Turbine Aero-Thermal Technologies for 65% Efficiency DE-FE0031616

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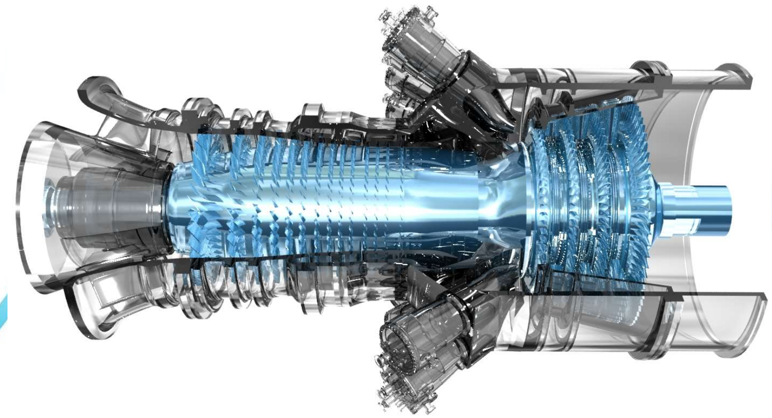

UTSR Project Review Meeting
Daytona Beach, FL
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UTSR University Turbine Systems Research
NATIONAL ENERGY TECHNOLOGY LABORATORY
U.S. DEPARTMENT OF ENERGY

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Project Objectives & Technical Approach

Overall objective

Develop feasible ***Conceptual Designs*** for advanced Aero-Thermal ***hot gas path front block components***, and define a turbine test rig plan for Future programs to validate, and further advance, the technologies

