

Pierre Q Gauthier PhD
Visiting Professor of Low Emissions Combustion Modelling

Introduction to Combustors for Aero-Derivative Engines and Large Industrial Gas Turbines

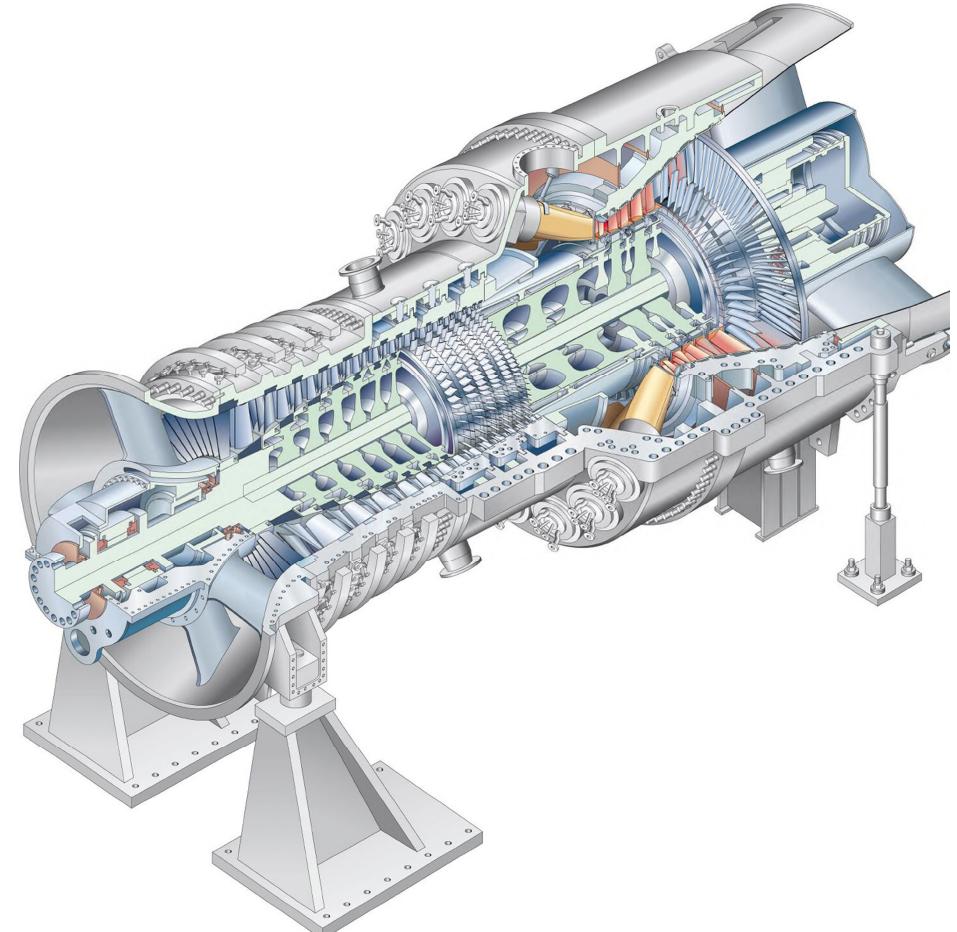
The Challenges of Industrial Gas Turbine Combustion Modelling

Not All Combustion Systems are Created Equal!

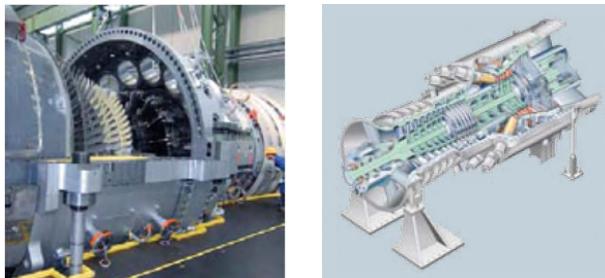
Introduction

Energy demand

- global consumption of electric energy is increasing
 - more renewables (wind and solar) in energy generation
 - stricter limits for pollutant emissions
- modern gas turbines with high efficiency and low emissions are needed
- development of new combustion technologies
 - CFD simulation reduces cost and time



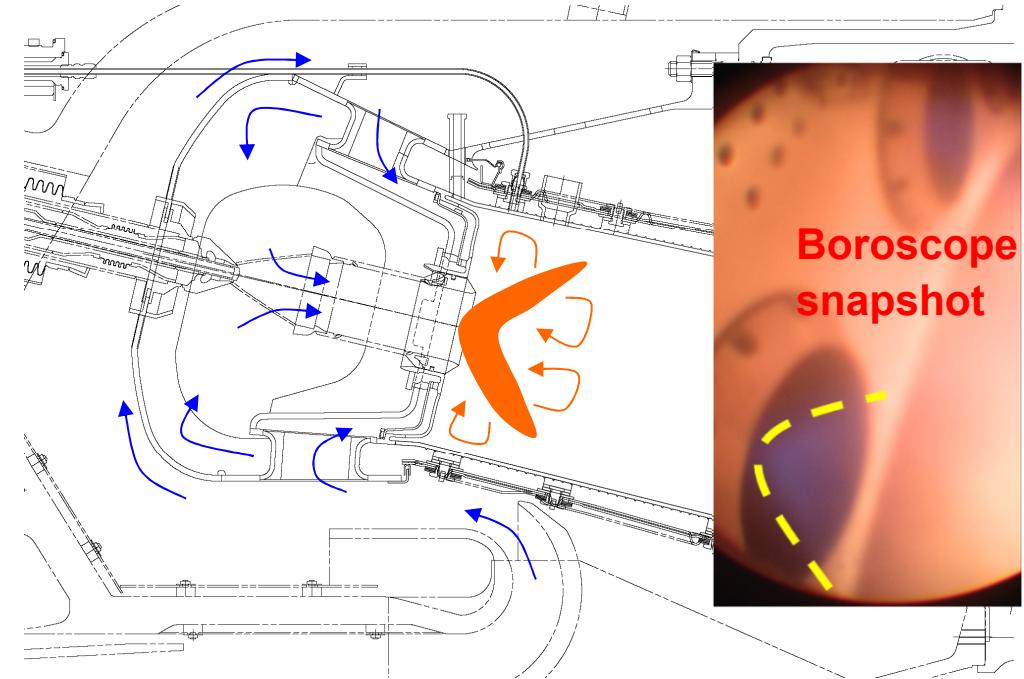
Siemens Gas Turbine Portfolio



Siemens largest GT
SGT5-8000H
450 MW

Aero-derivative	SGT-A65 TR	53-66 MW
	SGT-A45	41-44 MW
	SGT-A30 RB	27-38 MW
	SGT-A05 AE	4-7 MW
	SGT-100	5.7 MW
	SGT-200	7 MW
	SGT-300	9 MW
	SGT-400	14 MW
Finspång engines	SGT-500	19 MW
	SGT-600	25 MW
	SGT-700	33 MW
	SGT-750	40 MW
	SGT-800	48-57 MW
60Hz	SGT6-2000E	117 MW
	SGT6-5000F	250 MW
	SGT6-8000H	310 MW
50Hz	SGT5-2000E	187 MW
	SGT5-4000F	329 MW
	SGT5-8000H	450 MW

Siemens SGT-800
Annular combustor with 30 burners



Siemens Finspång largest GT
SGT-800
57 MW

Gas turbines produced over a wide range of ratings

SGT-750

GT competitiveness

- Efficiency
 - High turbine inlet temperature and effective cooling
 - Knowledge of turbine inlet depends on combustor knowledge
- Reliability and availability
 - Combustion instabilities may lead to fatigue failure
- Total life cycle cost

SGT-750 Efficiency data

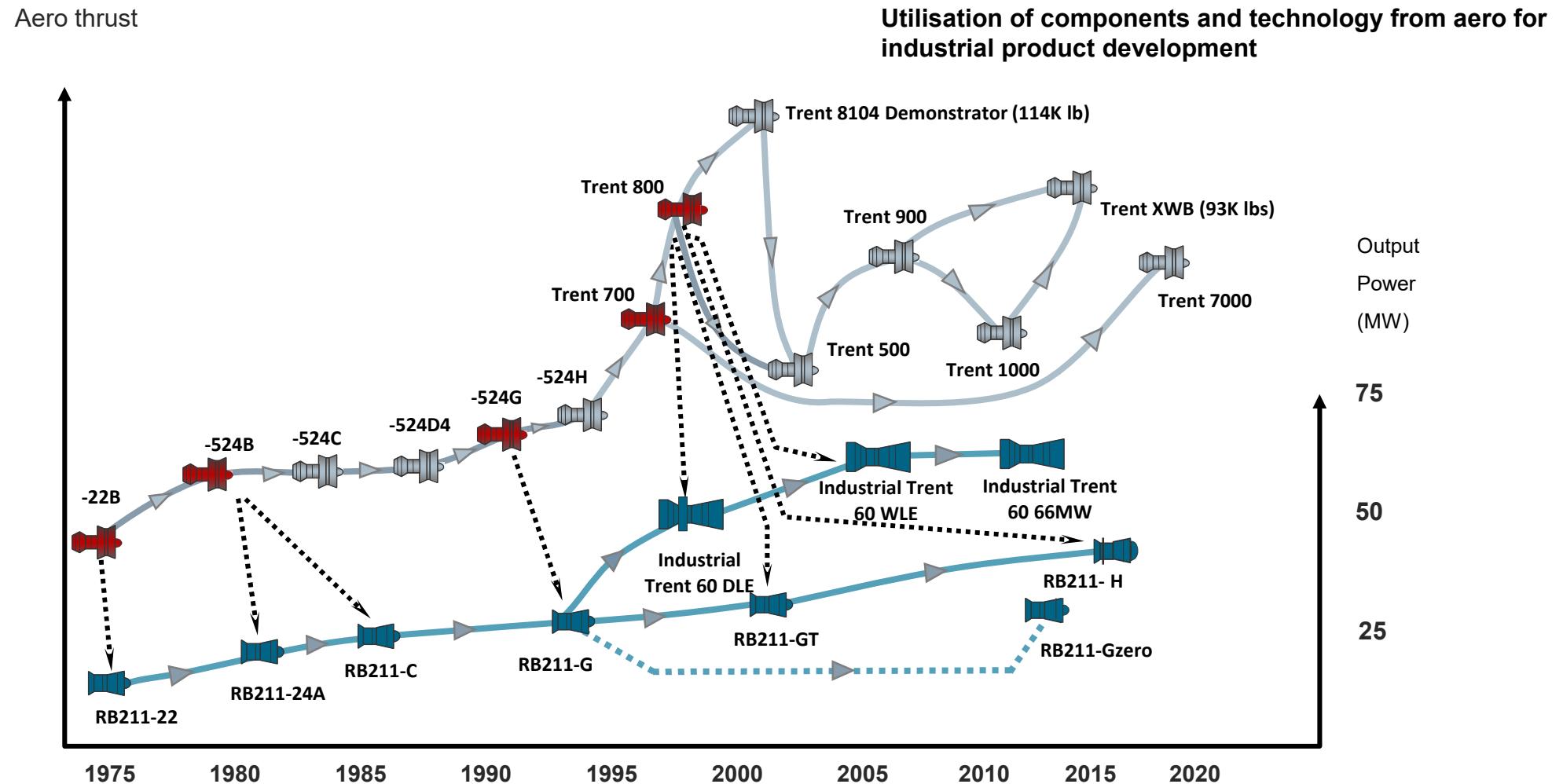
	Power	Efficiency
Shaft	41.0 MW	41.6%
Electric	40.0 MW	40.3%
Combi	47.7 MW	51.7%

- Emission levels
 - Low NOx requires limited flame zone temperature and well mixed air/fuel
 - Reduced NOx often leads to instabilities & increased CO/UHC
- Ability of flexibility
 - Gas/liquid fuel type and energy content strongly influences the combustion
 - Load flexibility to back up renewables

