High Temperature Additive Architectures for 65% Efficiency

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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 I – Discovery (July 2018 – January 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
- Down select 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 II– Demonstration (January 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

Agenda

Additive at GE Gas Power

Nozzle Design Overview

Phase I Summary and Outcomes

Phase II Plan and Progress

Advanced Manufacturing Works – Greenville, SC

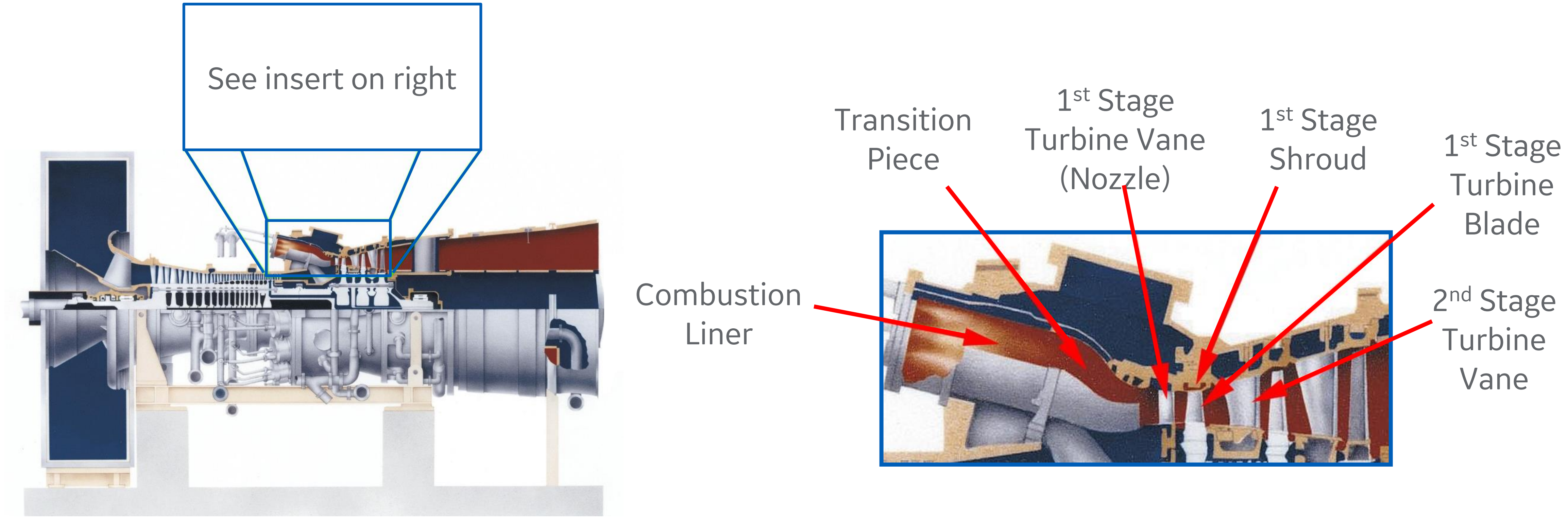
Merging design and manufacturing technology to deliver better products

