GE
Energy

GE Energy's DOE Advanced IGCC/Hydrogen Gas Turbine Program




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Technology External Programs

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DOE Advanced H_2/IGCC Gas Turbine Program

DOE goals

- ✓ **Performance:** +3 to 5 % pts efficiency
- ✓ **Emissions:** 2 ppm NOx by 2015
  Fuel flexibility – Syngas & H_2
- ✓ **Cost:** Contribute to IGCC capital cost reduction

Program timeline

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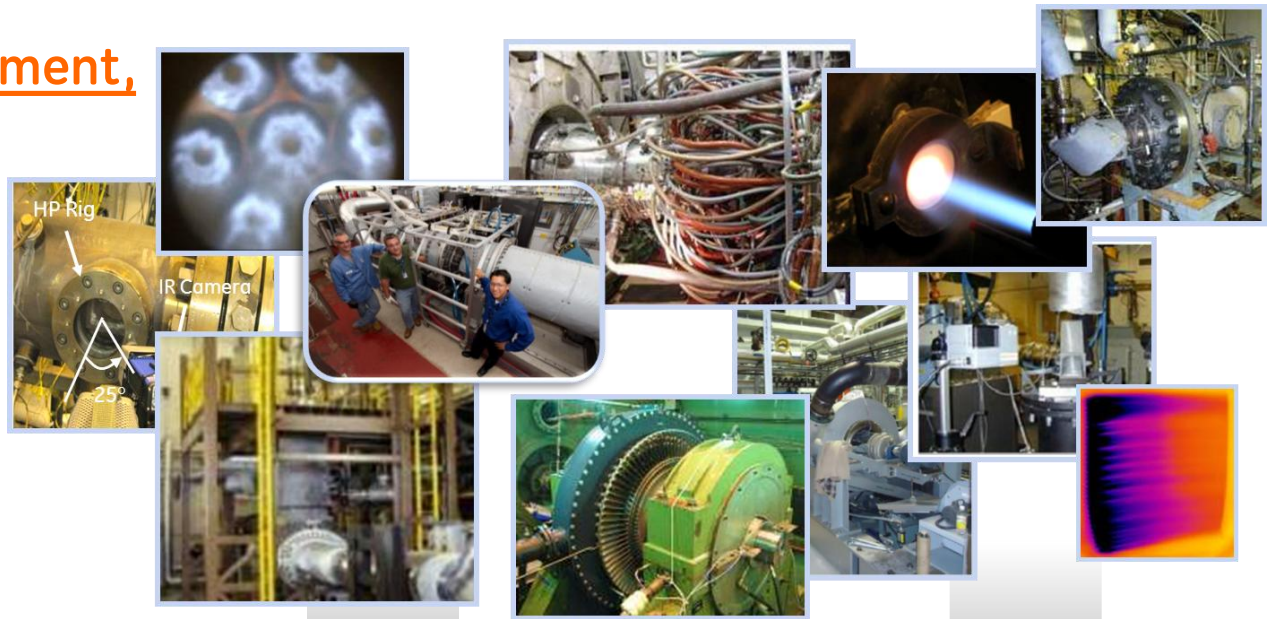
Technology Advancement

Innovation & Development,

Test & Learn

	emissions	efficiency	output	cost
• Combustion	✓	✓	✓	✓
• Turbine	✓	✓	✓	✓
• Materials	✓	✓	✓	✓
• Systems	✓	✓	✓	✓



IGCC-CCUS Industrial

IGCC-CCUS Power

NG Combined Cycle

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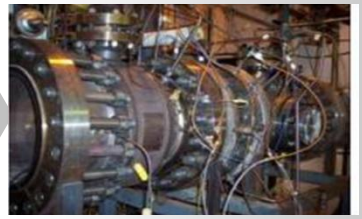
Pre-Mix H2 Combustion . . . 6+ yr Journey

(many said it could not be done)