Technical Approach

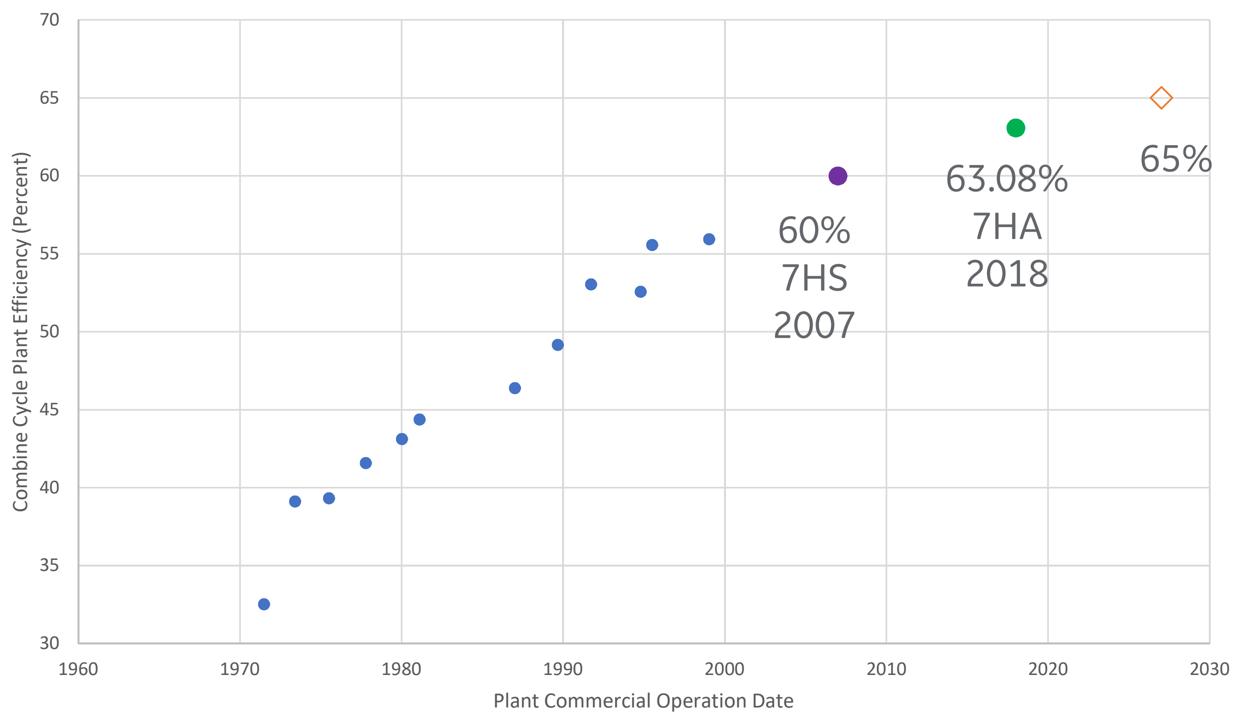
Phase I - Discovery

- Generate ***advanced concepts*** to address the following technologies:
  - Blade Tip/Shroud Interaction
  - High Blockage Trailing Edge
  - Secondary Flows & Hot Gas Migration
  - Unsteady Aerodynamic Interaction
- Establish ***technology maturation and test plan*** to address technology gaps for future execution

