Fuel Flexibility and Alternative fuels for Aeroderivative Gas Turbines

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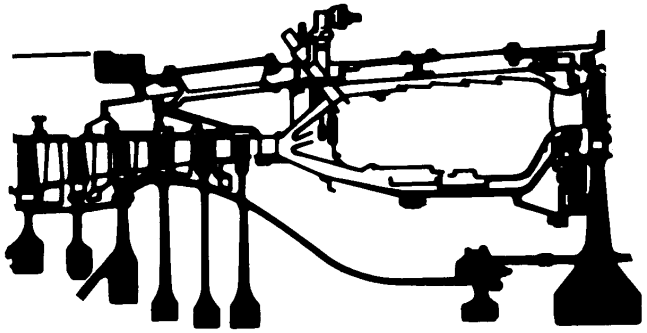
Agenda

- Introduction to Rolls-Royce combustion systems
- Standardisation Methodology
- Past challenges
  - Typical world scatter
  - The emissions challenge
  - When things go wrong
- Plan for the future
  - Novel fuel challenges
  - Free fuel?
  - Collaboration
- Conclusions

Combustor Comparison

Conventional

18 off conventional injectors



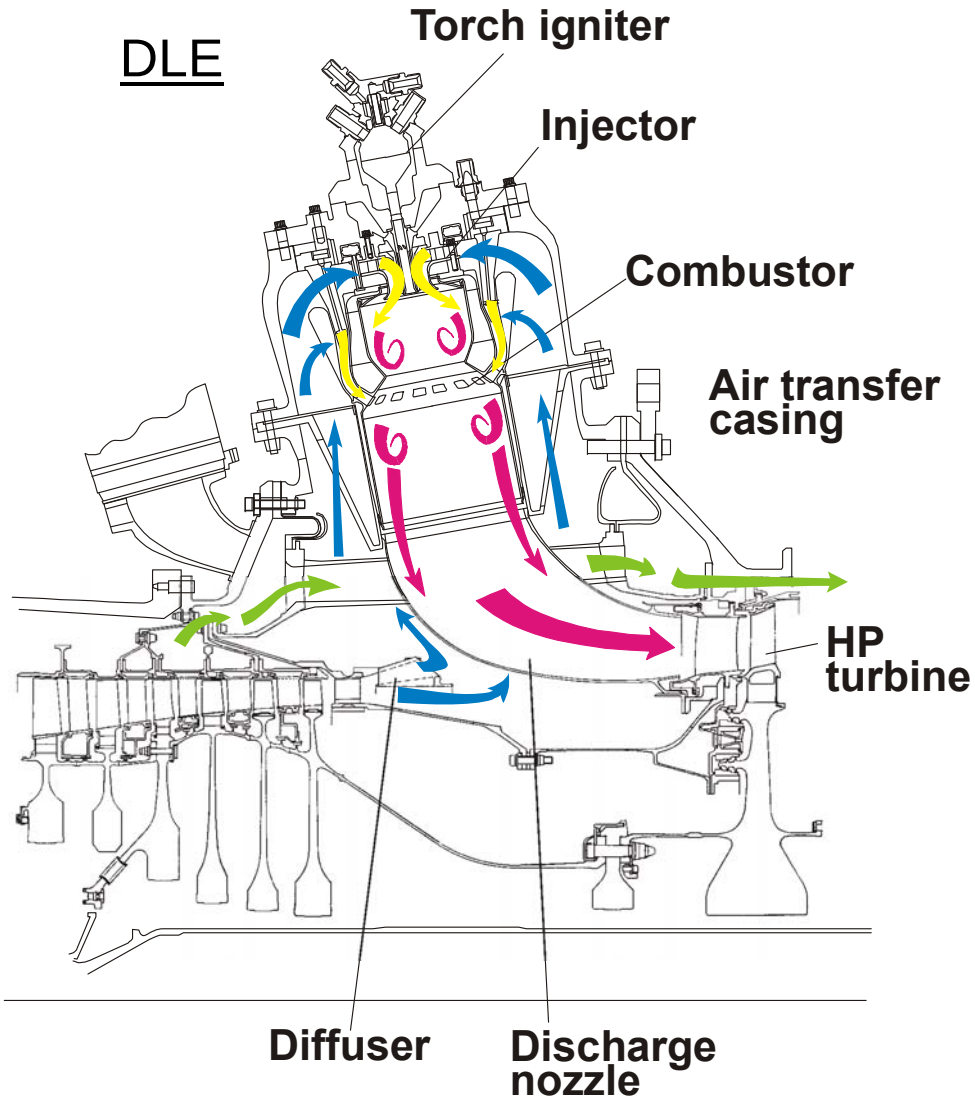
Airflow

Pre-mix flow

Combustor

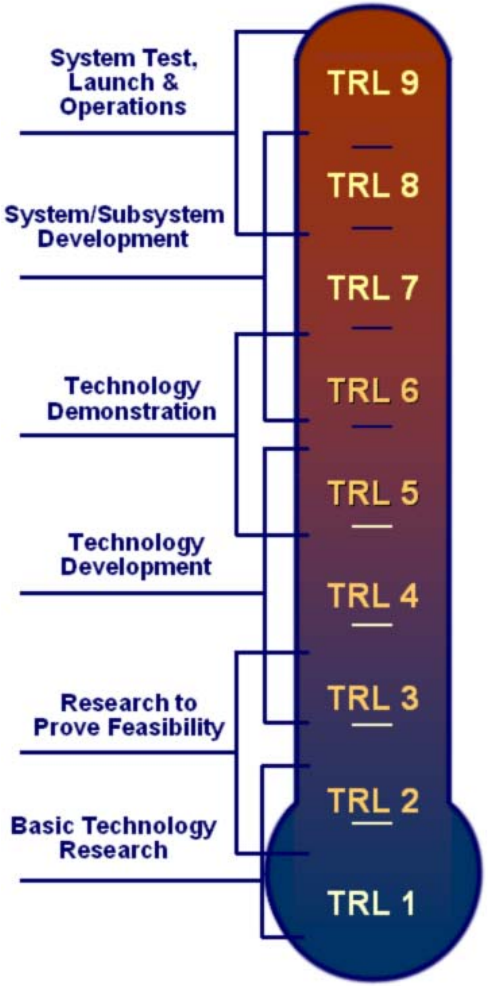
Cooling air

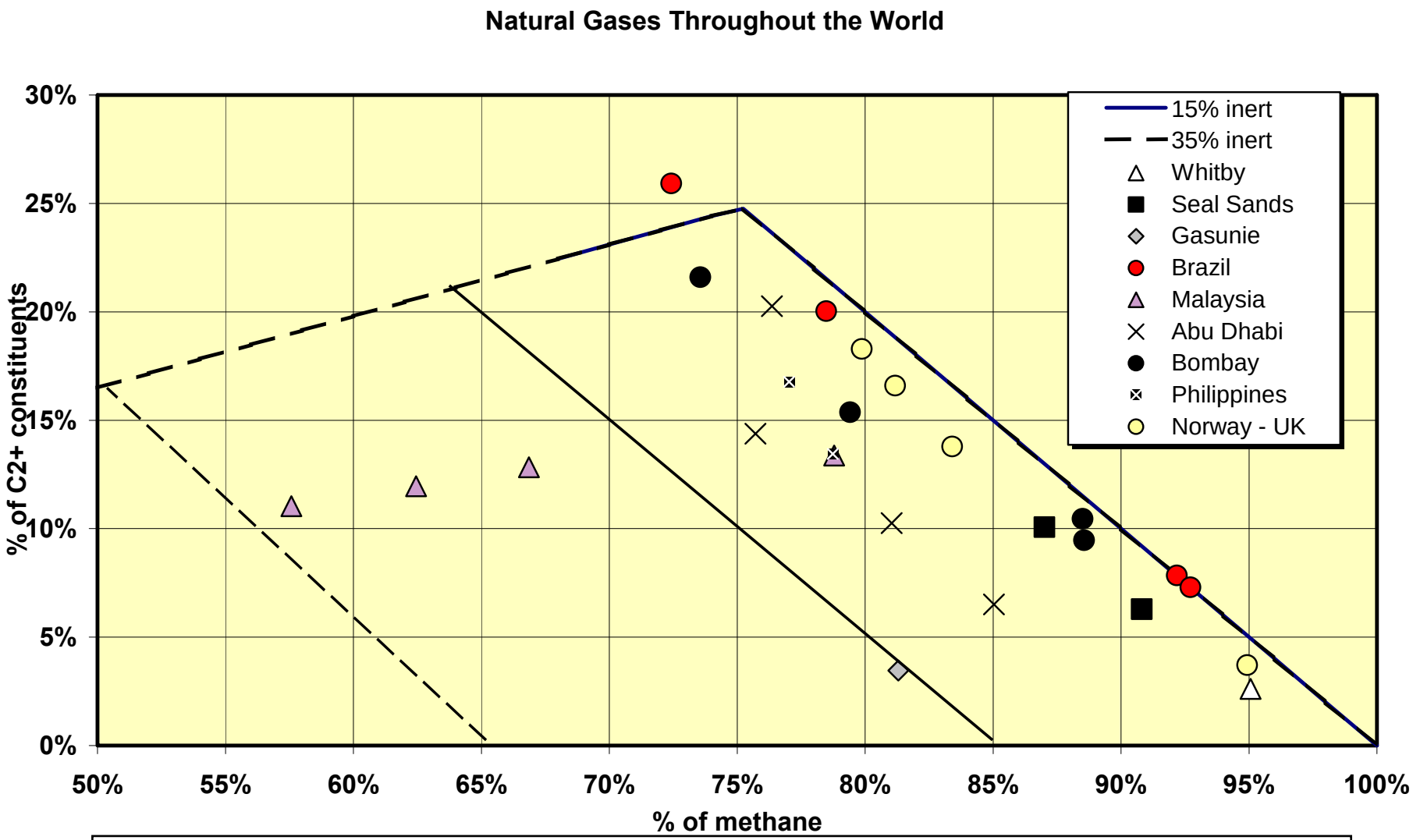
DLE



Fuel standardisation methodology

- Adherence to NASA developed TRL scale
- Need to respect the following customer requirements:-
  - Safety
  - Operability /Performance
  - Reliability / Availability
  - Emissions
  - Life
- Never assume that a fuel will always adhere to what is written in the specification!