Challenge

NOx
Flashback
Dynamics
Fuel Flexibility

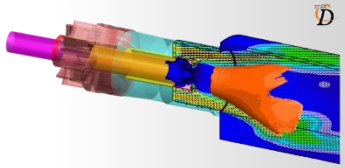
H2 Fundamentals



Entitlement Data

Innovation

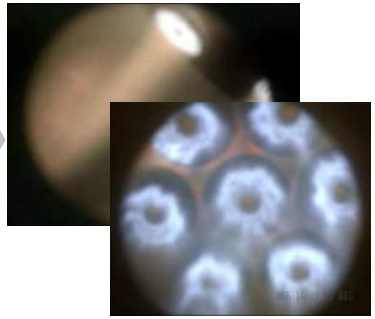
Sub-component
(rapid prototyping)



Modeling & Design
Concept Characteristics

Subscale Test

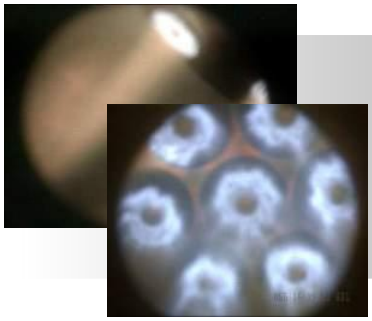
(test, analyze, learn)



Optimized Modeling &
Preliminary Design

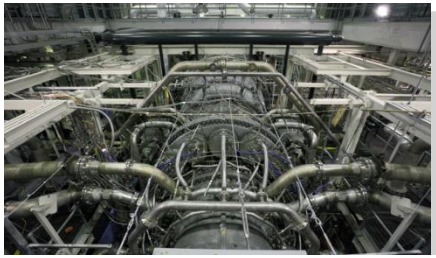
Full Size Test

(test, analyze, learn)



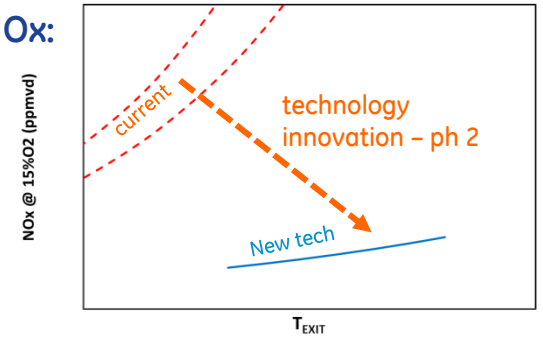
Engine Test

(validation, learn)



Optimized Modeling & Detailed Design

NOx:



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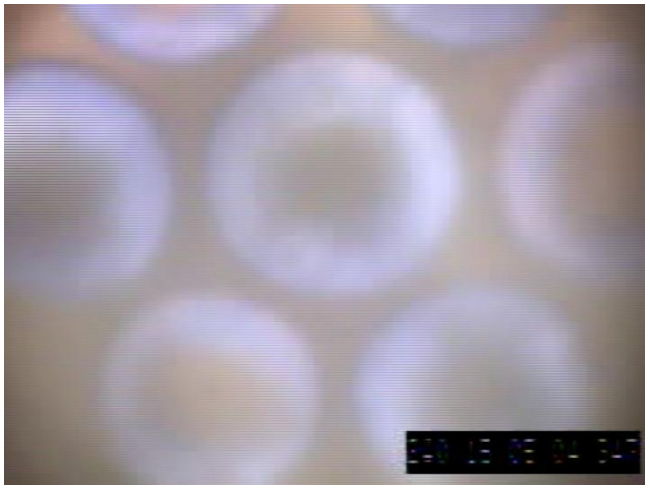
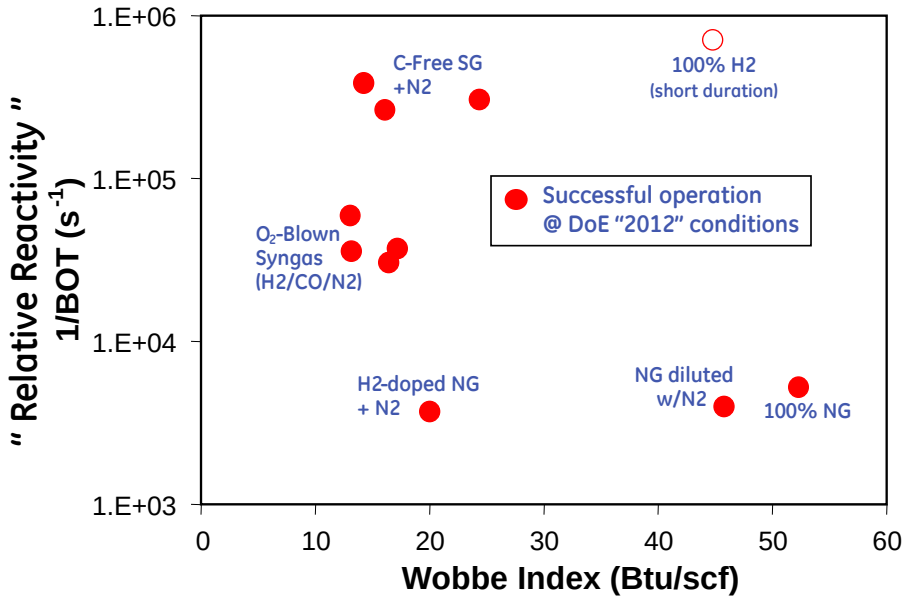
Combustion - Full Can Testing



- 24 Rig Tests in 2009-2011
- 90+ hours operation on high-H_2 fuels
- Single digit NOx emissions at target conditions with H_2-N_2 fuels.

- Fuel 60-100% H_2, balance N_2 and/or Natural Gas (NG)
- Exceeded F-class temp and pressure
- Operability with NG and syngas



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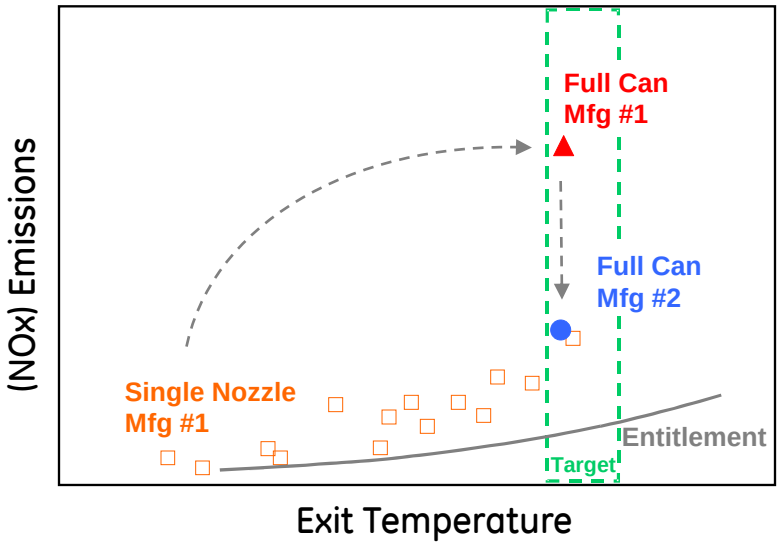
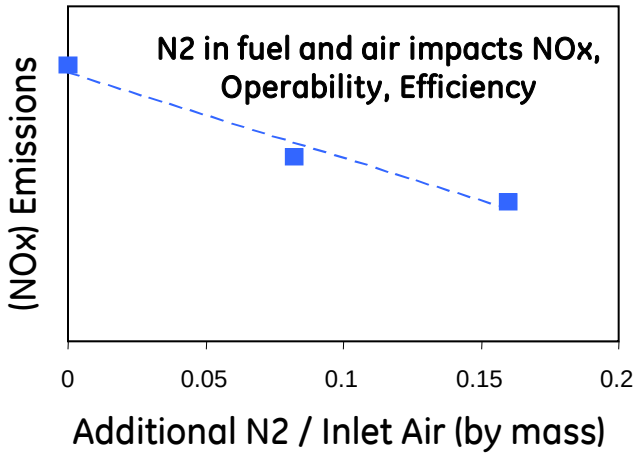
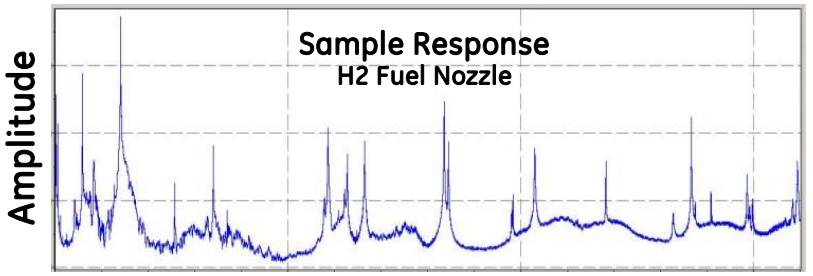
Combustion – Technology Development