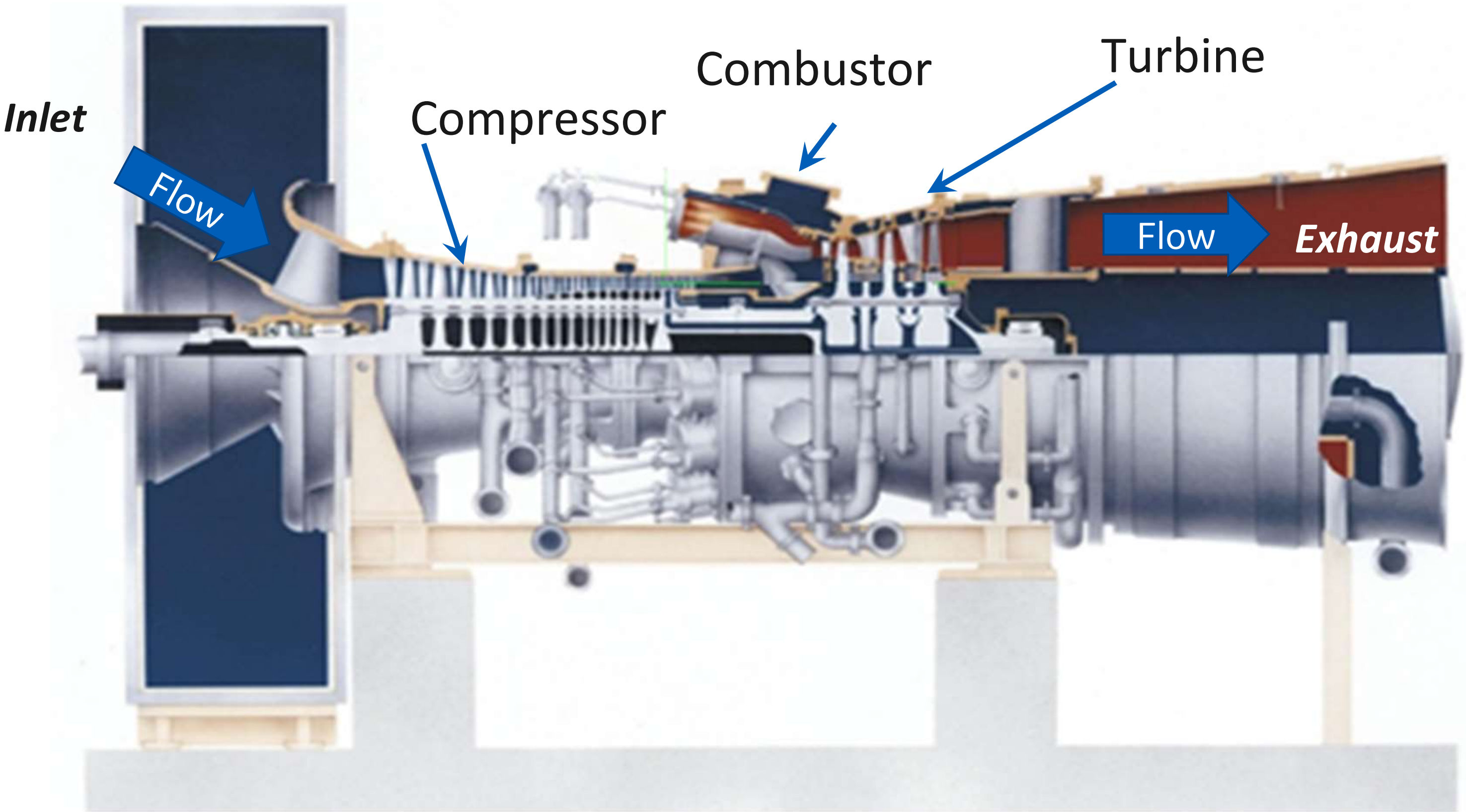
Agenda

- Industrial Gas Turbine Terminology
- Major Loss Mechanisms
- Program Objectives – Phase I
- Active Work & Next Steps
- Future Product Validation

