



GE VERNOVA

High Temperature Additive Architecture for 65% Efficiency

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2024 University Turbine Systems Research and
Advanced Turbines Program Review Meeting

Tuscaloosa, AL

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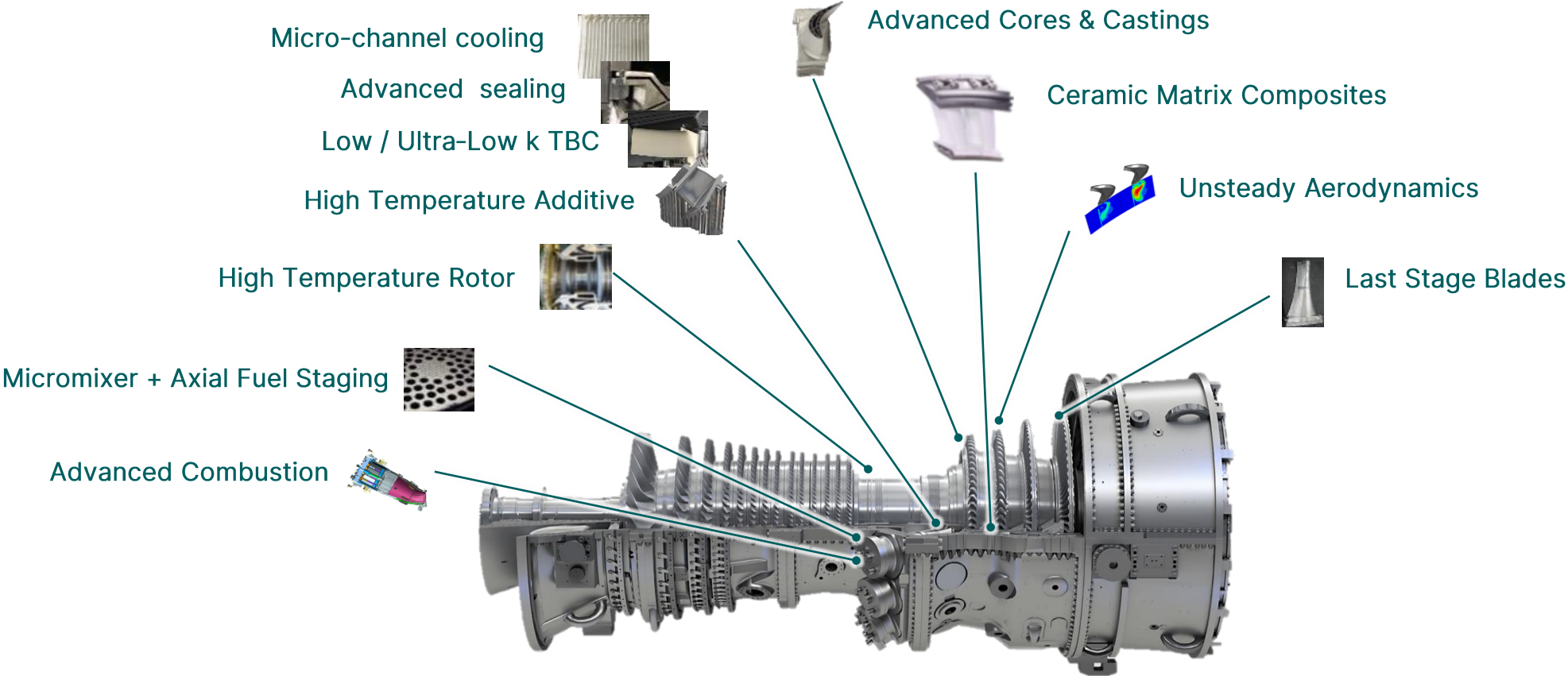


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GE-NETL Partnership Leads to Record Performance GE VERNOVA