- Robustness
  - Gain operating margin
  - Design for durability
- Scale-Up
- Trade-offs

  (e.g. performance, durability, and cost)







Frequency response testing to guide design.

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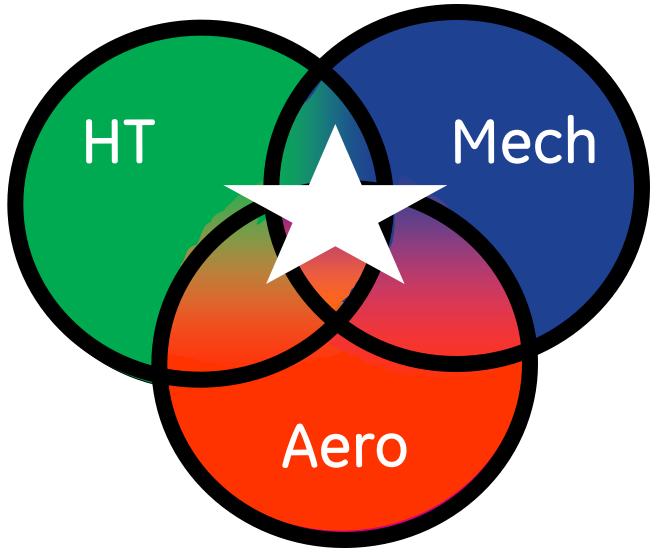
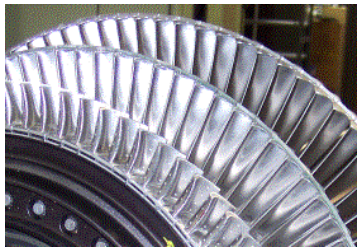
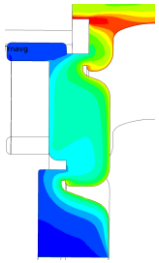
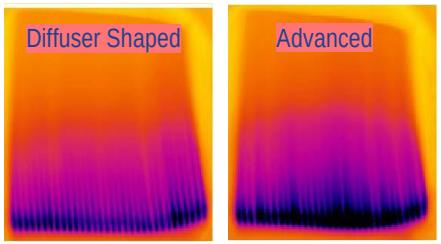
Turbine System Goals

- Increasing firing temp and output
  - **Advanced** materials & coatings
  - Increased mass flow
- Advanced turbine technology
  - Reduced cooling flows
  - Reduced leakage/purge flows
  - Advanced aerodynamics