Additive
- >16,000 parts shipped
- 1st GT parts produced/fielded

Ceramics
- 1st fielded CMCs
- Thermal coatings

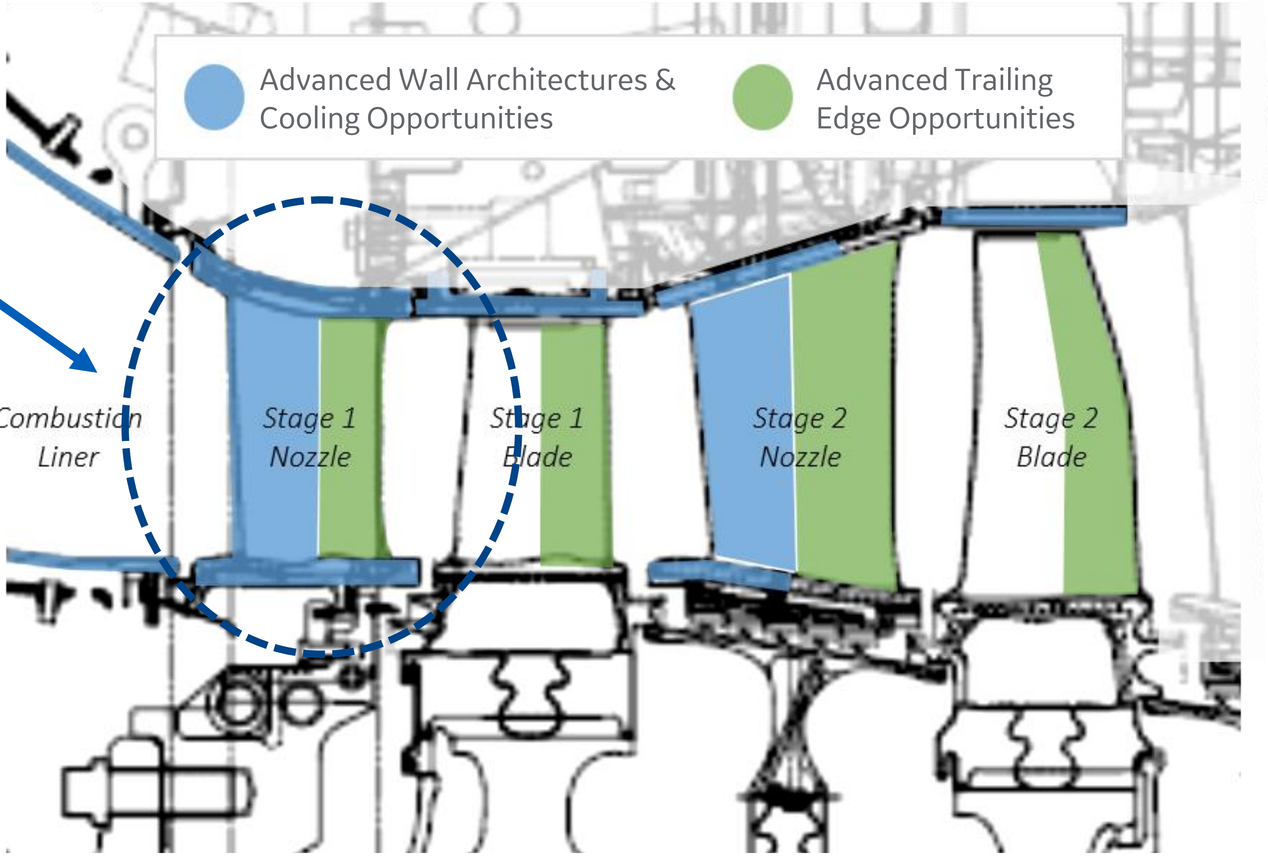
Process optimization
- Automation/CMT/Digital
- Hot Gas Path Special Processes
- Reduced cost and lead time