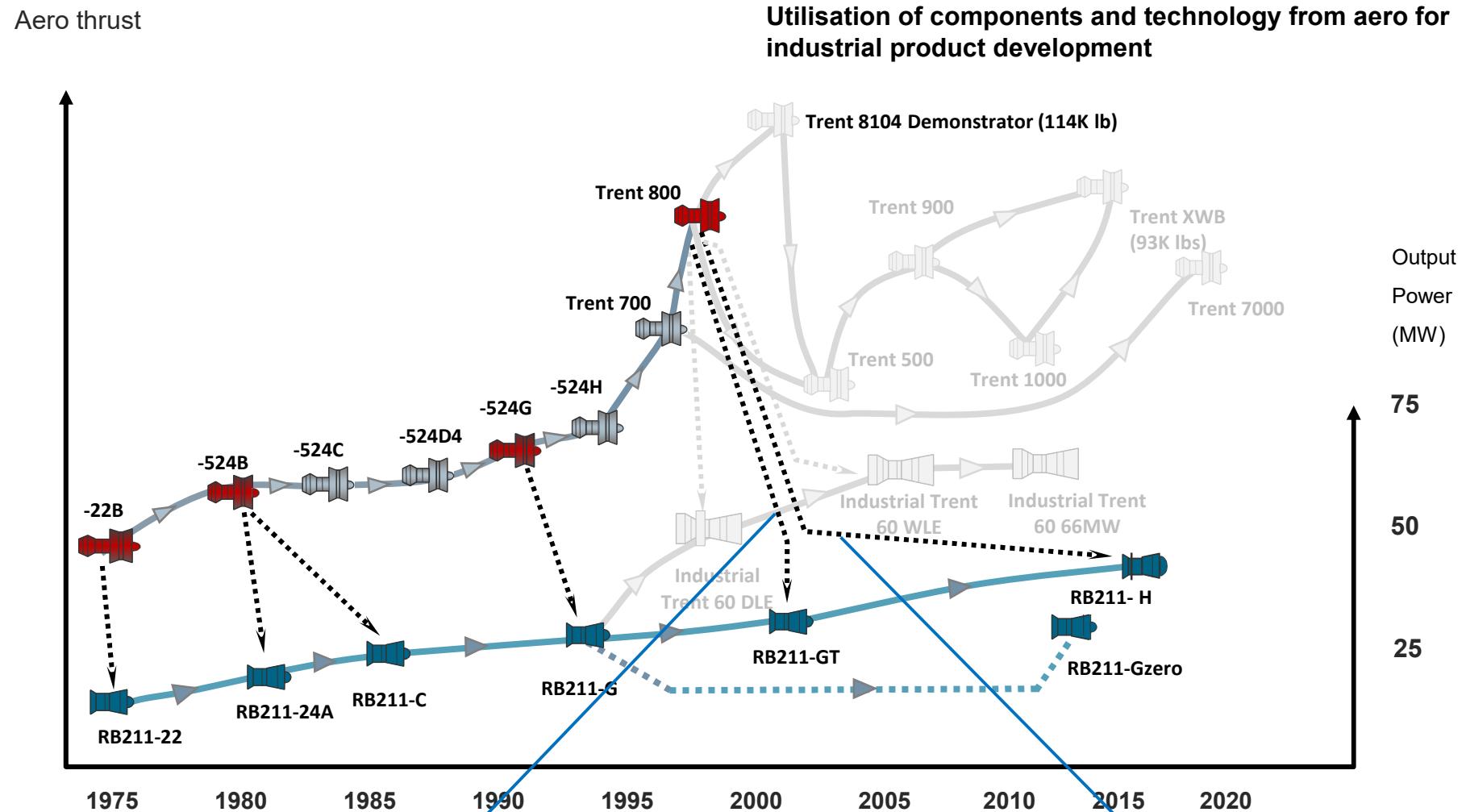


Siemens Aero-Derivative Gas Turbines Powered by Rolls-Royce

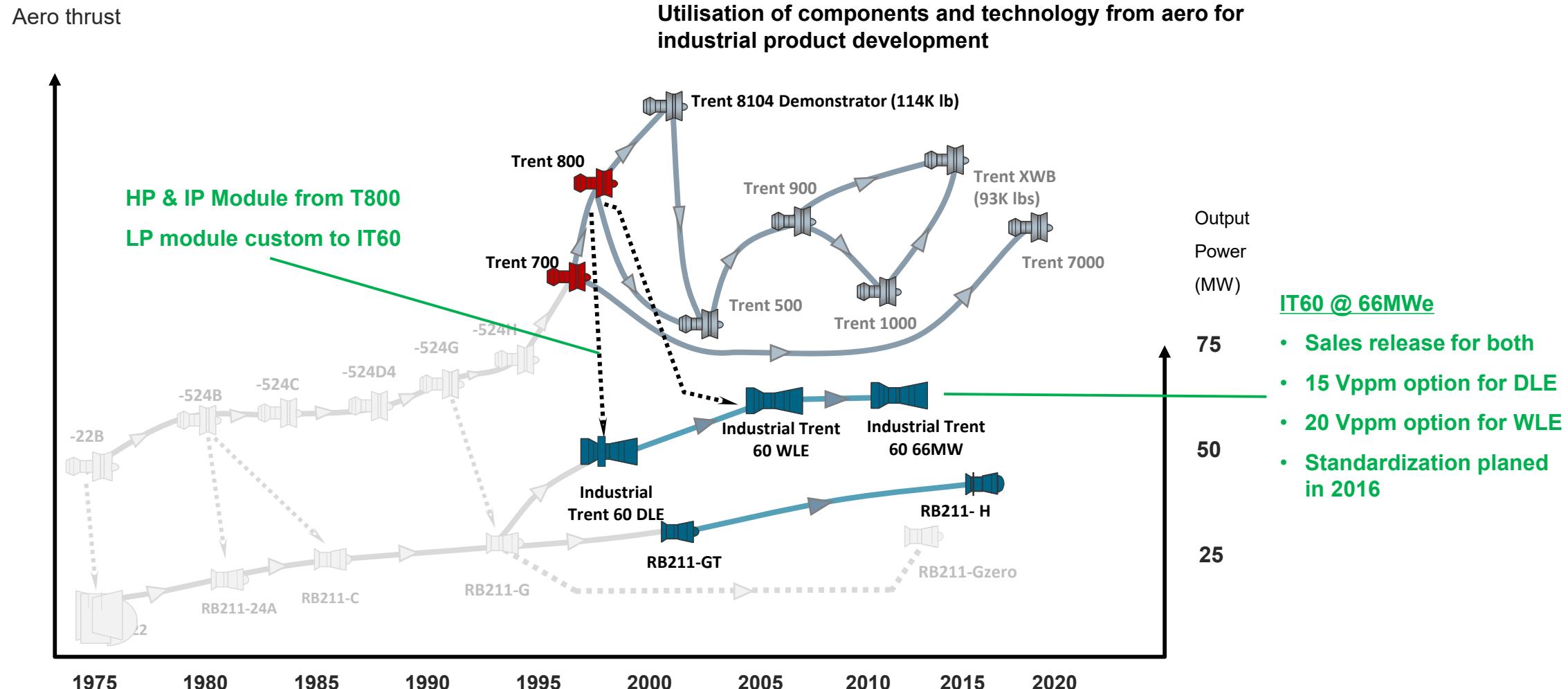
SIEMENS



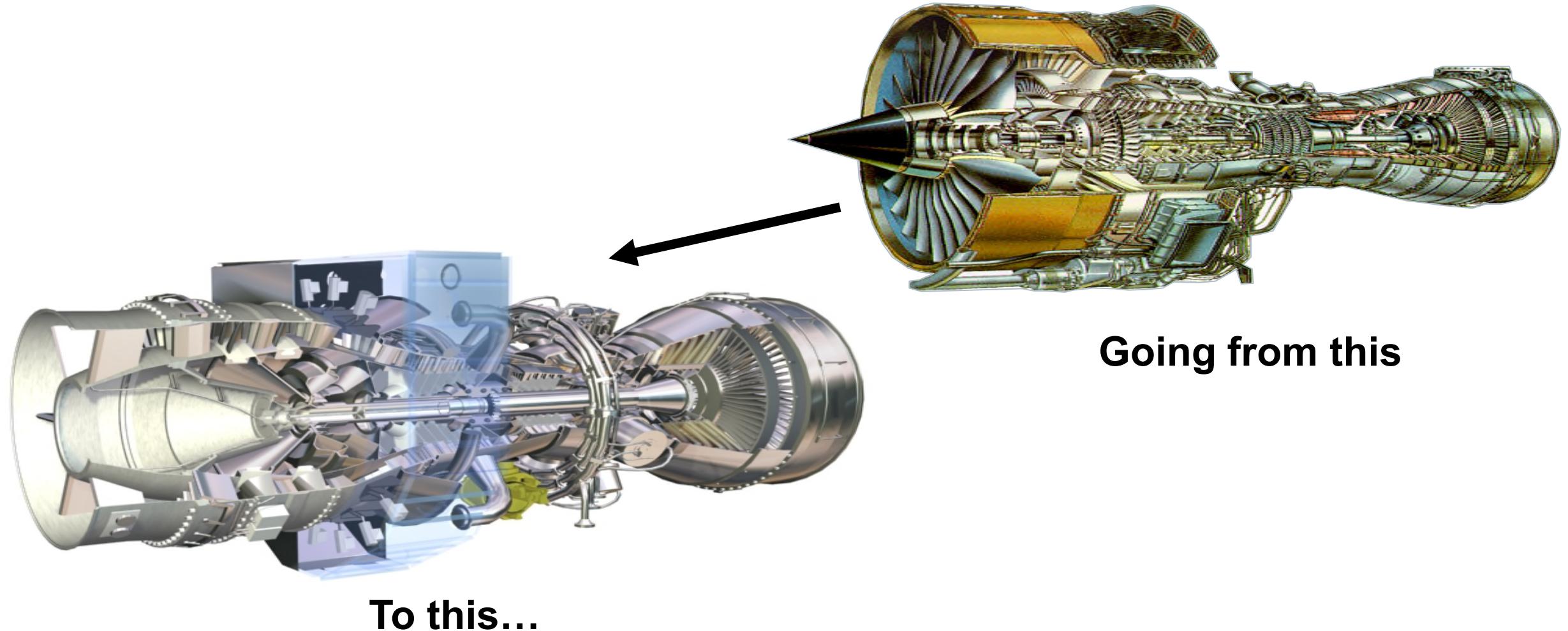
Siemens Industrial RB211



Siemens Industrial Trent 60

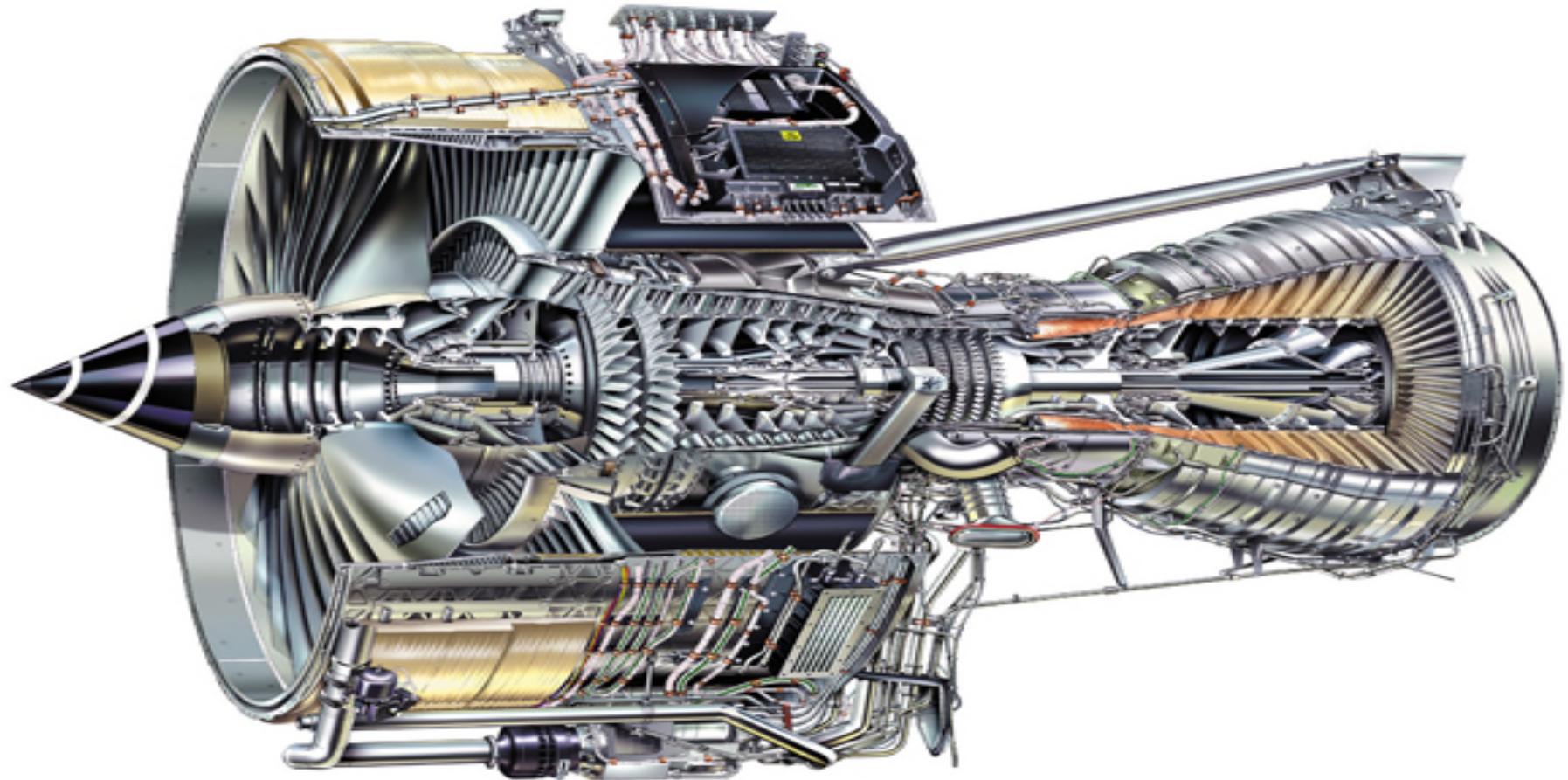


The Industrialization of the Trent



Trent 800

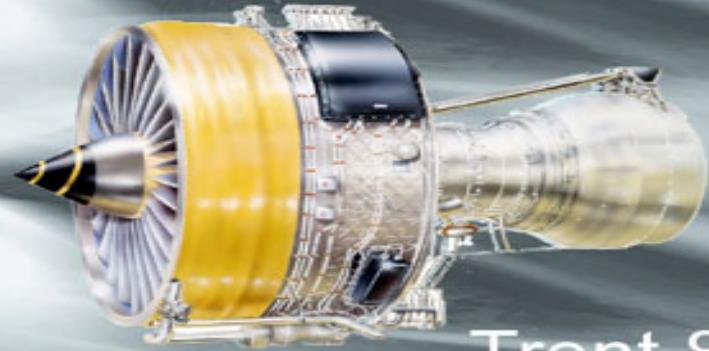
Engine Design