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

Agenda

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

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



Merging design and manufacturing technology to deliver better products



Additive

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

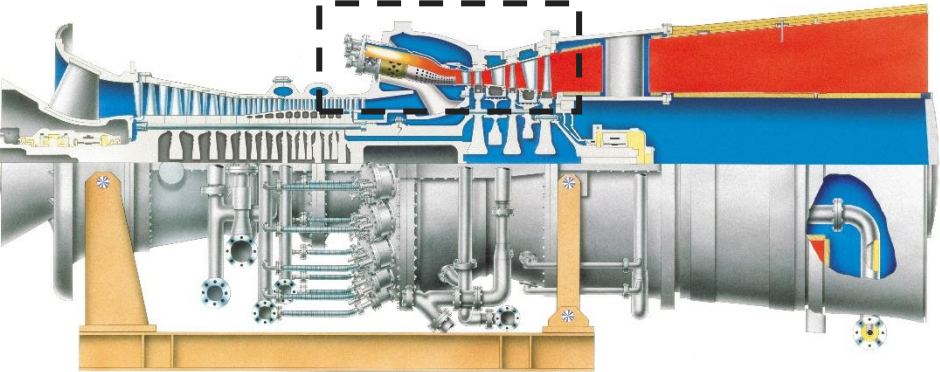
Ceramics

- 1st fielded CMCs
- Thermal coatings

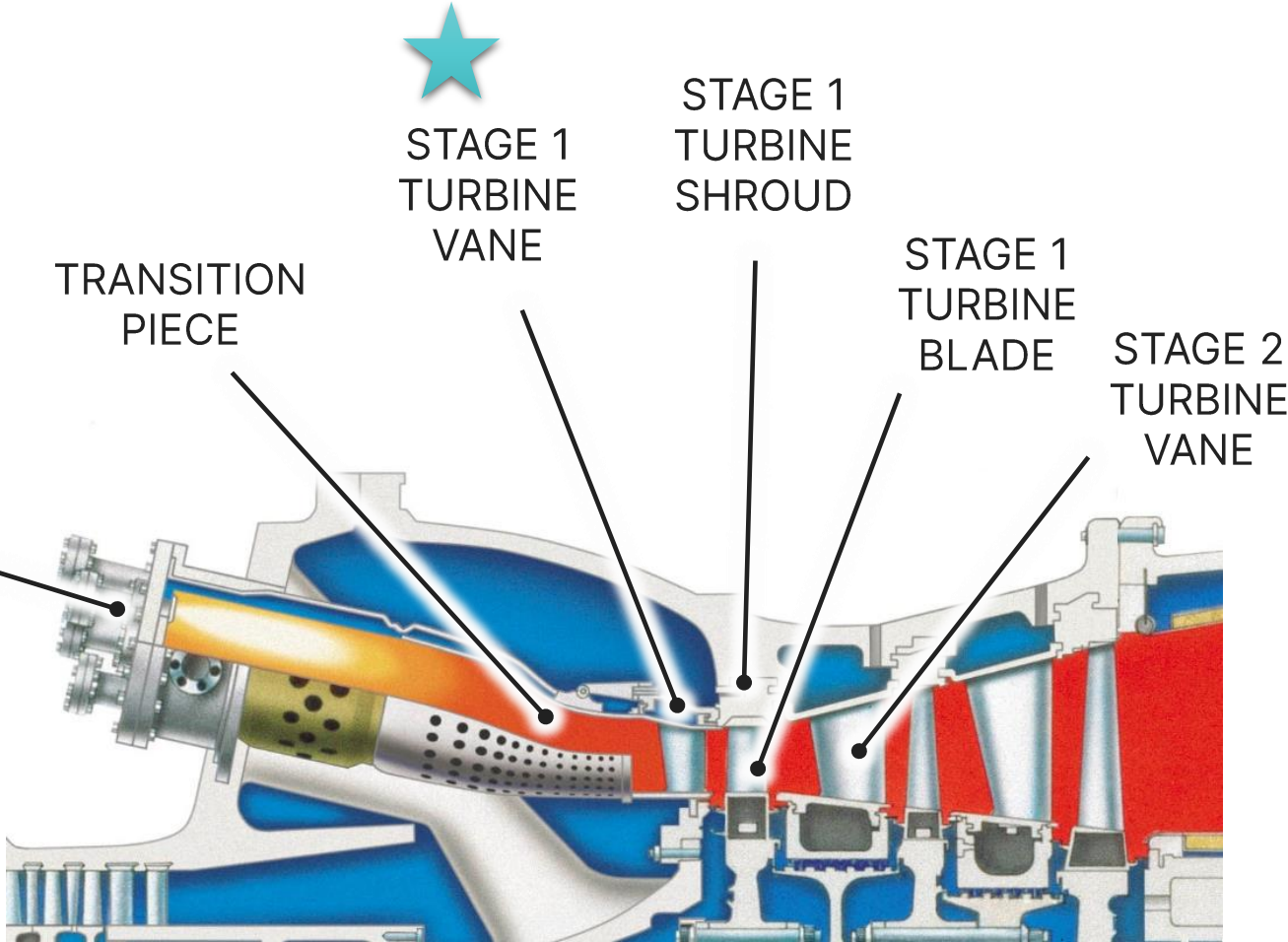
Process optimization

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

Industrial Gas Turbine Terminology

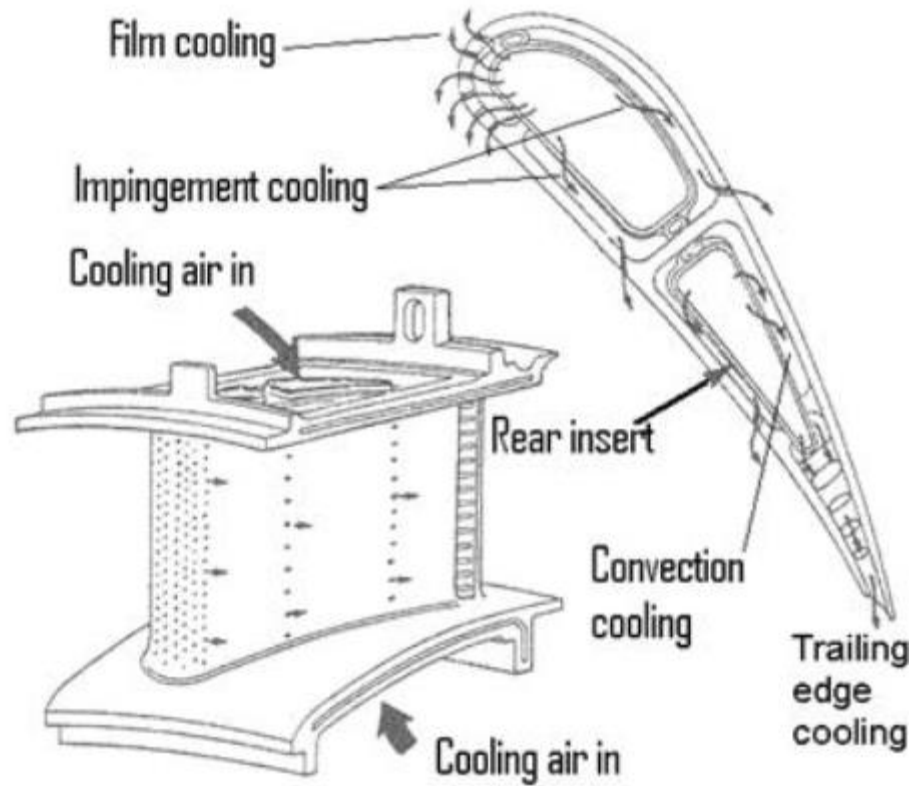


COMBUSTION SYSTEM & LINER