Industrial Gas Turbine Terminology



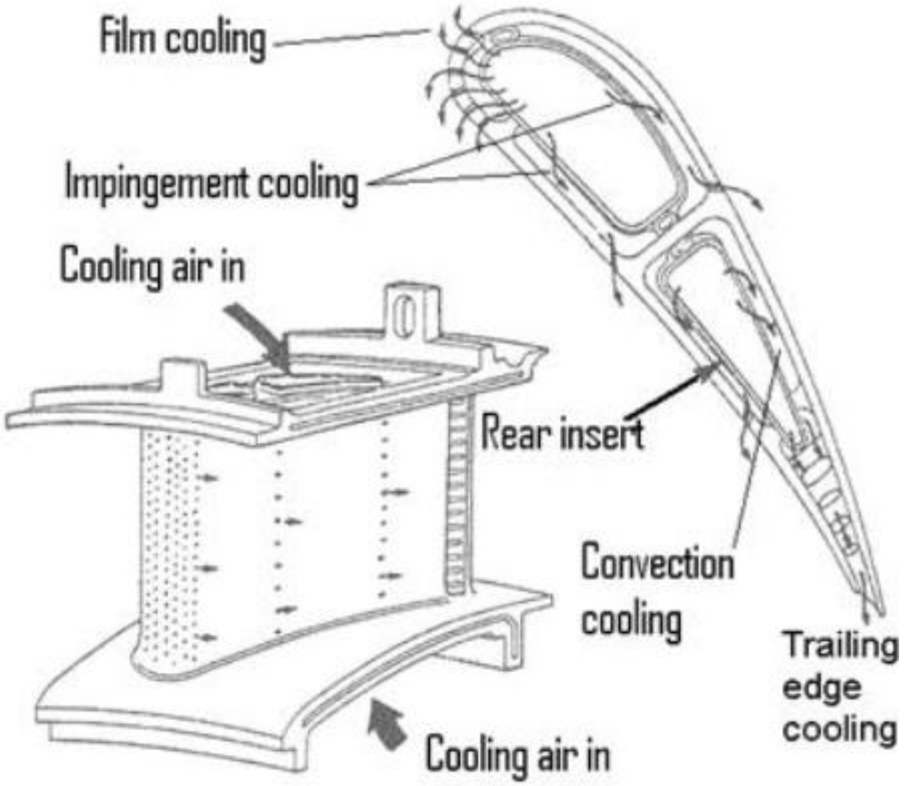
Turbine Section Advanced Manufacturing Opportunities

Component
we are focusing on
in this project

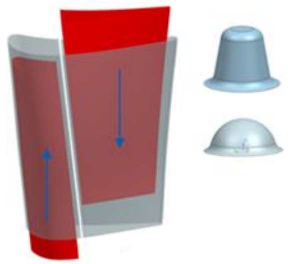


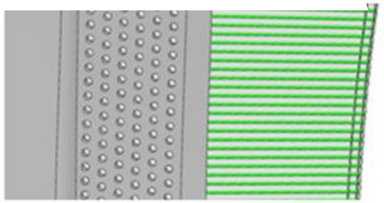
Turbine Vane Conventional Cooling Fundamentals

Internal Cooling Flow Circuit

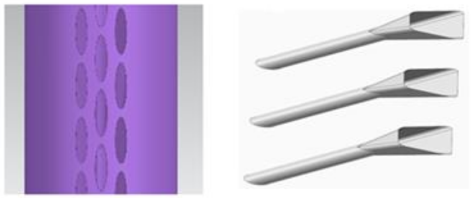


AF Impingement Inserts- Must Be Insertable, Which Limits Aero Design And Does Not Allow For Advanced Impingement Features



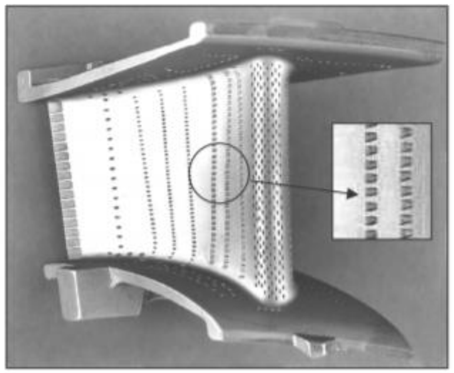


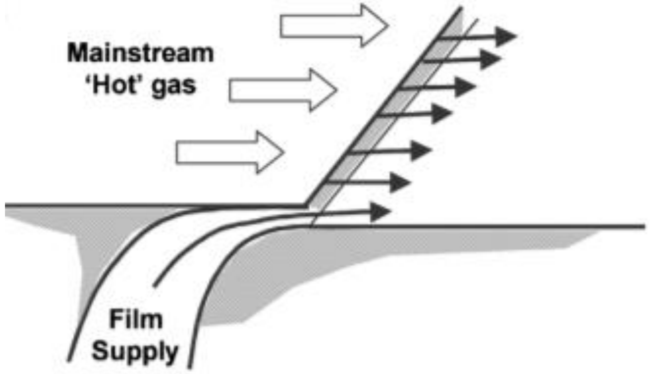
TE Cooling Geometry – Limited By Machining And Casting Processes, Coolant Exits With Excess Heat Capacity