Three Independent Shafts

Annular combustor designed for liquid fuel

Low speed power turbine designed to balance power between LP shaft and thrust output

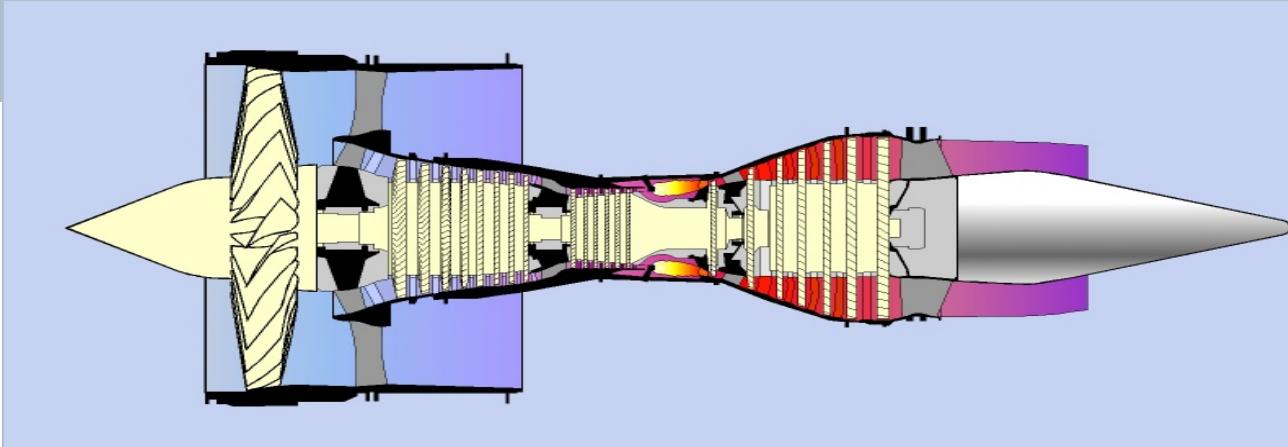


Trent 800

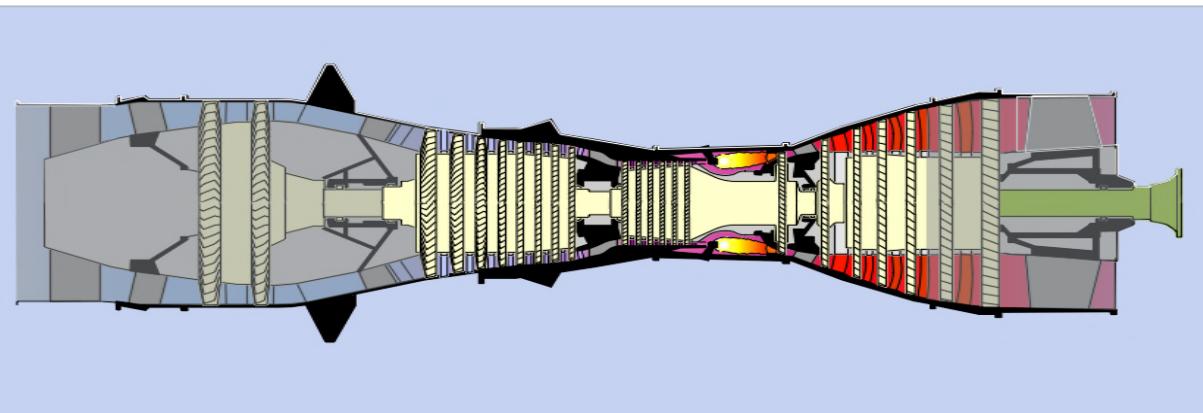
Thrust	75,000 – 95,000lb
Fan Diameter	110in
Bypass ratio	6.1
Weight	13,100lb
Total aircraft in-service	216
Total engines in-service	492
Service engine hours	Over 10 Million