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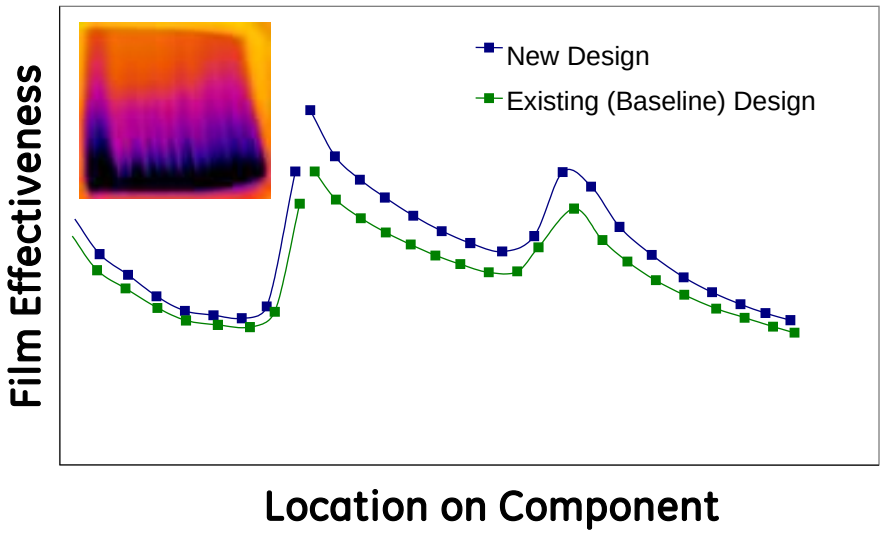
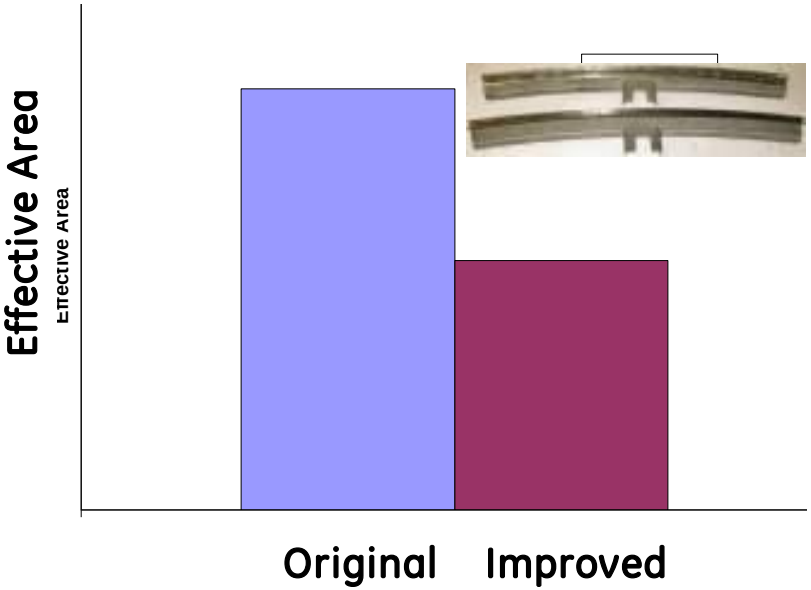
Heat Transfer Development

Advanced Film Cooling



TP/S1N Seal



Achieved target flow reductions for Round 1

Jugular experiments completed for Round 2

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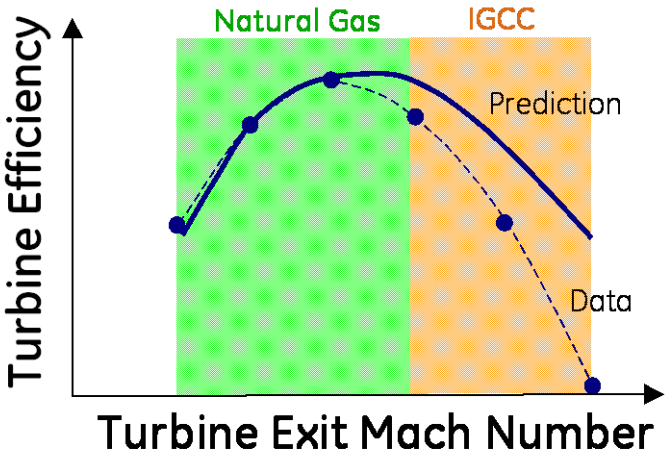
Aerodynamic Development – Round 1