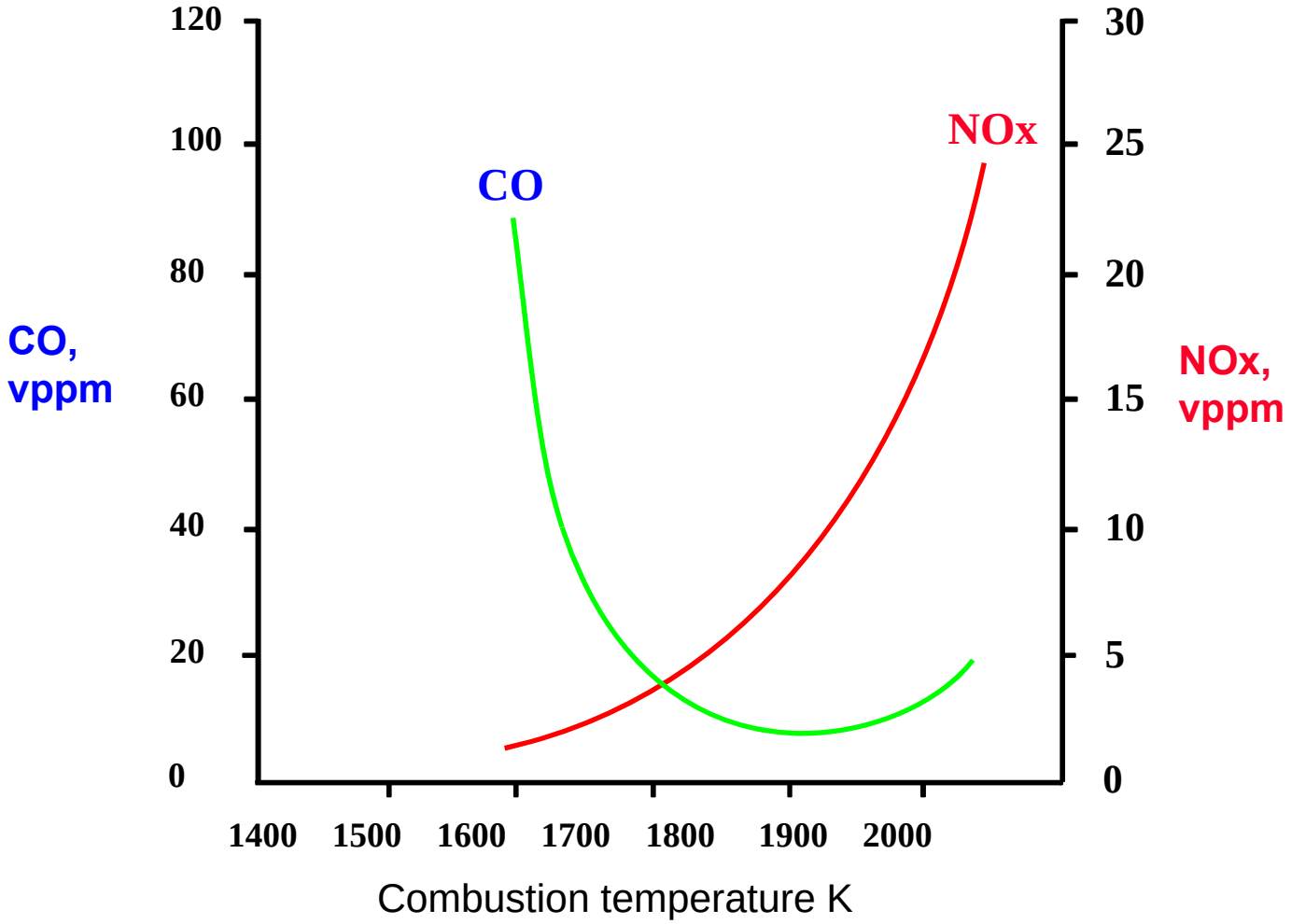




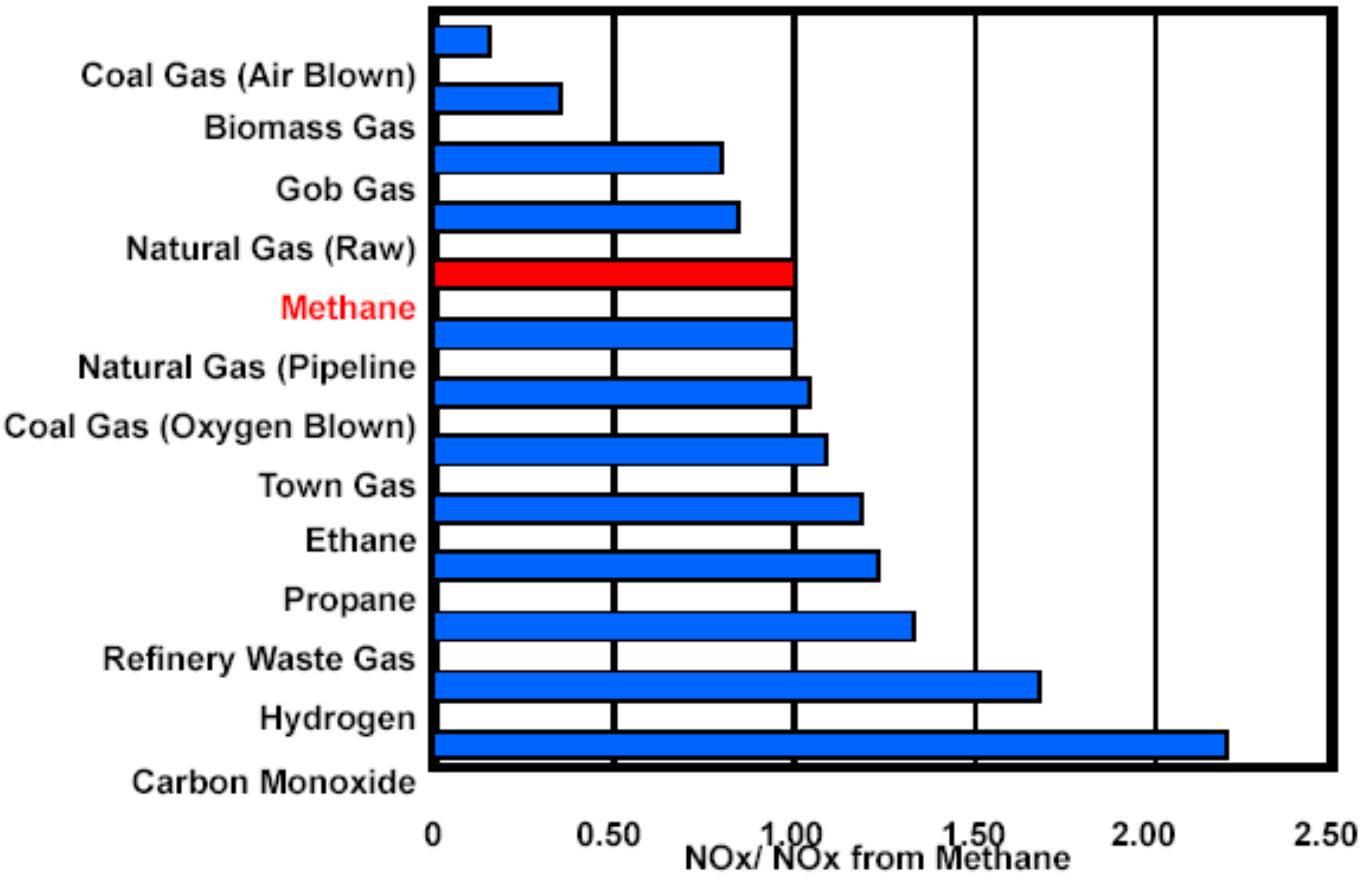
Challenge increases with pressure and temperature