Applying Aero Technology in Marine and Energy

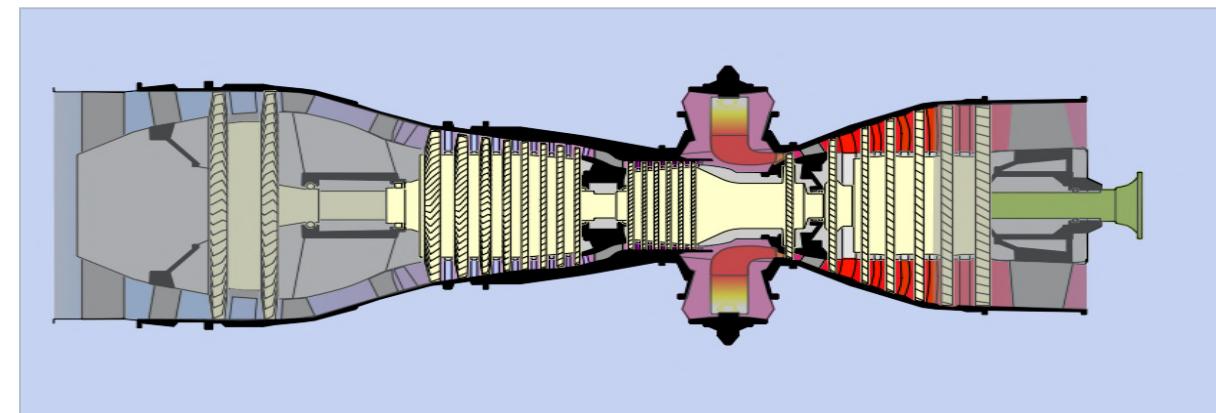
SIEMENS



Civil Turbofan - Trent 800



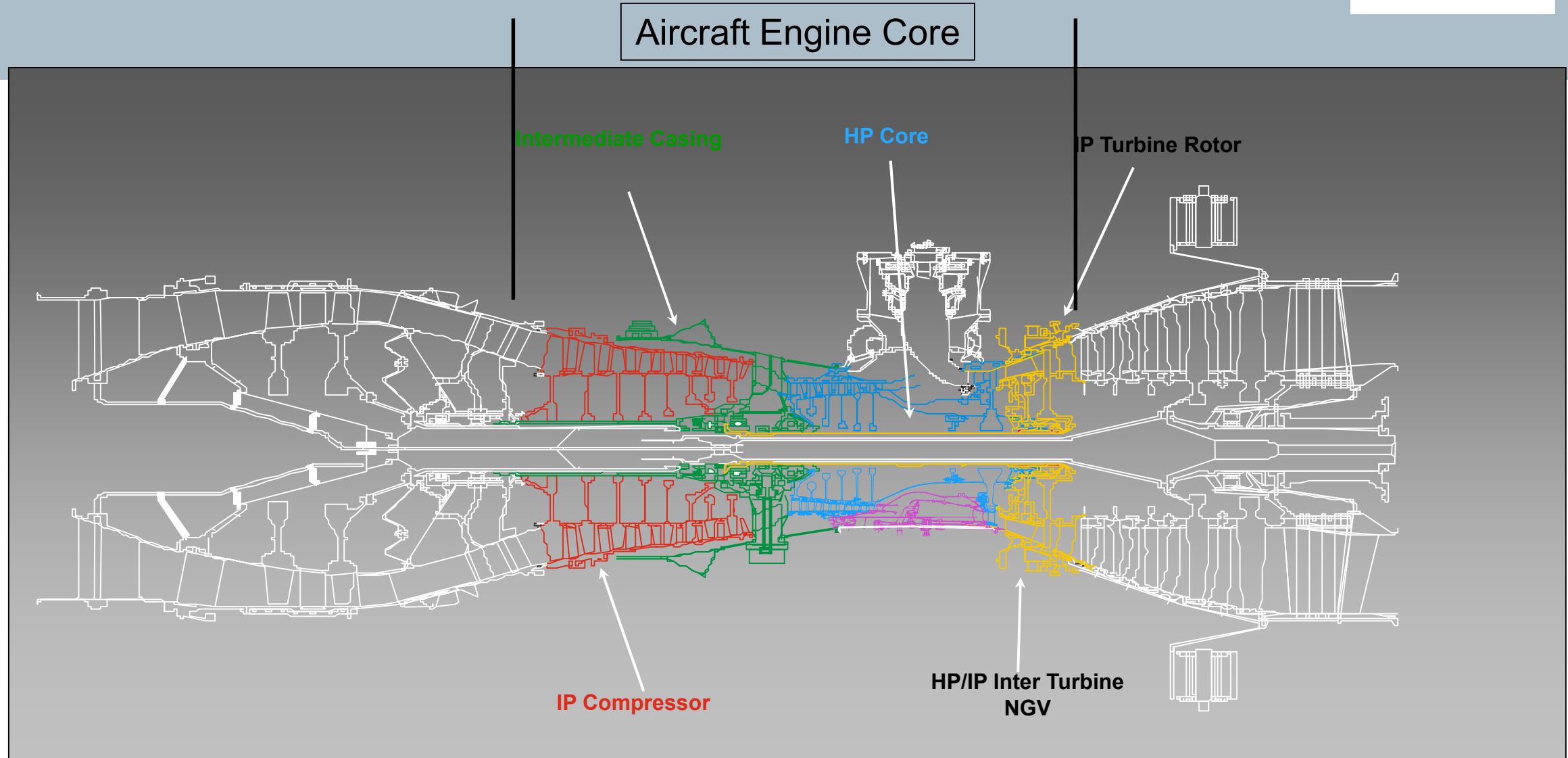
Marine Trent



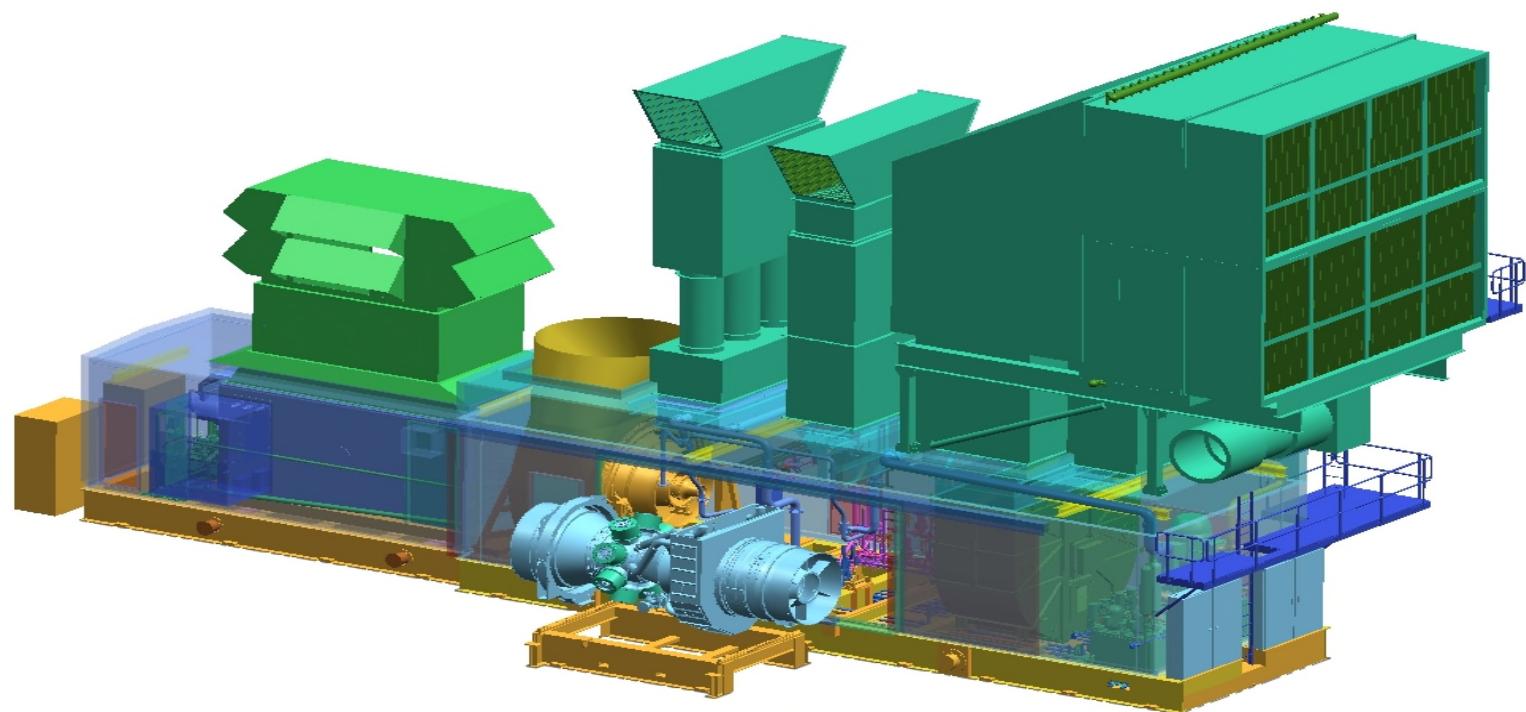
Industrial Trent

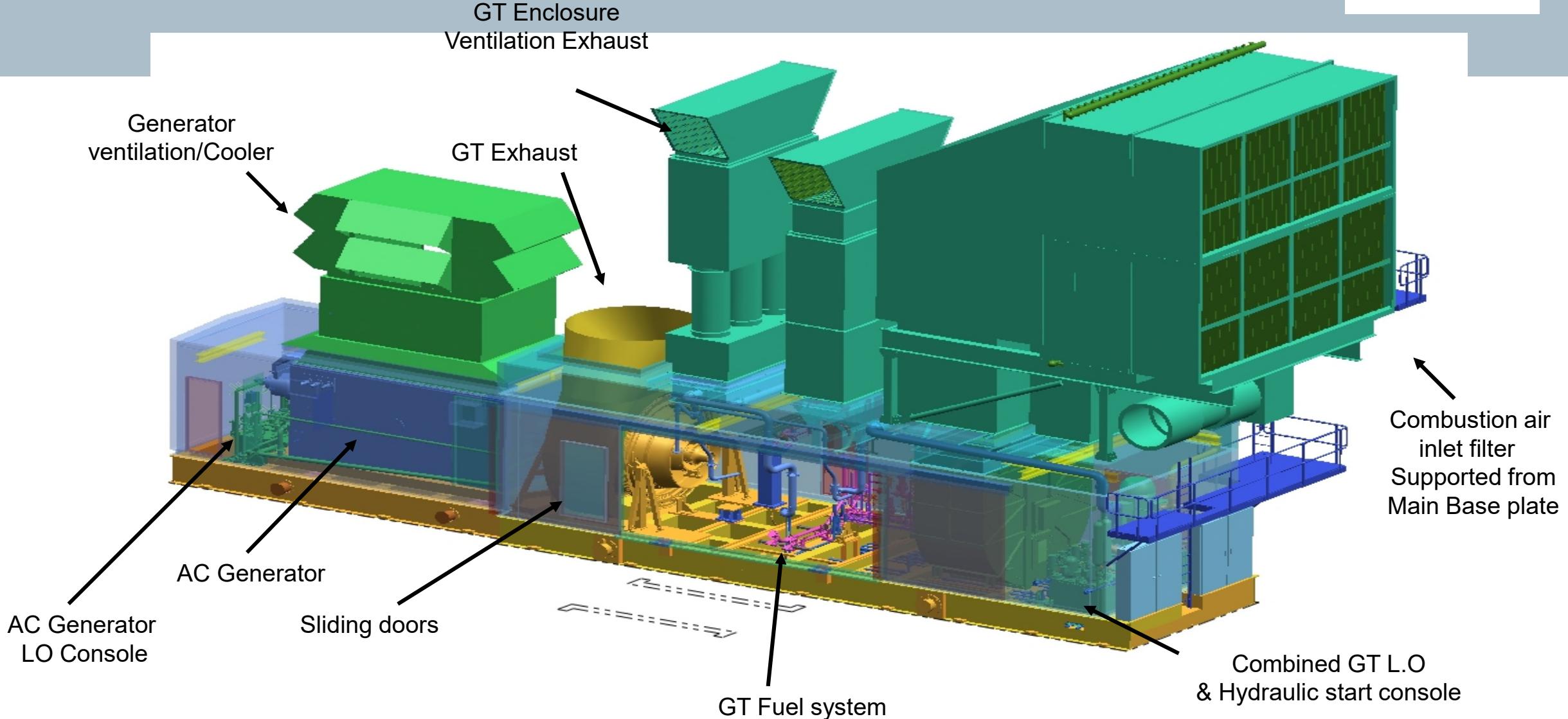
Aero Engine Lineage of the Industrial Trent

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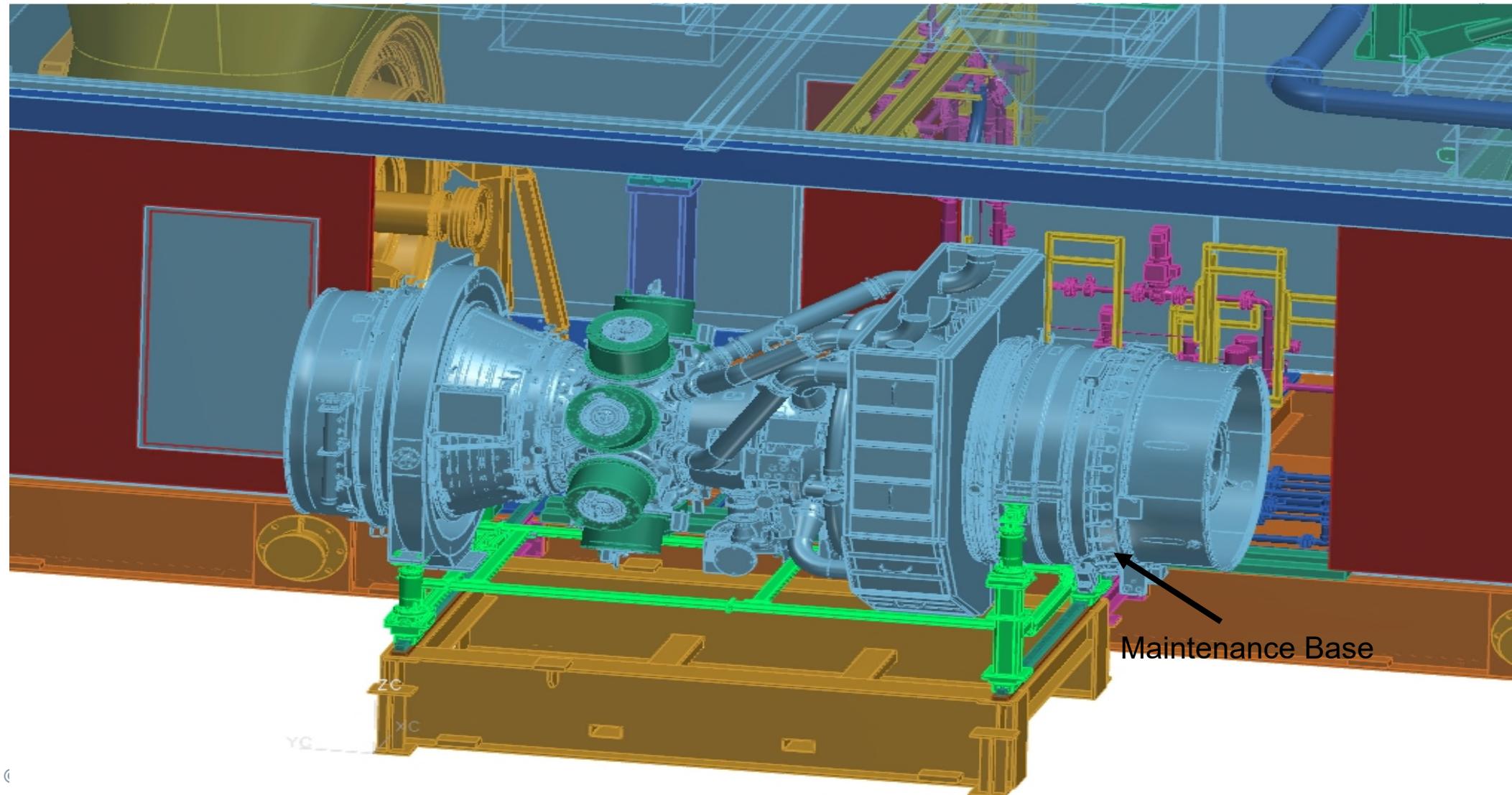