Turbine Aero Validation Rig

Test Setup & Results



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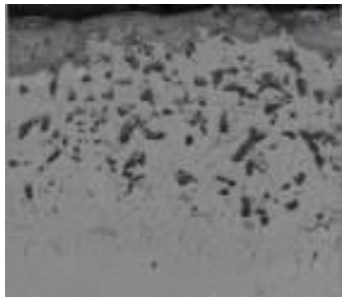
Advanced Materials (Coatings)

Goals

- Enable higher temperature operation for increased efficiency and output
- Address unique conditions

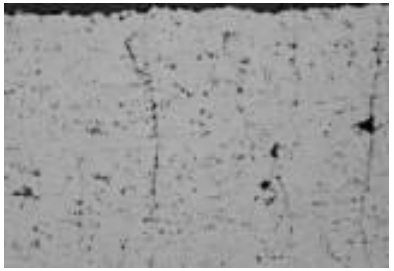
Overall Approach

- Characterize the environment
- Devise representative laboratory tests
- Benchmark degradation
- Develop new coatings
- Downselect to best performers
- Evaluate best performing TBC's and BC's



Field Hardware Inspection

Thermal Shock Test



Optimized Coating

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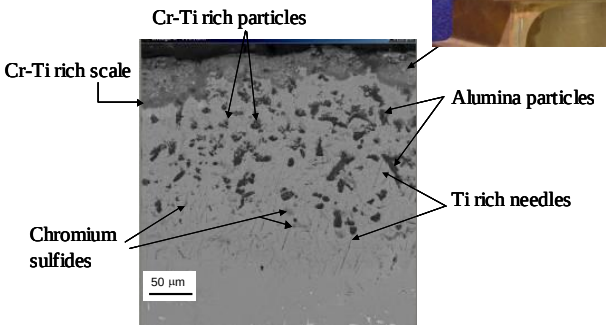
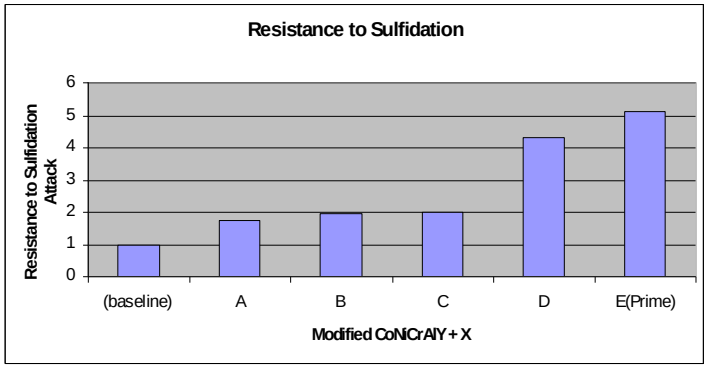
Advanced Materials (Coatings)

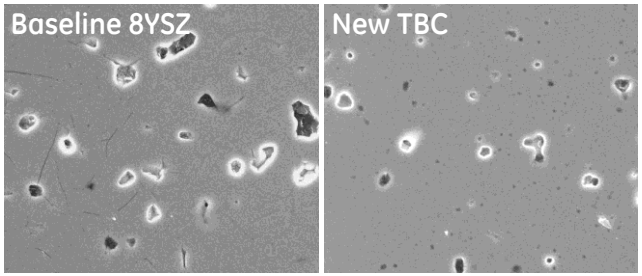
- Reproduced damage modes
- Many architectures evaluated
- Performance improvement demonstrated
- Down selections made to final TBCs and bond coats

