, 2900°F, 3100°F and 3200°F within +/- 5°F
Coolant: 660°F, 760°F with short excursion to 830°F within +/- 10°F

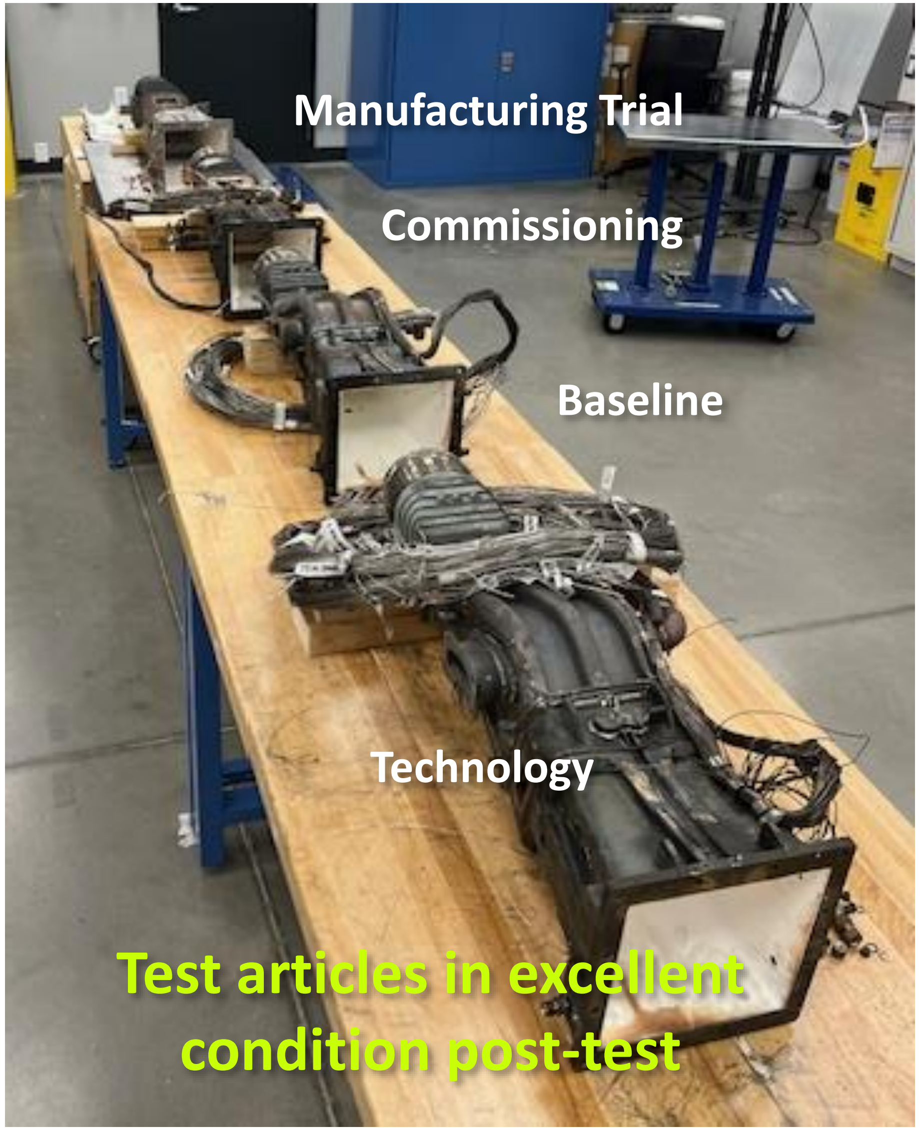
Objectives Achieved

Collected 75 data points.
Generated Baseline Airfoil Cooling Effectiveness Curve by Gas Temperature, Coolant Temperature, Coolant Flow and Gas Flow sweeps.

General Trends

Consistently colder metal temperatures than Baseline for same conditions.

Next Steps



Data Collection

Baseline and Technology test articles to be cut for further inspection, cold flow and metallurgical processing.

TC depth and TBC thickness to be measured.

Data Analysis

Revisiting Heat Transfer models for Technology and Baseline test articles.

Data-matching models to include as tested cooling flows, TBC thickness and operating conditions.

Comparing heat transfer model prediction to TC data.

QUESTIONS?

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