Advanced Multi-Tube Mixer Combustion For 65% Efficiency

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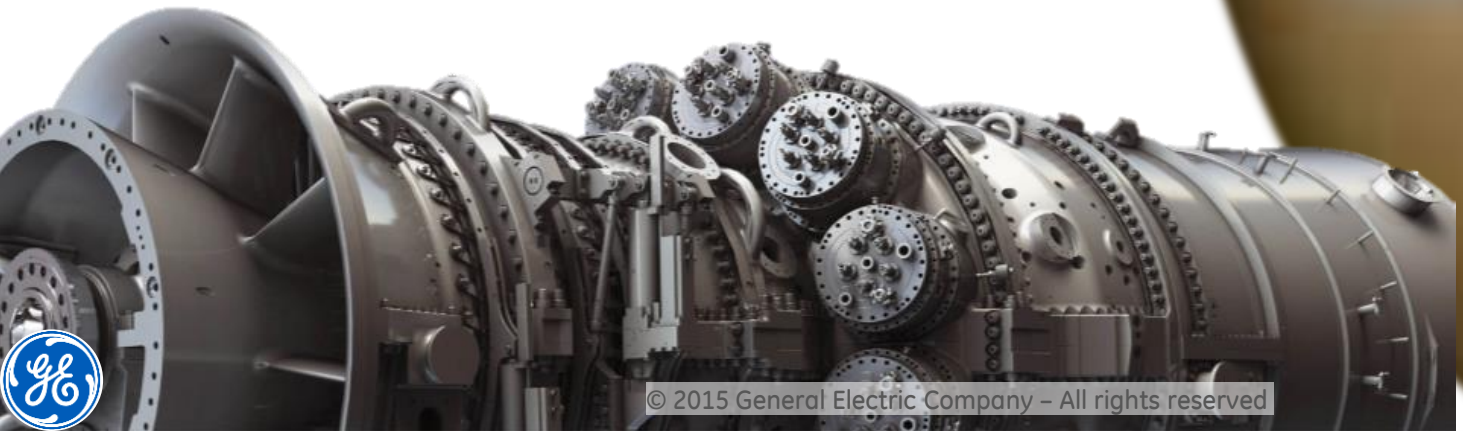
Imagination at work