Field Hardware Inspection Results





Sulfidation Resistance Test Results



Microstructural Evolution of TBC After Accelerated Isothermal Exposure

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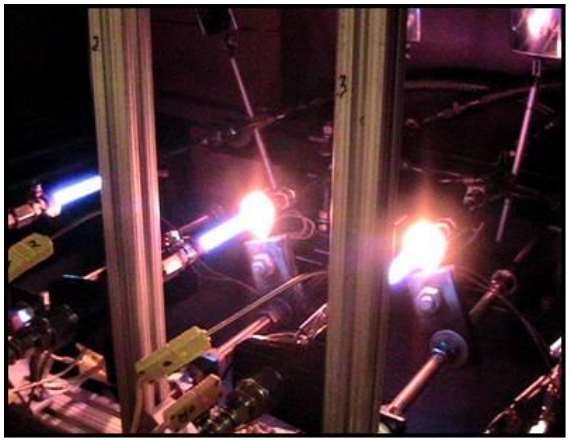
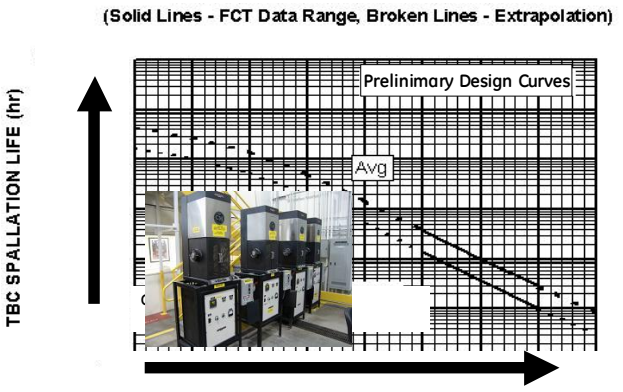
Adv Materials (Coatings) Next Steps

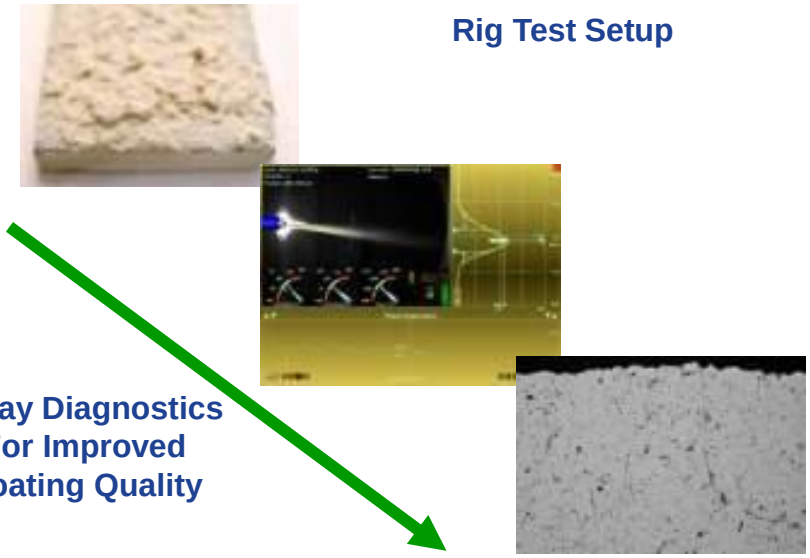
- Continue thermal gradient rig testing of down selected TBC/BC systems
- Generate design quality data
- Process optimization