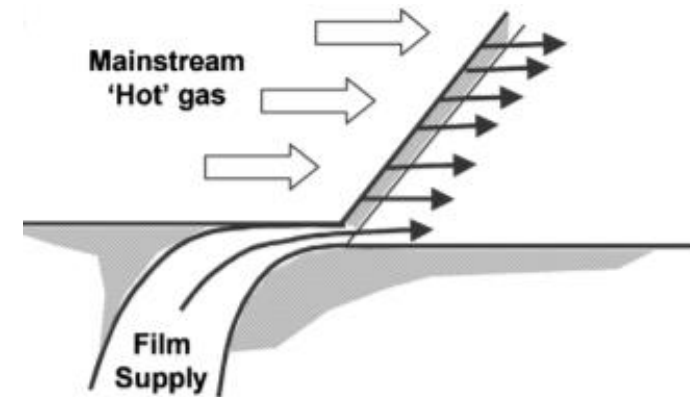
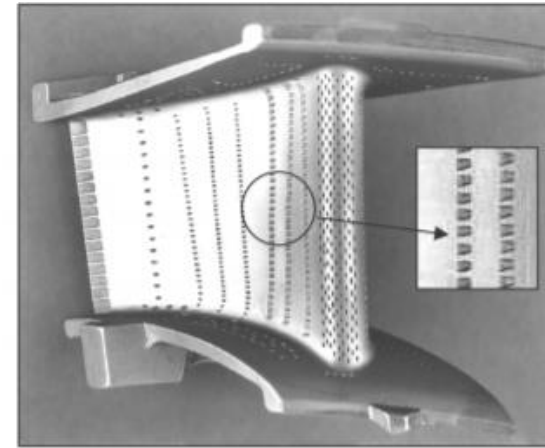


Turbine Vane Conventional Cooling Fundamentals

Internal Cooling Flow Circuit



Surface/External Film Cooling



Project Objectives & Technical Approach



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)