Film Cooling Geometry – Limitations By Subtractive Machining Methods Do Not Accommodate More Efficient Film Geometry

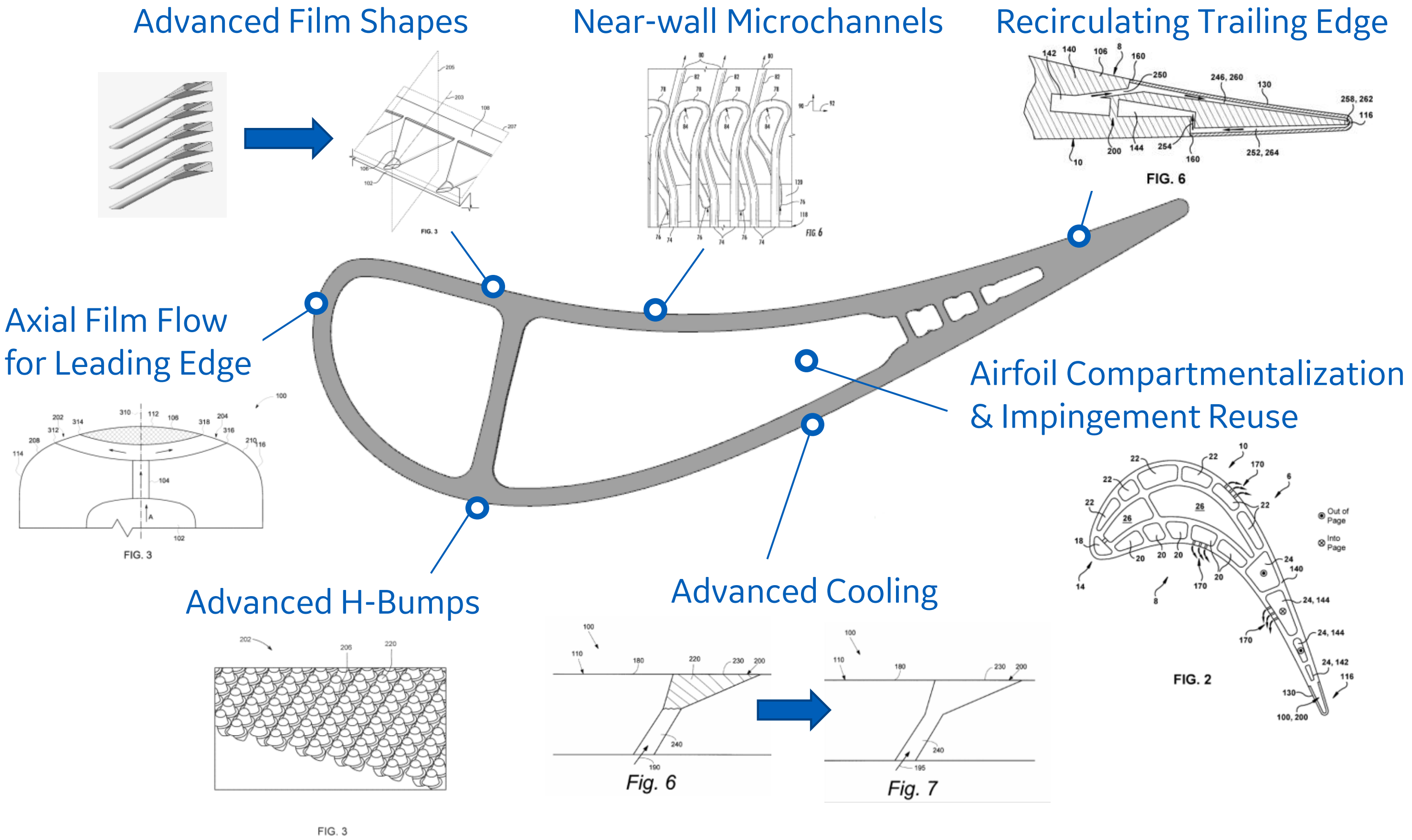
Surface/External Film Cooling



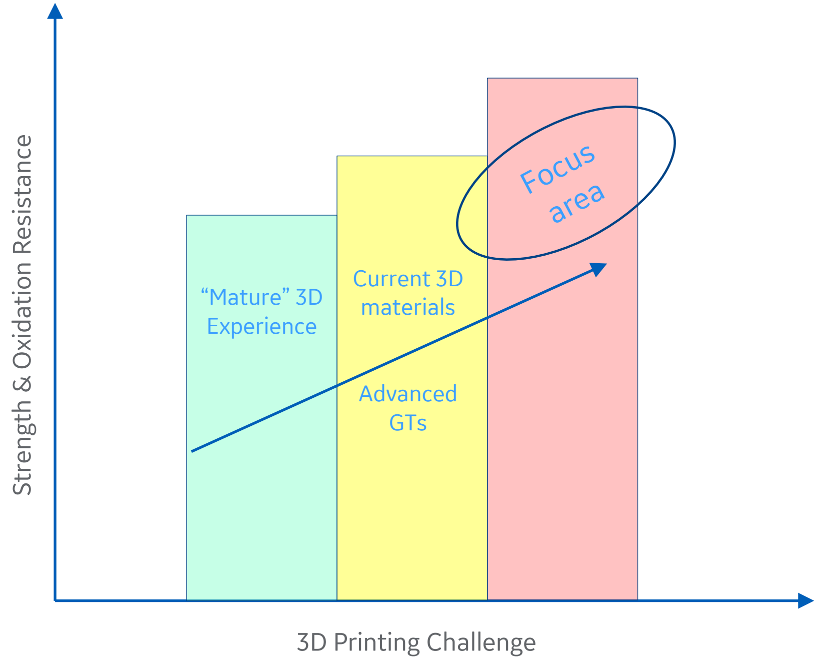


Nozzle Design – From "Design what you can make" to "Make what you can design"

Conceptual Design & Feasibility



Additive Modalities & Materials



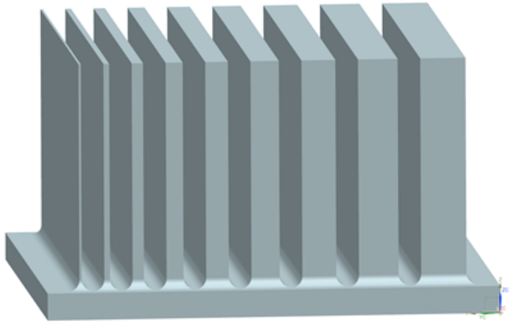
Program focus is on high-temperature alloys, and additive modalities that enable their use

Phase I Results and Key Learnings

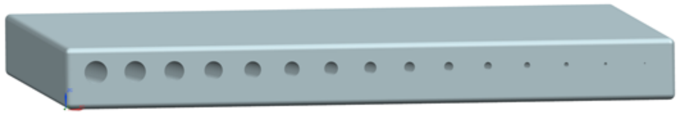
Outcomes

- Generated solid model of advanced cooling concepts and wall architecture, identified estimated performance benefit based on preliminary thermal/mechanical design results
- Completed print trials of artifact geometry coupons representative of Phase 1 design concept, identified risks and benefits of each additive modality
- Direct Metal Laser Melting (DMLM) with Rene108 material system along with Binder Jet (BJ) with Rene N2M material system in modular component concept identified as primary path. Fused Deposition Modeling (FDM) will not be pursued.
- Created test plan to mitigate risks/unknowns identified in Phase I concept design, leveraging both laboratory and representative engine environment testing