Rig Test Setup



FCT Design Curves

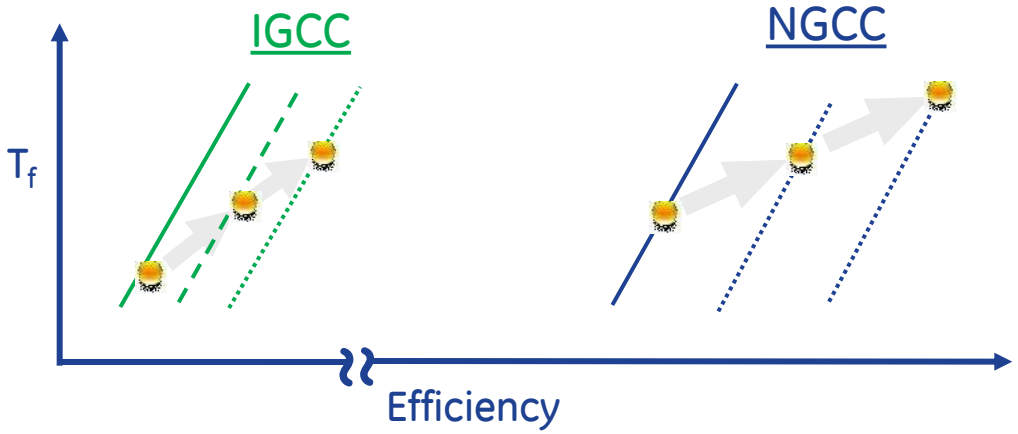


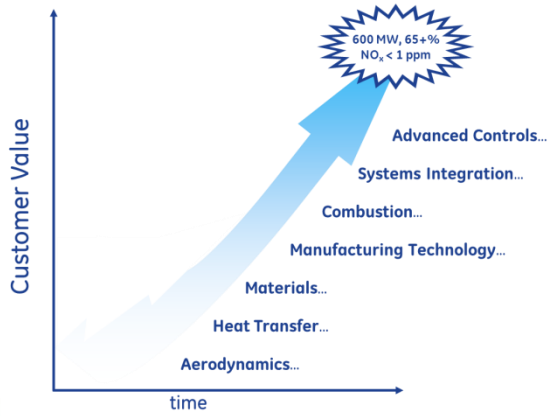
Spray Diagnostics For Improved Coating Quality

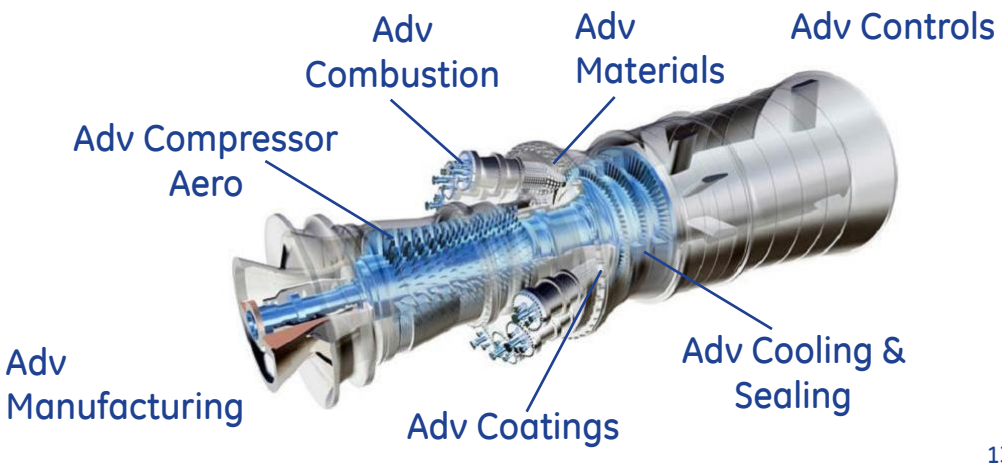
Technology Advancement:

. . . Fundamentals & Innovation Today

. . . Tomorrow's Advanced Turbines







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Acknowledgements

Special thanks to the US Department of Energy National Energy Technology Laboratory and their support on the DOE/GE "**Advanced Hydrogen Gas Turbine Development Program**"

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1. This material is based upon work supported by the Department of Energy under Award Number DE-FC26-05NT42643

Thank you!

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