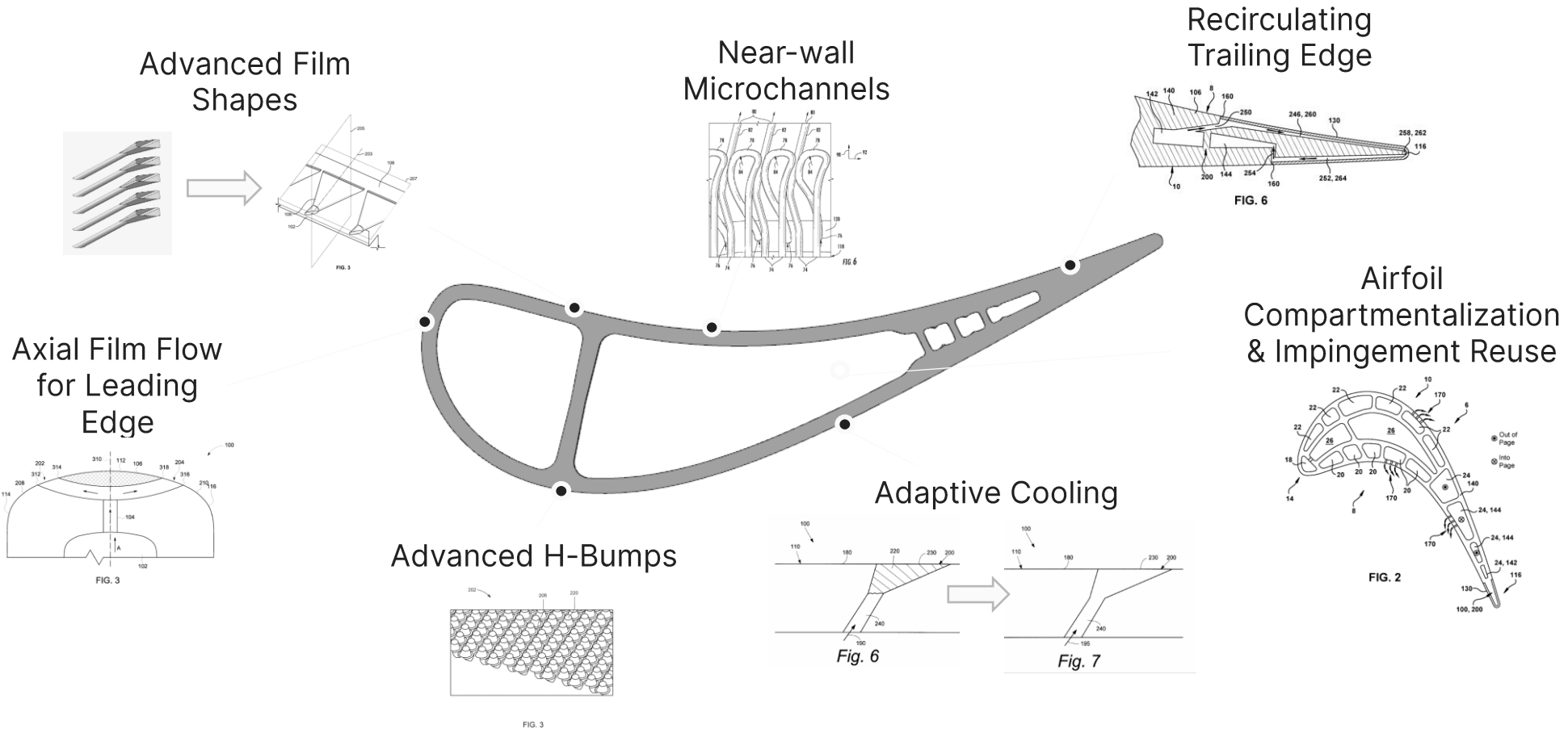
- Generate advanced wall architecture and airfoil concepts enabled by additive manufacturing
- Identify and evaluate additive methods and materials that enable desired geometry through coupon print trials
- Downselect a primary concept and additive method/material plus a backup to carry forward into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

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

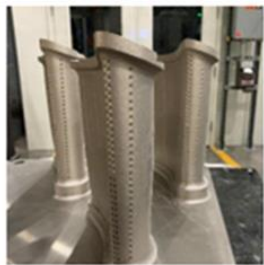
Cooling Technology

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.



Additively Printed Airfoils

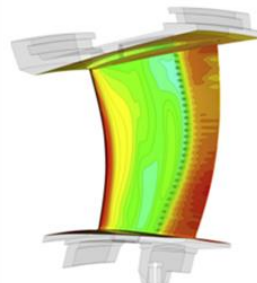
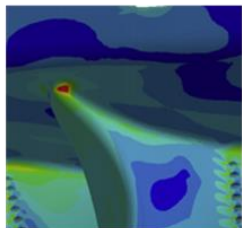


Additively Printed End walls

Additive Process Capability and Control

Powder removal on production viable designs.

Repeatability demonstration/ dimensional control.



Detailed Design – Heat Transfer and Structural

Additive Material Properties

Properties for several modalities.

Detailed Design

Heat transfer and structural mechanical.