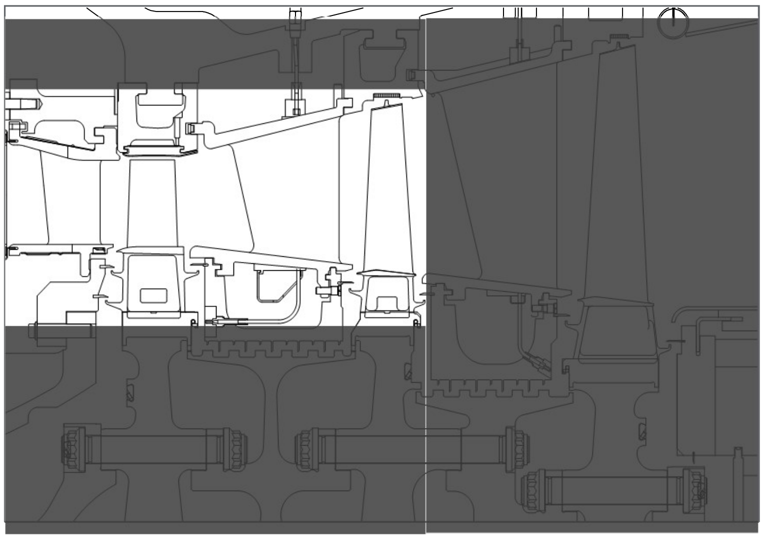
CC Plant Efficiency Timeline

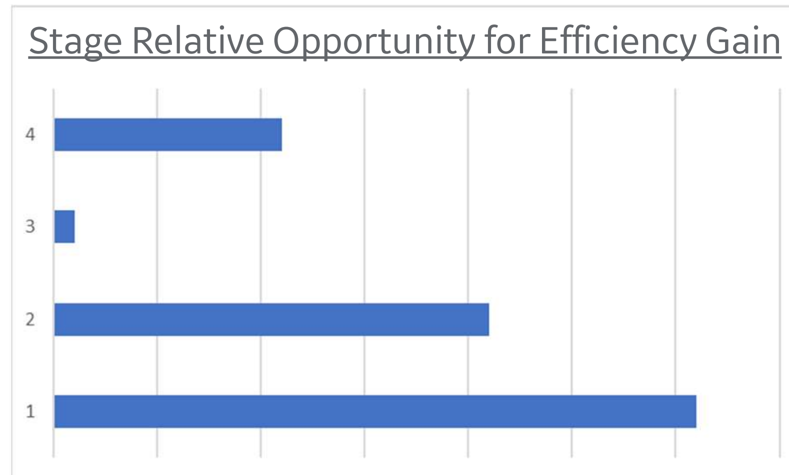


Industrial Gas Turbine Terminology



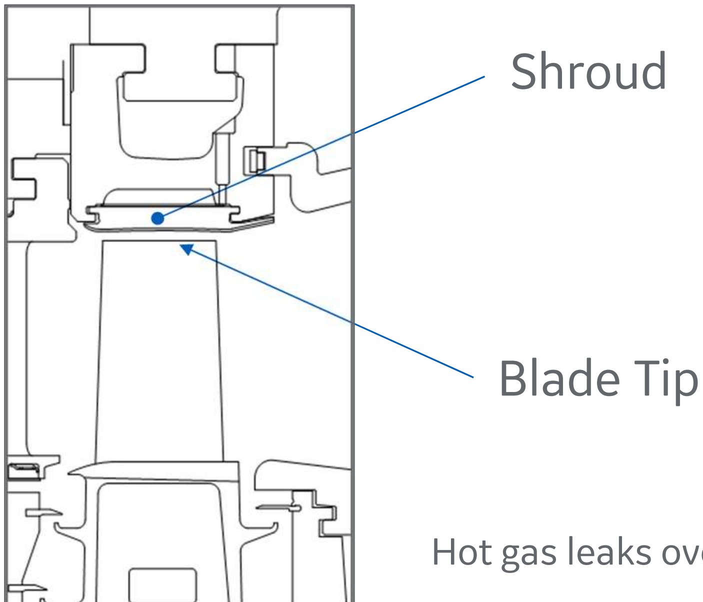
Turbine Stages 1 & 2



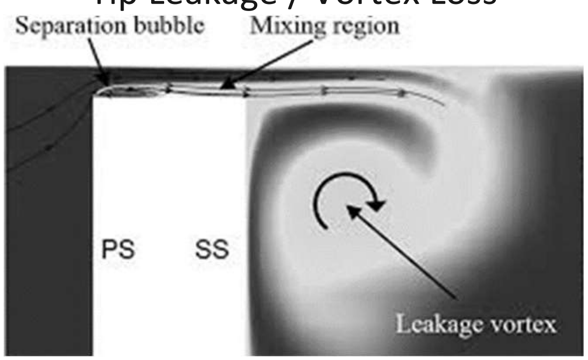


First two stages have greatest opportunity to impact Gas Turbine efficiency

Blade Tip/Shroud Interaction



Tip Leakage / Vortex Loss



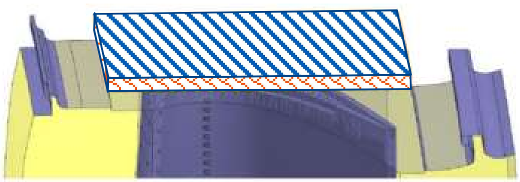
Hot gas leaks over the blade's tip

- The potential stage work of that flow is mostly lost
- Thermal loads on the tip, the shroud, and on downstream components increase
- Over-tip leakage flow forms a vortex that generates additional losses

Blade Tip/Shroud – Tip Leakage, Vortex Loss Studies

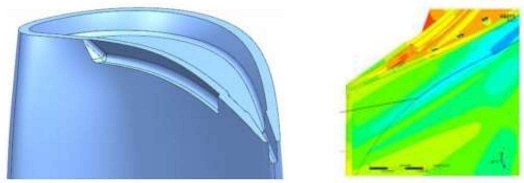
- The Phase I program investigated over-tip performance loss mechanisms
- CFD analyses was used to predict the detailed flow physics and quantify performance opportunities
- Component features for Future high-speed rotating rig testing have been identified

Blade Tip Interactions Studies



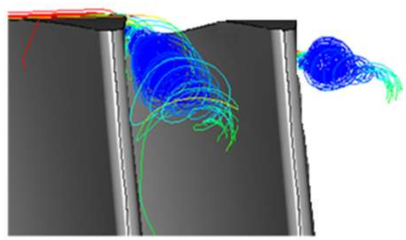
- Analytical/CFD shroud abradable geometry studies were performed
- Improved system identified