New Package Needed to be Developed

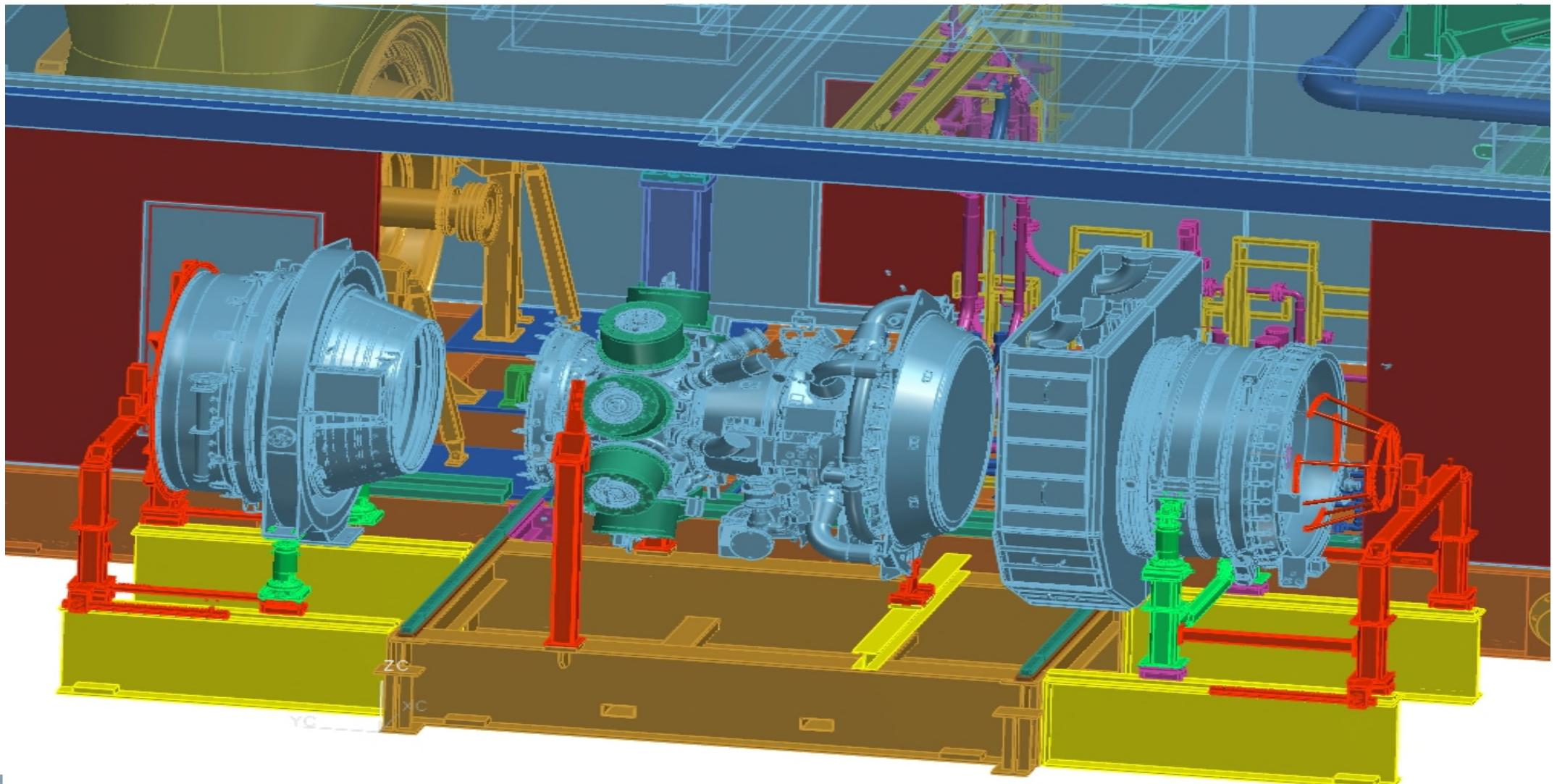




Engine Removal Via Enclosure Mounted Handling Equipment

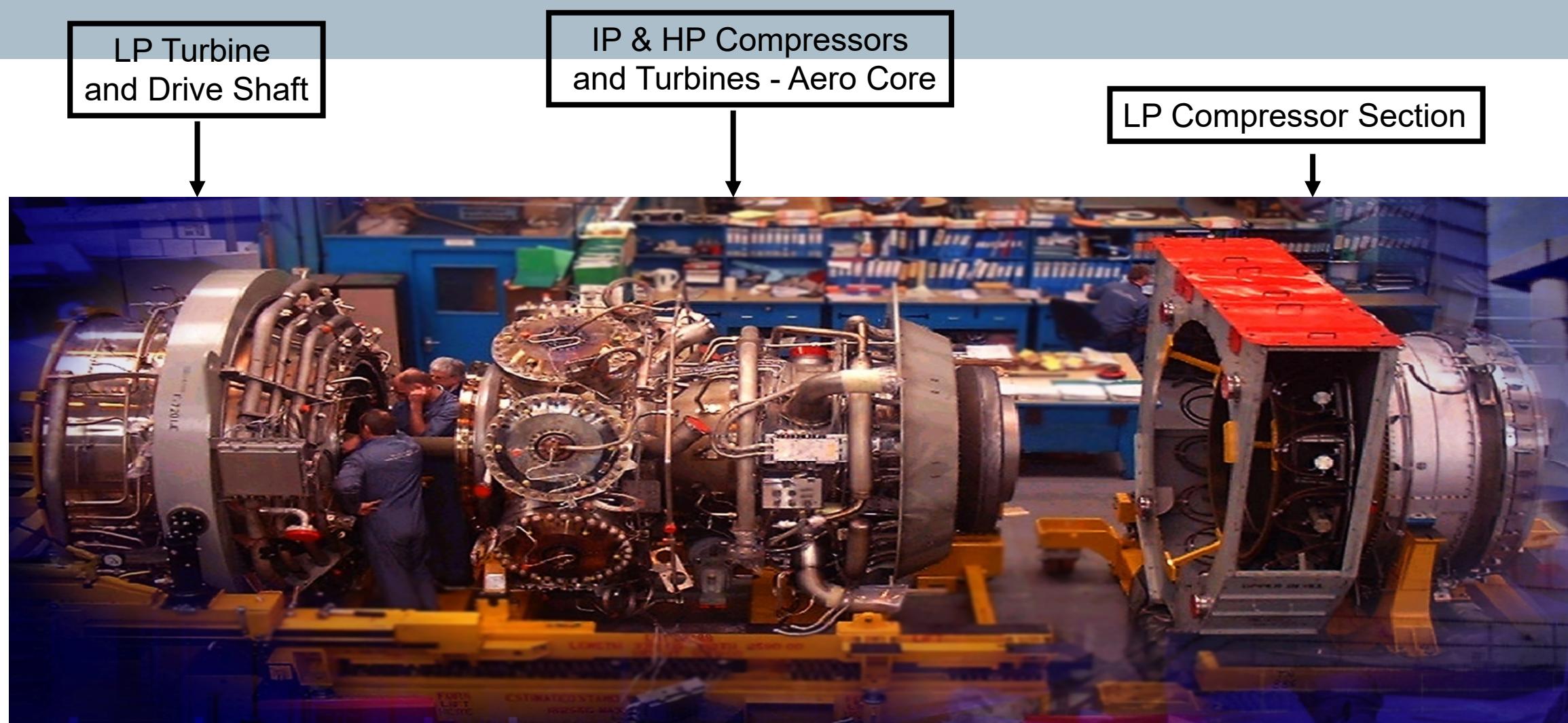


Ability to Complete Engine Module Change Out at Site



Maintenance Capabilities of the Industrial Trent

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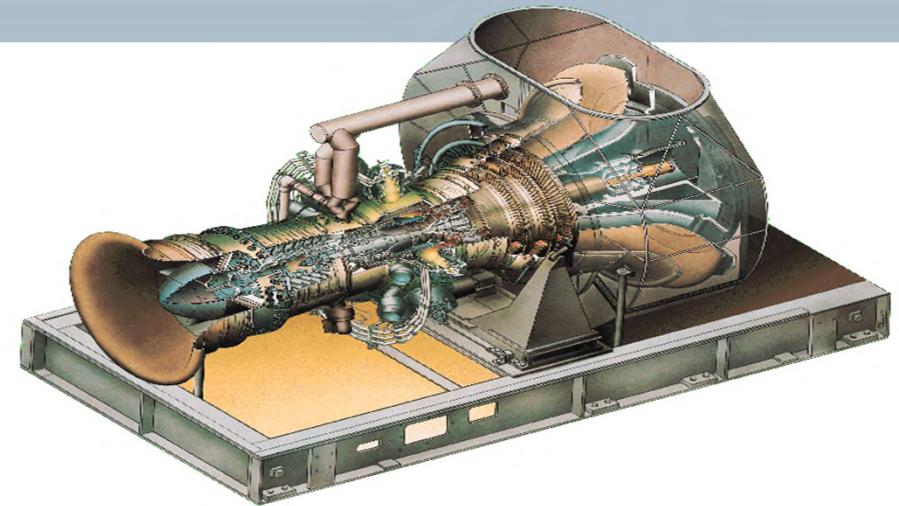


Engine Three Way Split

Current Product Range

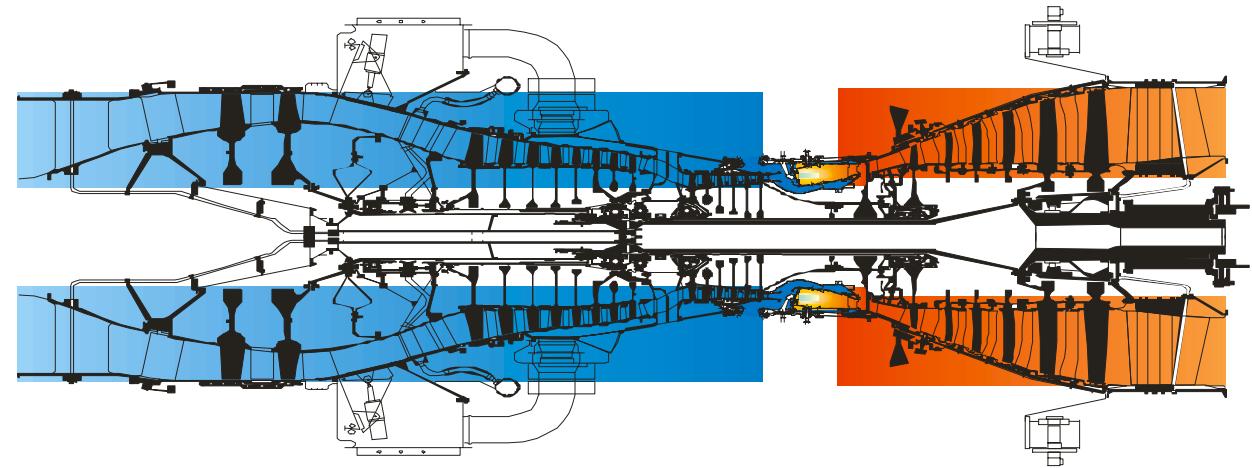
Industrial RB211

- 2 shaft gas generator (G, GT)
- Dual fuel or DLE
- Free power turbine (RT61, RT62, RT62HM)
- GT61: 33.3MW, 40.5% Thermal Efficiency
- GT62: 29.4MW, 38.0% Thermal Efficiency



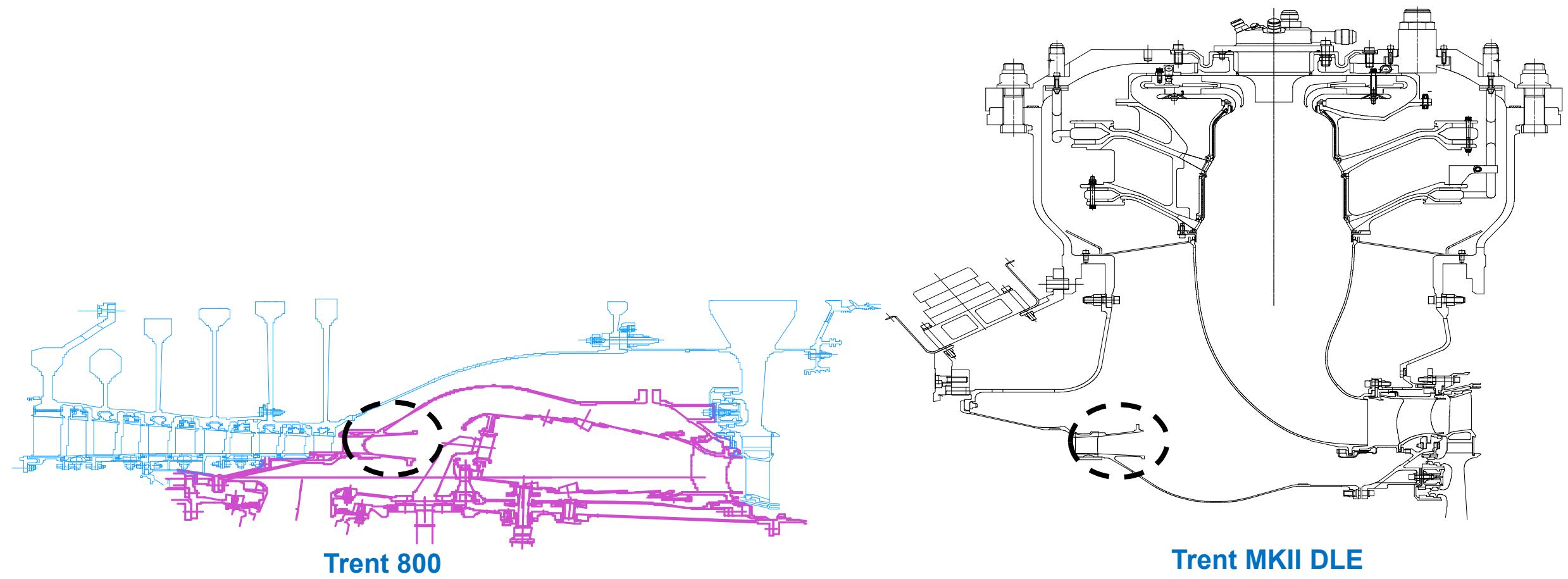
Trent 60

- 3 shaft, direct drive
- Power generation (50Hz, 60Hz)
- WLE Dual Fuel or DLE
- Mech. Drive
- WLE: 58.9MWs, 42.1% Eth
- DLE: 52.3MWs, 42.4% Eth



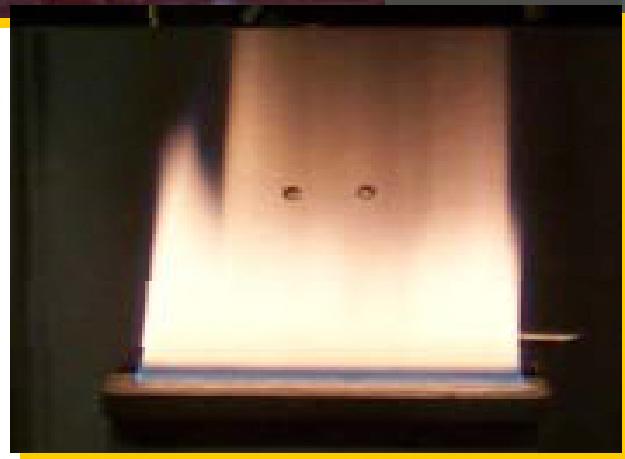
Why the Vastly Different Combustion System?