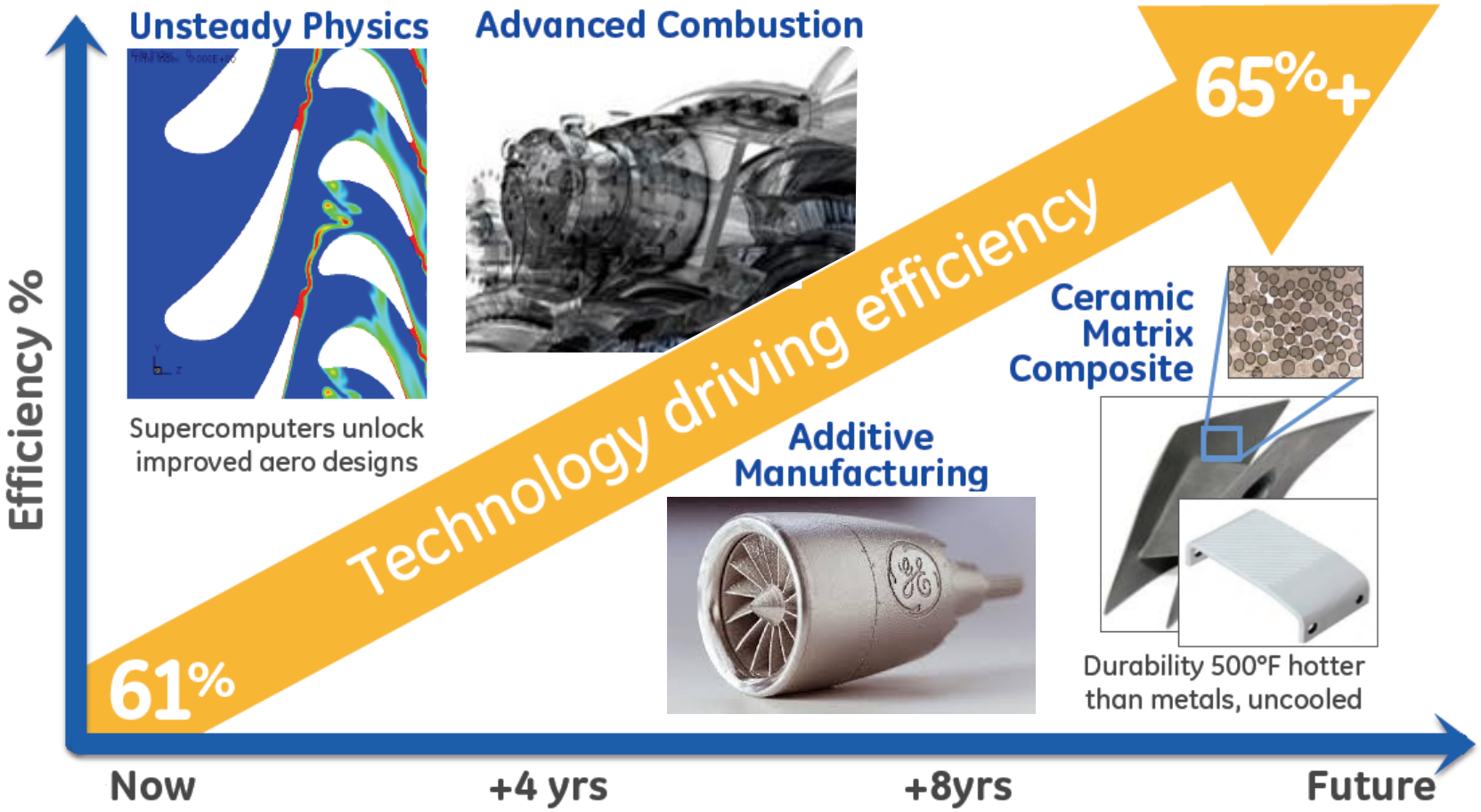
65% GTCC Efficiency

WHY is reaching 65% important?

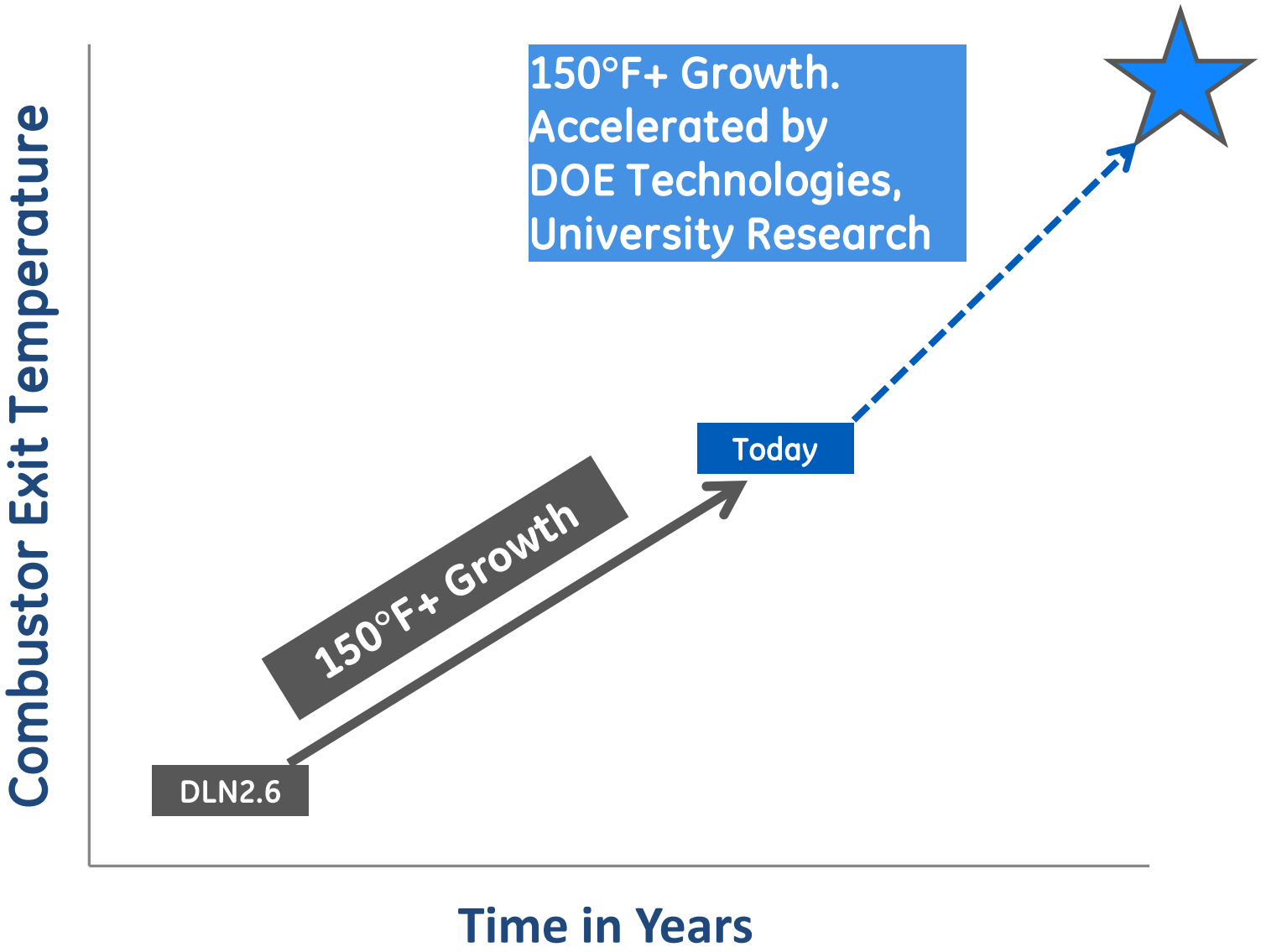
- ✓ Less emissions produced
  - → Tons per year less CO_2 than 60% GTCC
- ✓ Lower $/kW & heat rate
  - → Faster adoption