Squealer Tip Studies



- Studies were performed on various concepts
- Performance opportunities exist
- Efficiency benefit is additive with shroud treatment

3-D Aero Tip Analysis



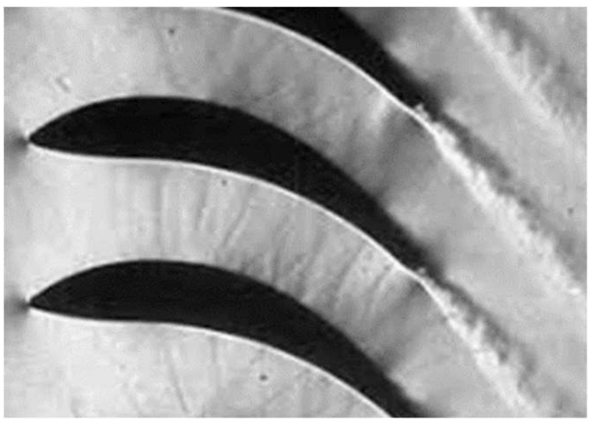
- Evaluated blade design concepts that reduce tip leakage loss
- Performance benefits quantified
- Efficiency benefits are additive with other approaches

High Blockage Trailing Edge Technologies

Objective: Reduce aerodynamic wake loss & trailing edge cooling flow

Approach: Combine airfoil shape, trailing edge cooling/discharge, and fabrication enablers to maximize the performance opportunity

Profile / Trailing Edge Loss
(Shock Loss too!)



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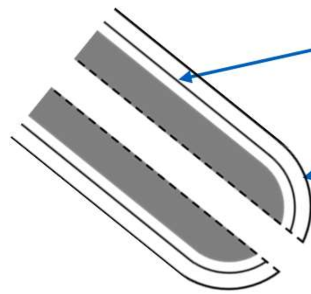


- TBC Thickness increasing causes
  - Excessive airfoil trailing edge thicknesses
  - High aerodynamic blockages
  - High aerodynamic losses
- Analytical/CFD studies performed to identify high-performance TE architectures for future testing

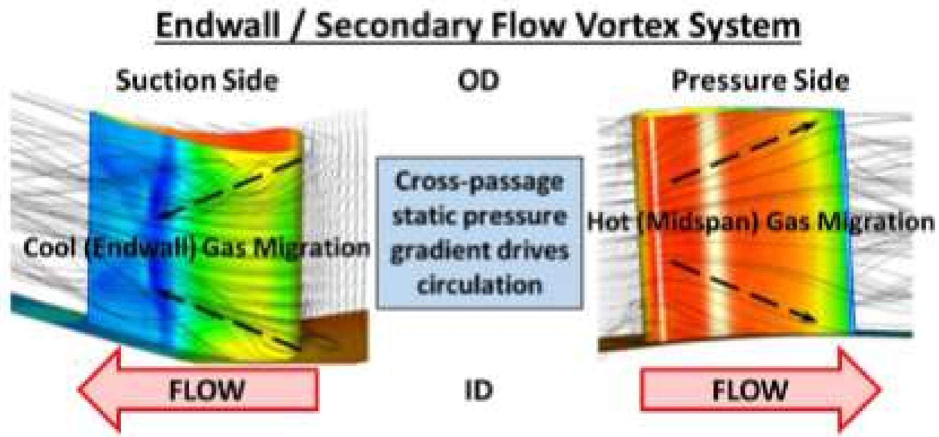
Secondary Flows & Hot Gas Migration

- Unsteady CFD was used to predict stage efficiency and aero-thermal fields through the stage.