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Diffusion Flames

Fuel and Air Mix and Burn At
the Same Time



Premixed Flames

Fuel and Air Mix and Then
Burn



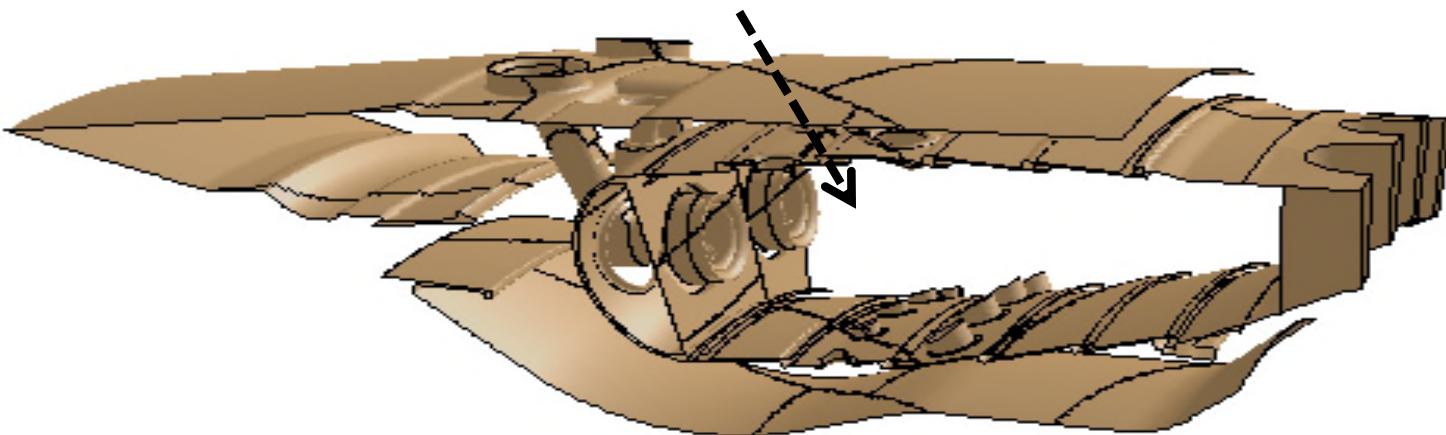
Diffusion Flame

Premixed Flame

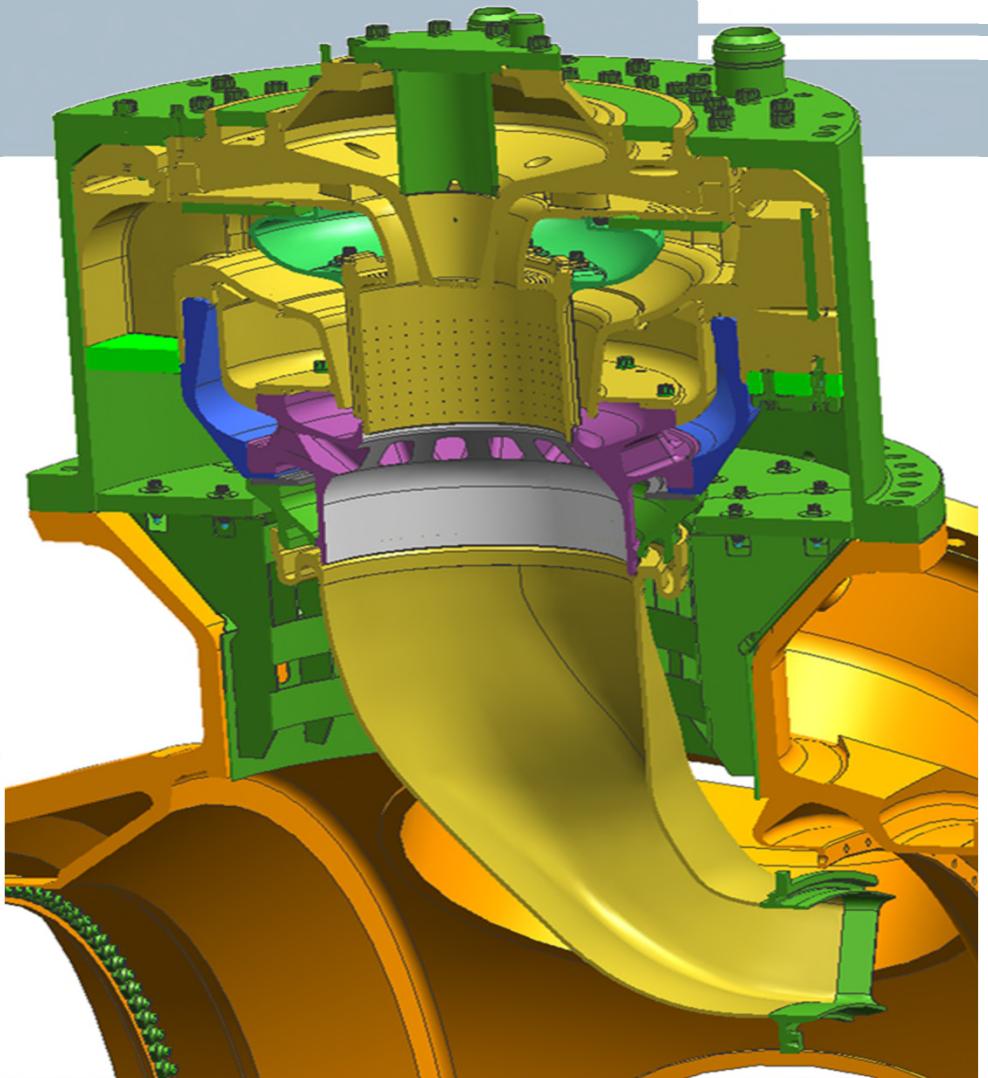
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Intricate 'plumbing' required to
Mix the fuel and the air before
entering the combustor

Fuel and Air meet for the first time
Inside the combustor



Typical Aero Combustion System



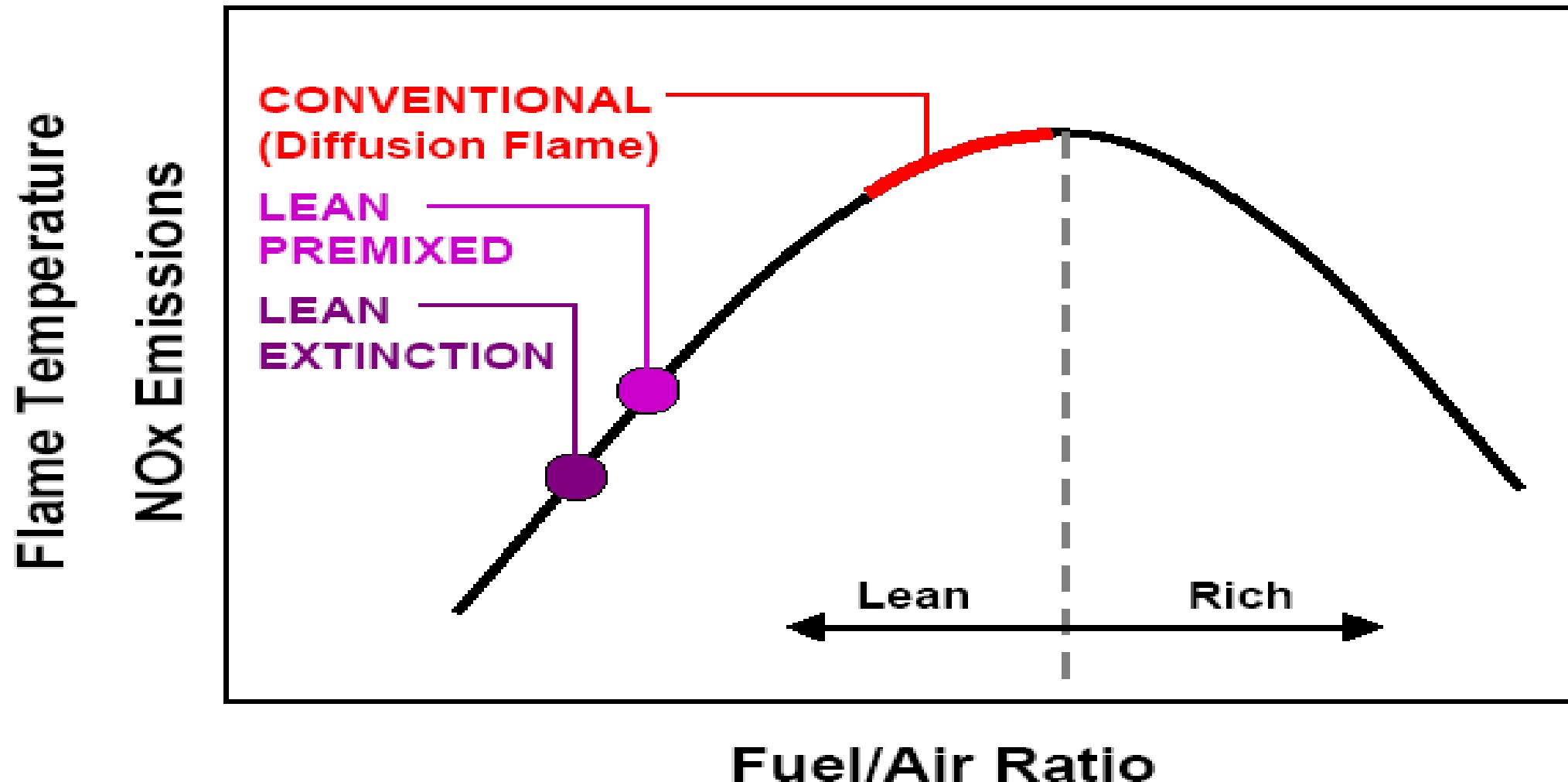
Industrial Combustion System

Why...?