Influence of Flame Temperature on CO and NOx Emissions

Indicative trend, level depends also on residence time



Influence of gas constituents on NOx emissions



Expect 10-15% fluctuations in emissions resulting from NG variations

Effects of liquid carry-over in fuel gas

HP turbine blade showing gross erosion of shroud and front seal fin

HP Seal Segments showing severe thermal erosion

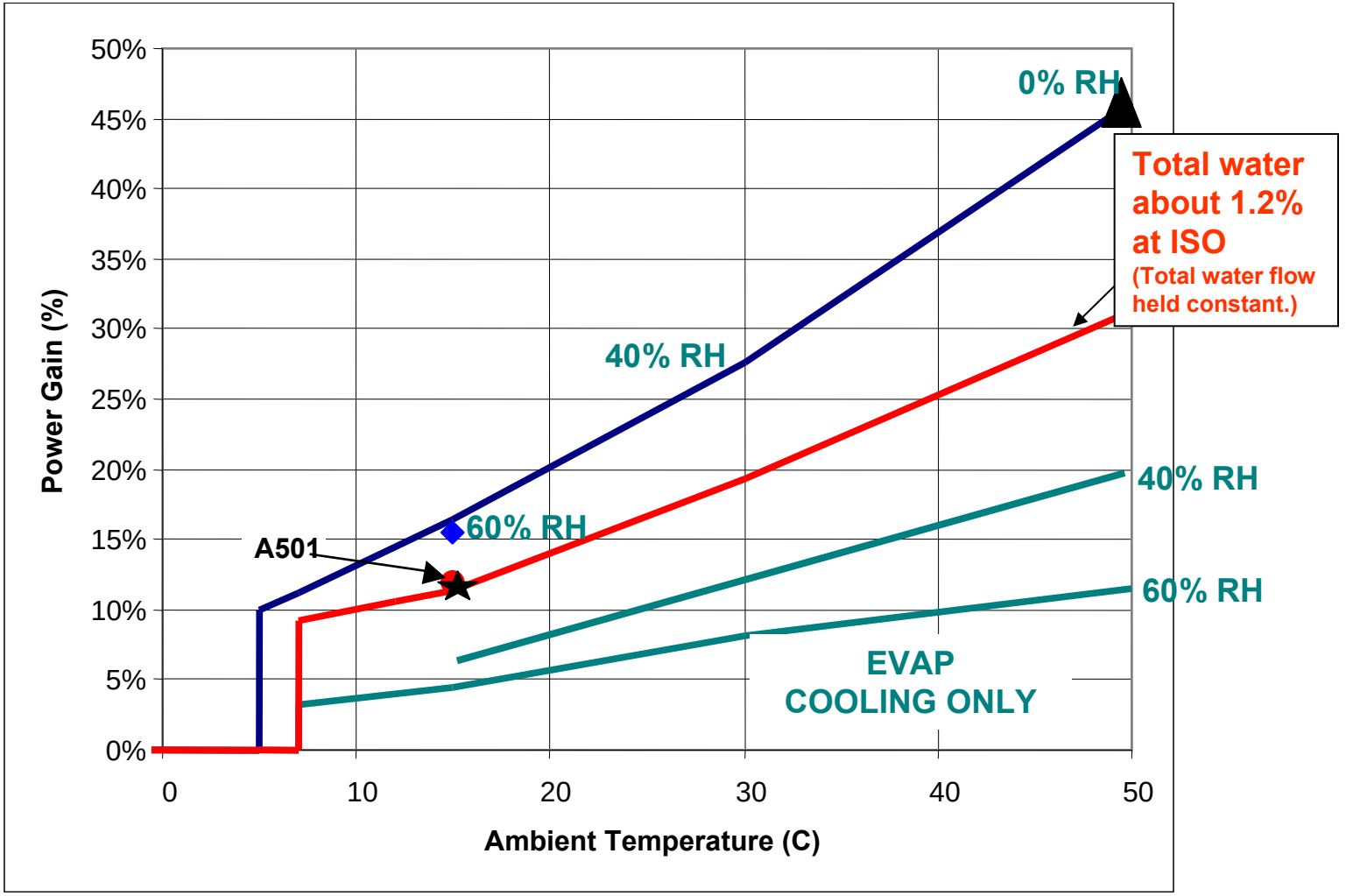
Combustor Outer Wall showing extreme overheating