- Three approaches were targeted to mitigate the secondary/endwall loss and hot gas migration.
  - Use of fluidics
  - Profiling the trench cavity and blade platform
  - Airfoil radial profiling

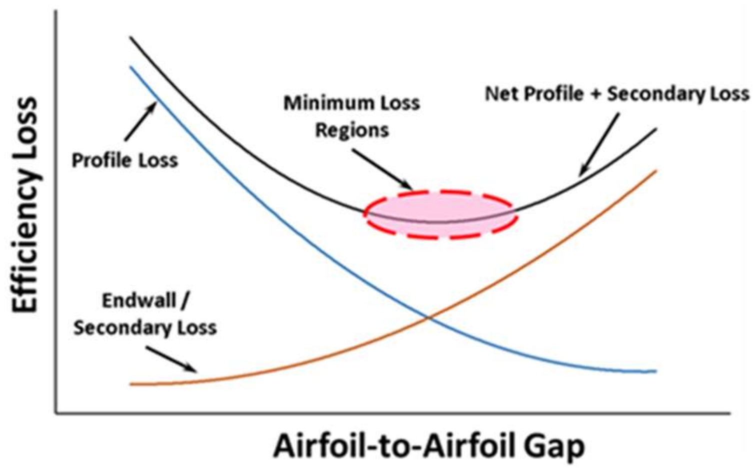
- A combination of these approaches provides a solution reduce secondary flow vortex strength and hot gas migration.

- Next steps include testing in a high-speed rotating rig will provide further insight into actual flow physics and performance



Unsteady Aerodynamic Interactions

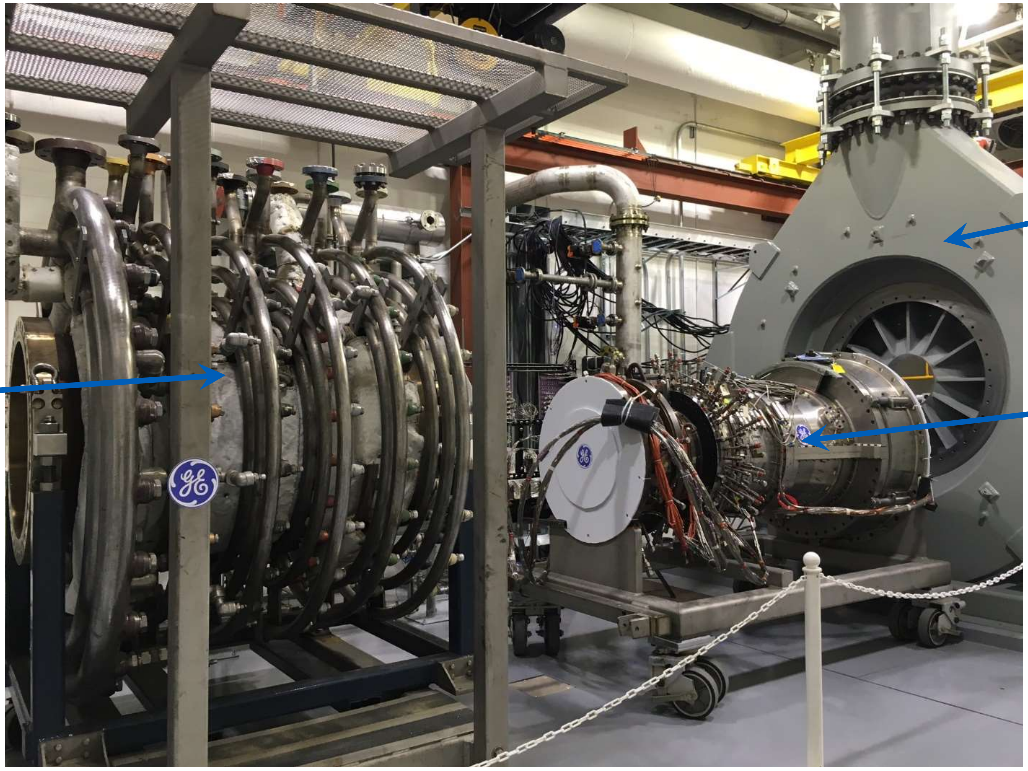
- Reducing the turbine's footprint positions airfoils close together, leading to flowfield interactions and loss
- Several fundamentally-different approaches were evaluated to reduce the unsteady loss
- Components and approaches to reduce unsteady interactions have been identified and are candidates for experimental assessment in future rotating rig testing