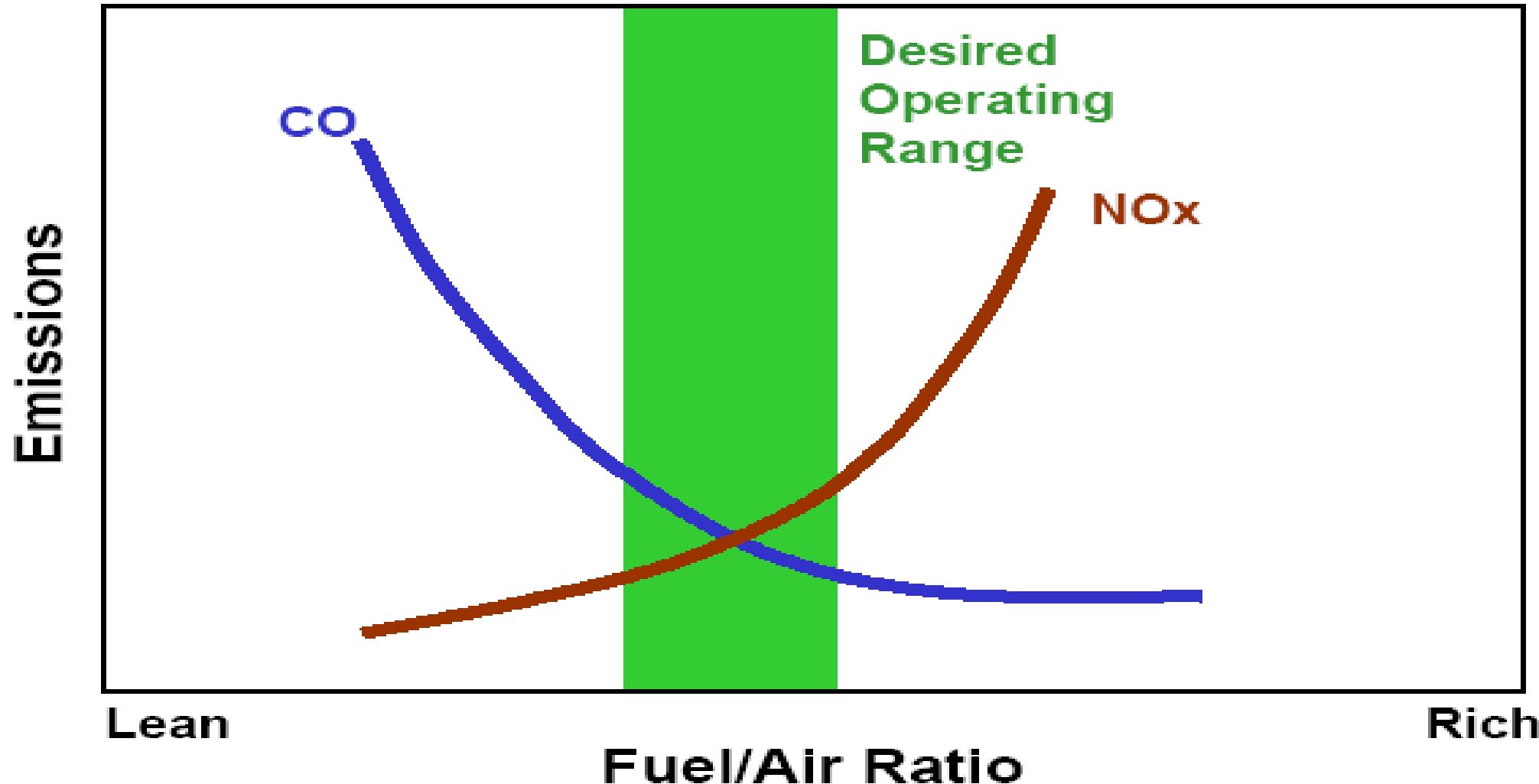
Emissions!

- Industrial Gas Turbines can run continuously for Thousands of Hours.
- Aero Gas Turbines have a much different cycle:
 - Take-off → Cruise → Land
 - Although Emissions are still an important consideration... they are often 11km above the ground!
 - Altitude re-light
 - Fuel efficiency

Effect of Stoichiometry on Flame Temperature and NOx Emissions



Emissions Characteristics



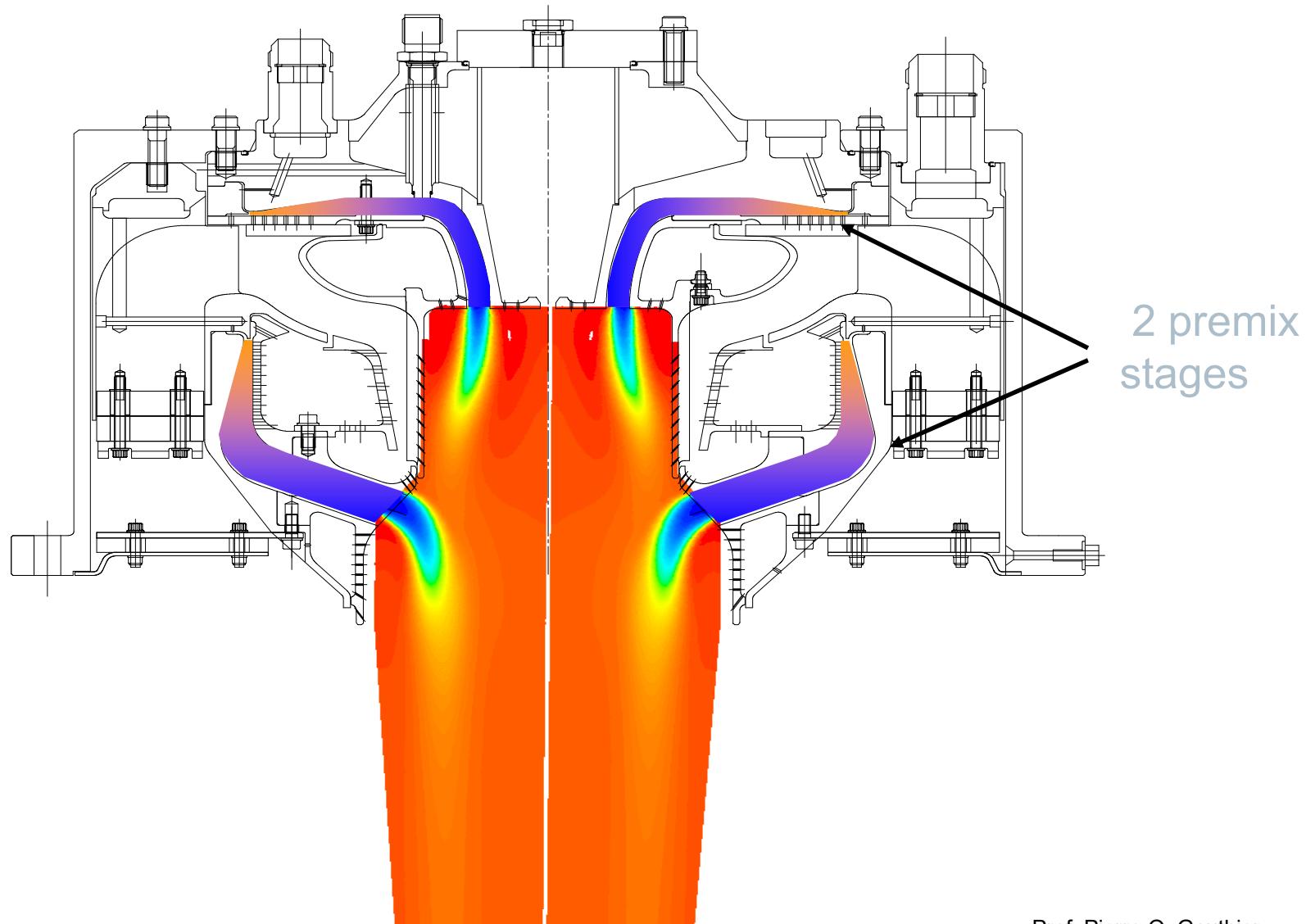
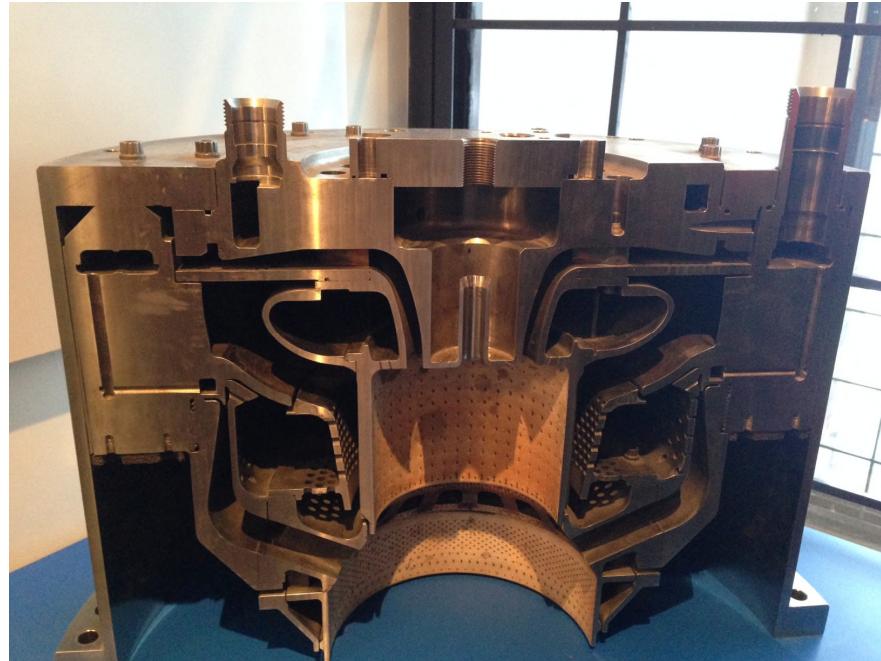
Mixing and Burning

- Get the Fuel and the Air premixed
- Not just mixed... but perfectly (or almost) premixed!
- Get this Mixing done within a strict Pressure budget
- Design and Injection System that will then sustain a stable flame for a range of powers and conditions
- Cool the Combustor Liner, without ‘interfering’ with the flame

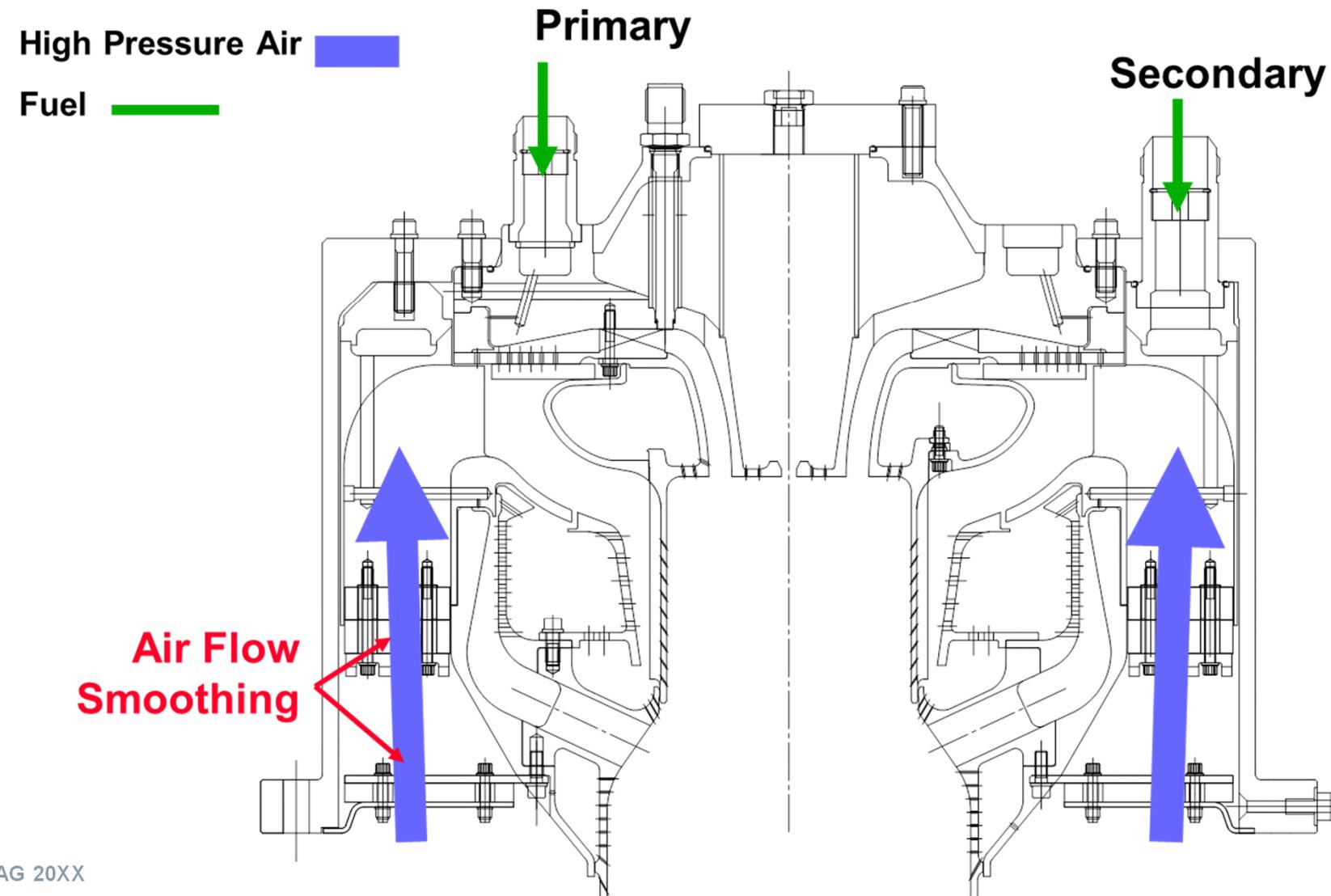
And...