Novel fuel challenges

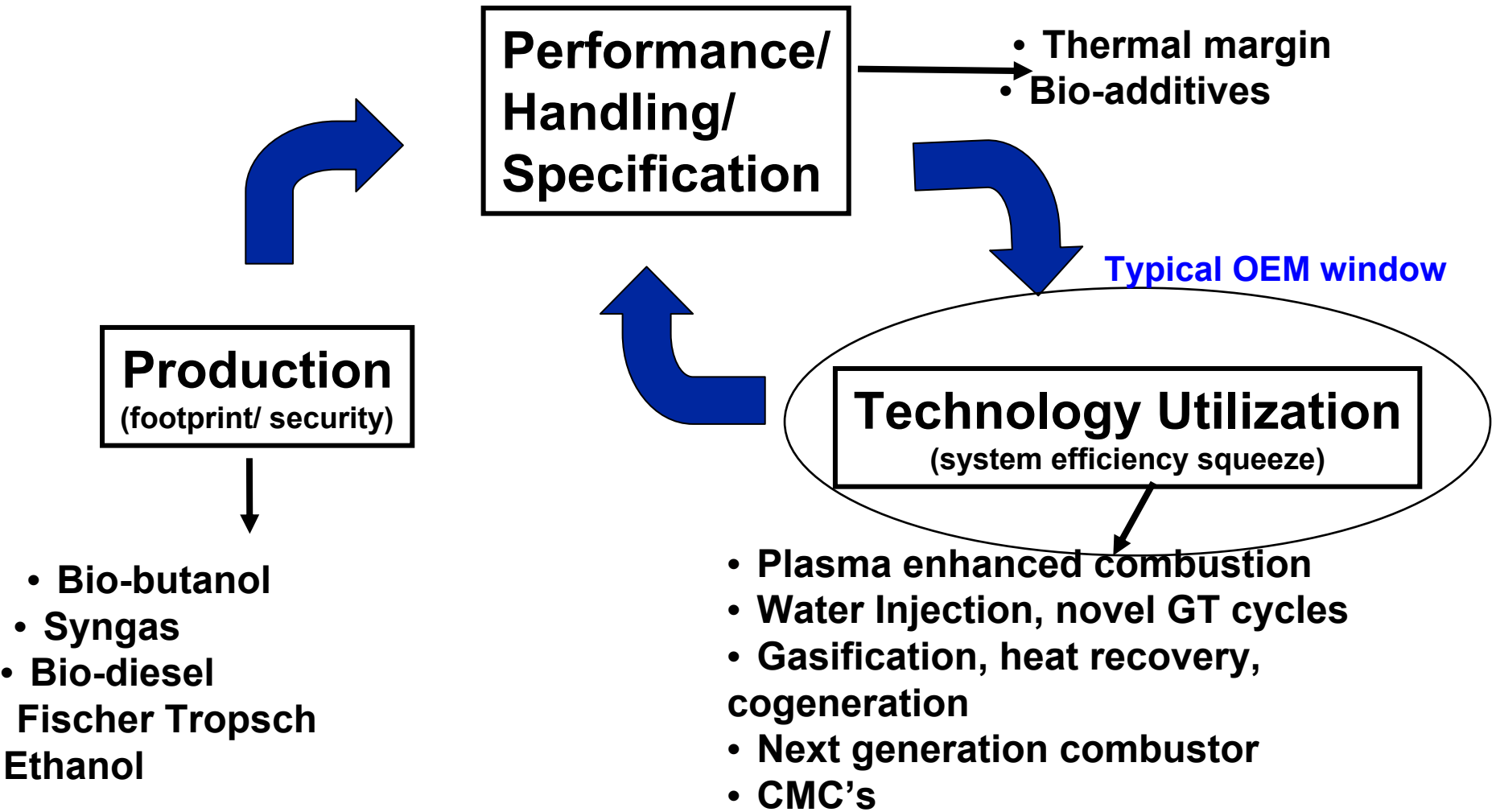
- **Biodiesel, 100% and blended**
  - Coking propensity
  - Hot end life
- **Ethanol**
  - Low flashpoint
  - Low energy density
  - Potential material compatibility issues
- **Syngas**
  - Combustion properties are highly dependant on ratio of H2:CO:inerts
  - Higher flame speed and flammability range = flashback and ease of ignition
  - Higher diffusivity will lead to storage / transportation issues
- **Regulation – where will it drive us to?**

Aerospace → Industrial technology reversal most prominent

Free Fuel (system efficiency)



Collaboration through roadmap clarity



There are no shortages of (partial) funding opportunities

Conclusions (1)

- The past is the best teacher you will find
- Dry Low Emission (DLE) combustion systems are now proven technology. What will be next? Regulation and innovation will ultimately decide.
- Extra precautions required to maintain fuel quality (absence of liquid or solid particulates)
- Novel fuels will bring new challenges which should drive (emerging) technological innovation. This coupled with the Aerospace → Industrial technology reversal means we have exciting times ahead
- Collaboration is the most cost effective and efficient way to develop innovative technology

A vision for the future from great minds

It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change

Charles Darwin

The most important single ingredient in the formula of success is knowing how to get along with people.

Theodore Roosevelt

Knowledge shared is knowledge squared.

Microsoft

The invention was nothing. The achievement was making the thing work.

Sir Frank Whittle