Technology Pipeline for 65% Efficiency



Picking up the Pace



Phase 1 Program

Advanced Cooling Technologies

- Survey GE Aviation and GE Power for advanced cooling techniques.
- Couple available techniques with recent/future materials and coatings to select a cooling approach that minimizes W_{nch} and dP/P.

Limited Test Campaign

- Select the system parameters required to reach the target temperature
- Implement the system parameters in GTTL hardware.
- Verify the 'recipe' at full scale conditions.

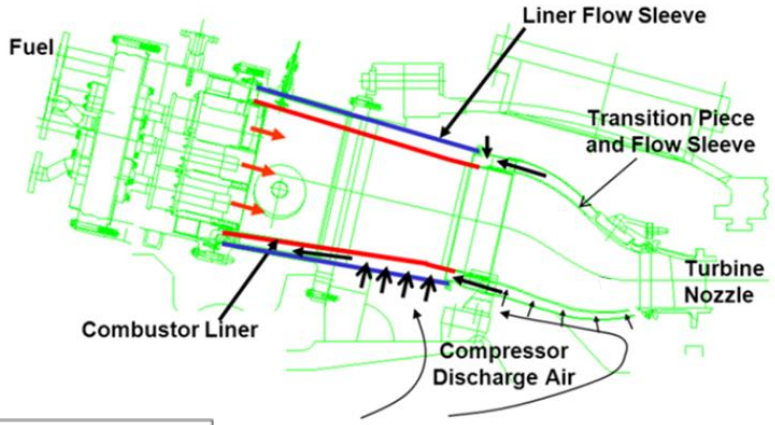
Configuration Proposal for Phase 2 Development

- Understand key trades and select key parameters.

Materials and Cooling Technologies

Challenge: Increase heat load while holding durability and dP/P

1. Research cooling technologies best suited to handle higher heat loads. Review both internal and external material
2. Pair with materials and coatings technology and combustor configuration to optimize cooling dP required for 65%