High Speed Rotating Rig Tests

Highly-Instrumented Turbine Rig Testing Provides Performance & Insight Into Flow Physics

Turbine Cooling Flow Manifold



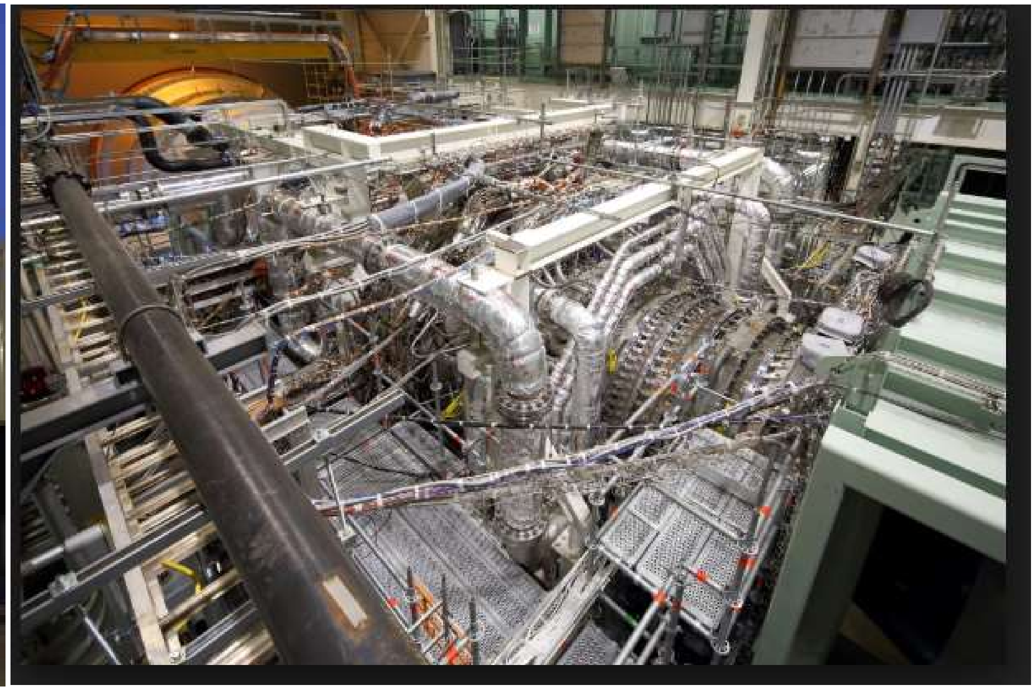
Turbine Exhaust Scroll

Turbine Rig (From 2009 DOE-funded research) prior to installation in test cell

Notre Dame Turbomachinery Facility 5 MW Test Cell Shown

Product Validation – Follows DOE-Funded Program

GE's Test Stand 7 Enables Validation Over A Broad Range of Operating Conditions



Summary

- This program's objective was to develop ***mechanically-feasible*** emerging ***aerodynamic*** and ***heat transfer*** technologies targeting Stages 1 & 2 of the gas turbine to improve the entire turbine system and overall Gas Turbine cycle efficiency

- In Phase I, GE investigated the following to improve the GT's efficiency….
  - Blade Tip/Shroud Interactions
  - High Blockage Trailing Edges
  - Secondary Flows & Hot Gas Migration
  - Unsteady Aerodynamic Interactions

- ***Advanced tip/shroud, trailing edge, hot gas migration, and unsteady interaction*** technologies have been defined with existing tools and following best practices, but critical elements of the proposed components ***challenge available empirical data***

- In the future GEP expects to utilize The Notre Dame Turbomachinery Laboratory facilities for aero-thermal rig testing

Questions?