Pinned Wall Trials

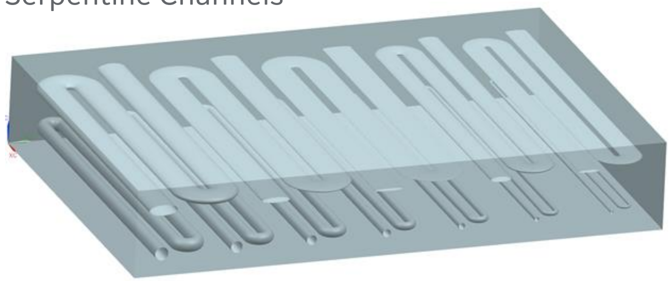


Walls with Constant Spacing and Variable Thickness Ranges



Round Cooling Holes

Round Serpentine and Elliptical Serpentine Channels



Artifact Coupons Create Relatively Fast And Lower Cost Learning Of Modality Capabilities And Challenges

Phase II Key Technology Gaps and Activities

Technology Gaps

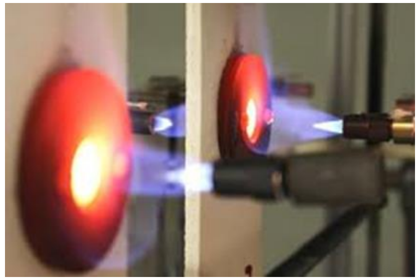
1) Cooling Technology
   - Empirical thermal correlations for additive cooling features needed.
     - HTCs
     - Film cooling effectiveness

2) Wall Architecture Technology Bench Testing
   - Jets Testing Rig to validate Phase I assumptions and design benefits

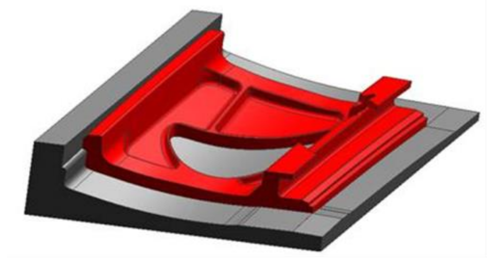
3) Additive Process Capability and Control
   - Multiple options to manage dimensions – model morphing, sintering setters, stock addition
   - Evaluating powder removal options

4) Additive Material Properties
   - Tensile, LCF, Creep

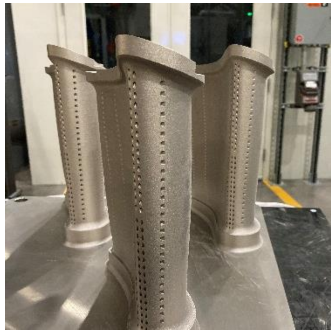
GER / GEGP Film Cooling Test Rig



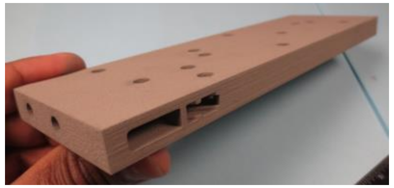
High Temperature Jet Thermal Shock Testing Rig



Ceramic Sintering Support (gray) for Outer Sidewall (red)



Additively Printed Airfoils



Powder Removal Coupon

Summary

The road to 65% CC efficiency is challenging

Additive Manufacturing is a paradigm shift in design for manufacturing.

In Phase I (July 2018 – January 2020) GE Gas Power has….

- Studied Advanced Wall Architecture and Airfoil Concepts enabled by Additive Manufacturing.
- Identified and evaluated Additive Methods and Materials, with DMLM and Binder Jet selected for further development on complex turbine components.
- Developed a Test Plan for future execution.

In Phase II (January 2020 – September 2024) GE Gas Power is ….

- Conducting bench testing of wall architecture and airfoil concepts
- Evaluating methods to optimize dimensional control and powder removal
- Conducting property testing of additively printed material to support design evaluation
- Producing and conducting lab testing of representative component hardware

Questions?