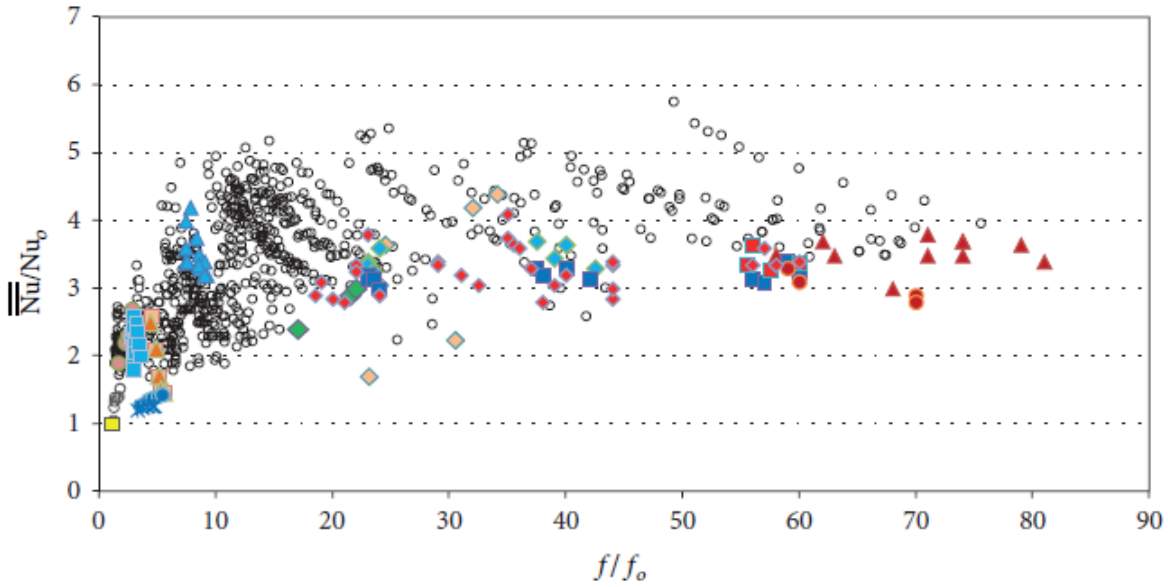
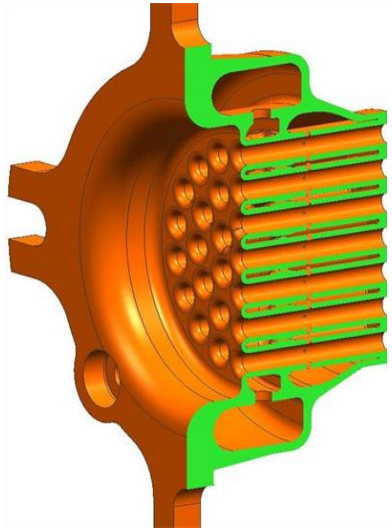


Figure: Ligrani, Phil. 2013. "Heat transfer augmentation technologies for internal cooling of turbine components of gas turbine engines. " *International Journal of Rotating Machinery* 2013.

Multi-Tube Mixer

The Multi-Tube Mixer is a distributed, premixed approach to combustion of high-hydrogen fuels.

- Utilizes jet-in-cross flow mixing of fuel and air
- Design air velocity above flame speed with reasonable pressure drop.
- Mixing length (L_{mix}/D) may vary based on fuel and conditions.



Multi-Tube mixer is easily scalable without changing fundamental geometry and adaptable to range of fuels.