All activities listed above are complete

Phase II Validation Testing

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

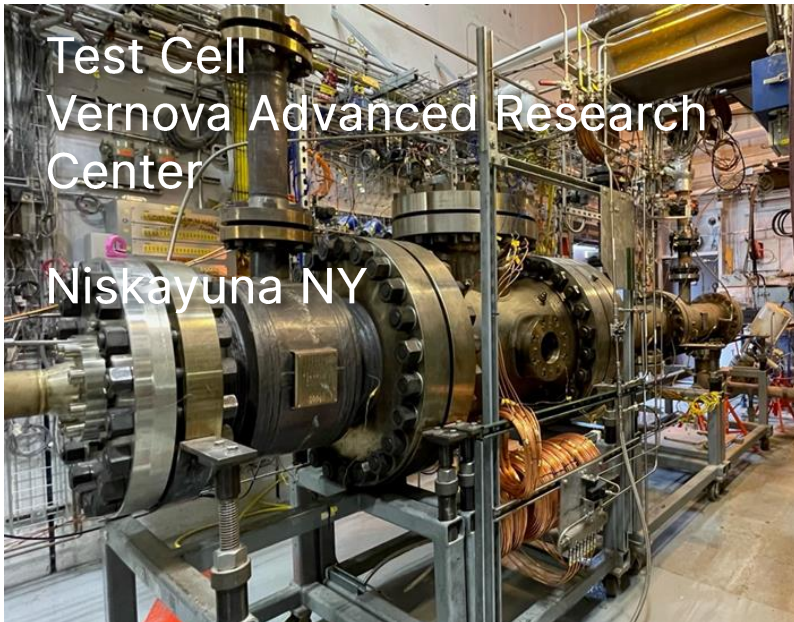
Objectives Achieved

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.



Post Validation Testing Evaluation



Data Collection

Baseline and Technology test articles cut for further inspection, cold flow and metallurgical processing. TC depth and TBC thickness measured.

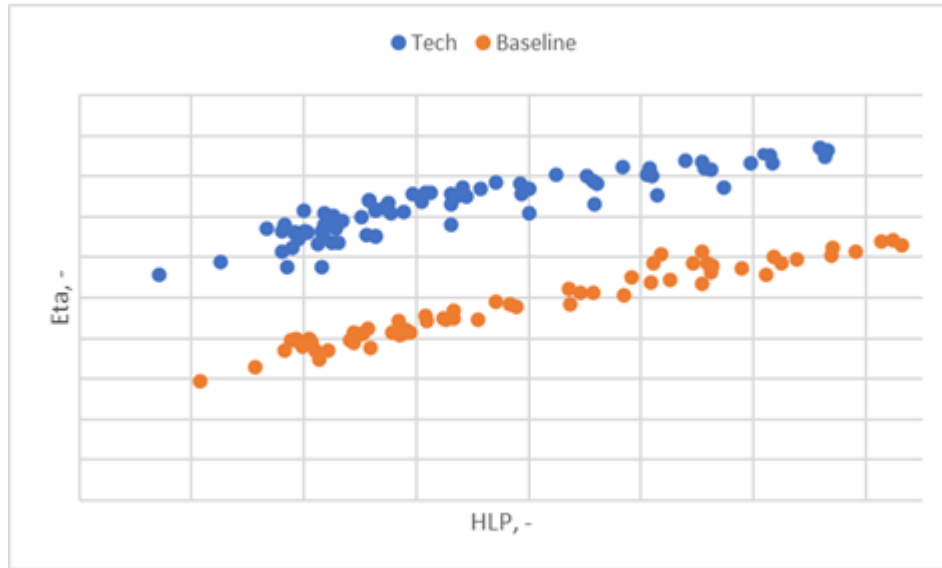
Data Analysis

Revisited Heat Transfer models for Technology and Baseline test articles.

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

Compared heat transfer model prediction to TC data.

High Temperature Additive Results & Program Completion



Cooling Flow Reduction

Target of a 15% reduction in S1N cooling flow, with similar or lower metal temperatures was exceeded.

TRL/ MRL Expectations

Technology	Starting TRL/MRL	Target TRL/MRL	Final Status TRL/MRL
Cooling Technology*	TRL2	TRL5	TRL5
Wall Architecture*	TRL2	TRL5	TRL5
Additive Modalities – DMLM	MRL3	MRL5	MRL5
Additive Modalities – Binder Jet*	MRL2	MRL4	MRL4
Additive Materials*	TRL2	TRL5	TRL5

Program Completion

Final report and presentation are in process, to be completed by end of the year.



QUESTIONS?



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