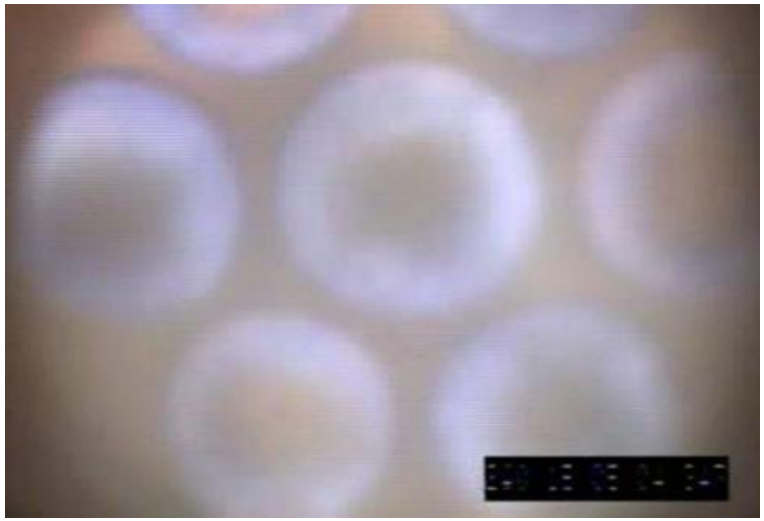
GT2012-69913

DEVELOPMENT AND TESTING OF A LOW NO_x HYDROGEN COMBUSTION SYSTEM FOR HEAVY DUTY GAS TURBINES

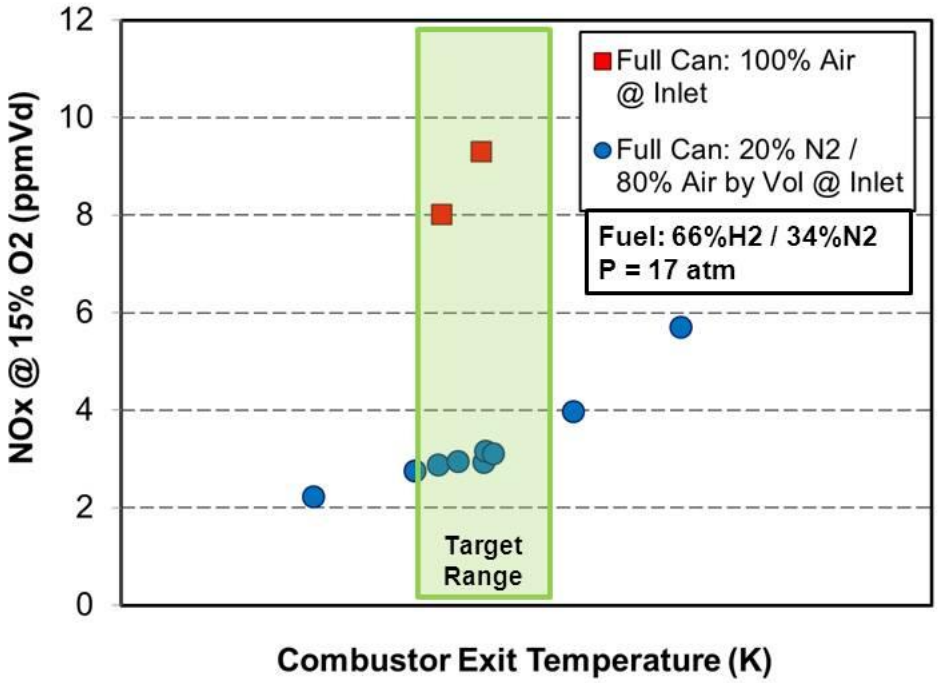
Larger scale MT Mixer Nozzle

Small prototype MT Mixer

Multi-Tube Mixer Full Can Rig Results



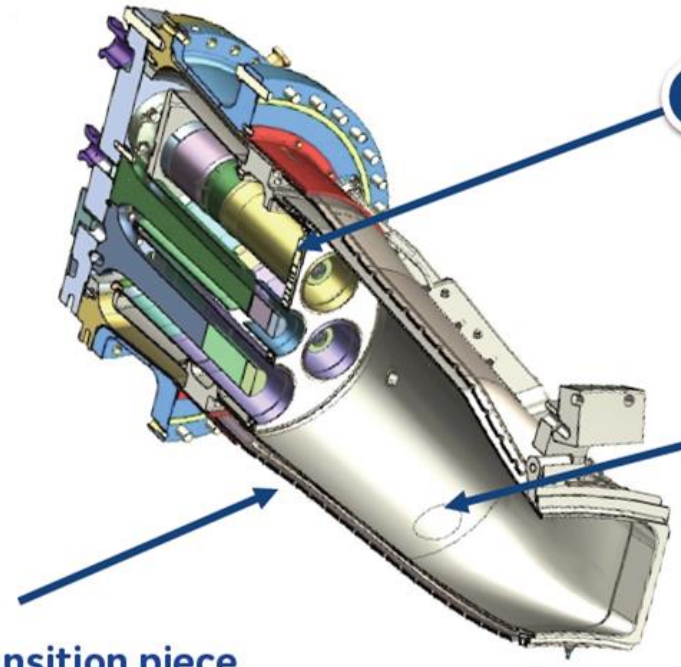
Fuel: 63/4/33 % H2/CH4/N2



- Single digit NOx (corrected to 15% O2) over target temperature range with hydrogen-nitrogen fuel
- Below 3 ppm NOx (corrected) with 20% of inlet air replaced with pure nitrogen.

DLN2.6+ with Axial Fuel Staging

Advantages
- Lower turndown
- Improved cooling
- Faster Installation



1 Advanced premixing
- Low NOx at high T_{fire}
- Fuel Flex – Inerts and MWI

2 Axial fuel staging (AFS)
- Low NOx at high T_{fire}
- Improved turndown

3 Unibody extended transition piece
- Reduced residence time
- Tailored TP cooling

Going to hotter temperatures with constant emissions

Final Summary

- 65% is an aggressive but necessary goal.
- Will require advancements in every aspect of combustion design.
- Multi-Tube Mixer and Axial Fuel Staging are excellent building blocks.
- DOE and University projects have already accelerated the pace of technology development, and will continue to be critical to the success of the project.

Questions?

Imagination at work