- Account for any Thermo-Acoustic-Instabilities (Noise)
- Get the Combustor Exit Traverse right
- Be able to do all of the above for a wide range of fuel compositions and fuel types!
- Turn a tidy Profit 😊

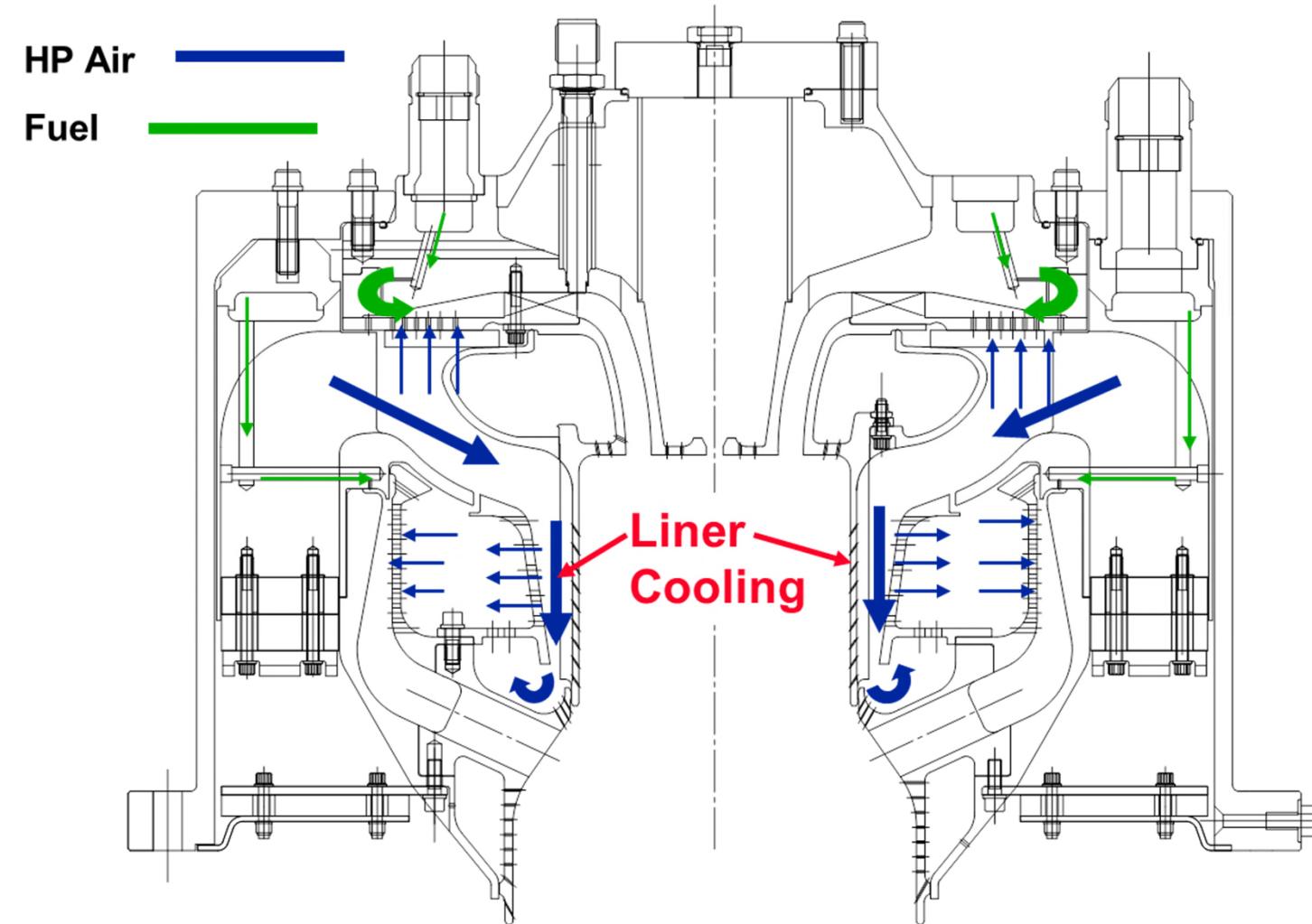
Industrial Trent – MarkIII DLE (66MWe)



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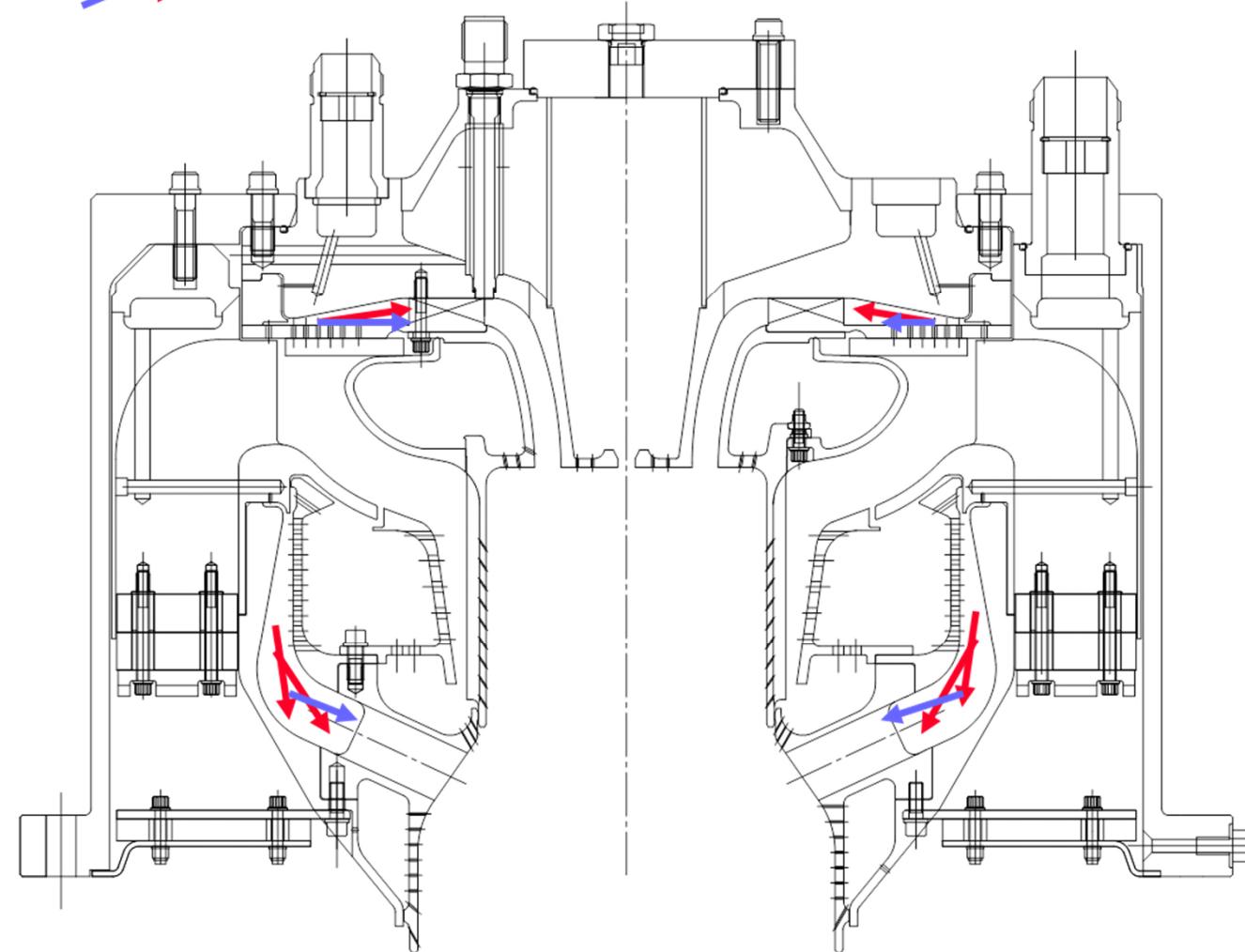


Industrial Trent – MarkIII DLE (66MWe)

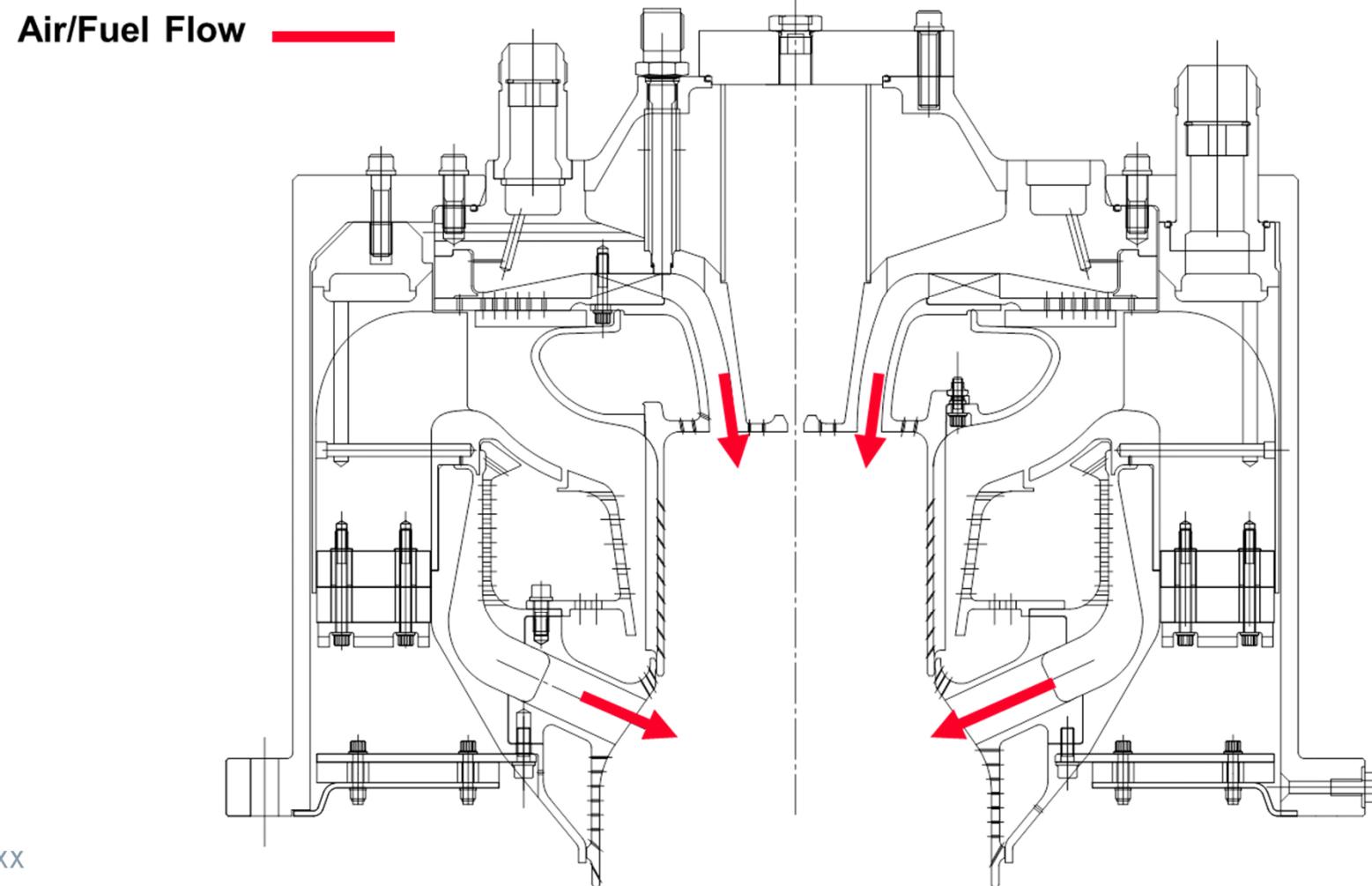


Industrial Trent – MarkIII DLE (66MWe)

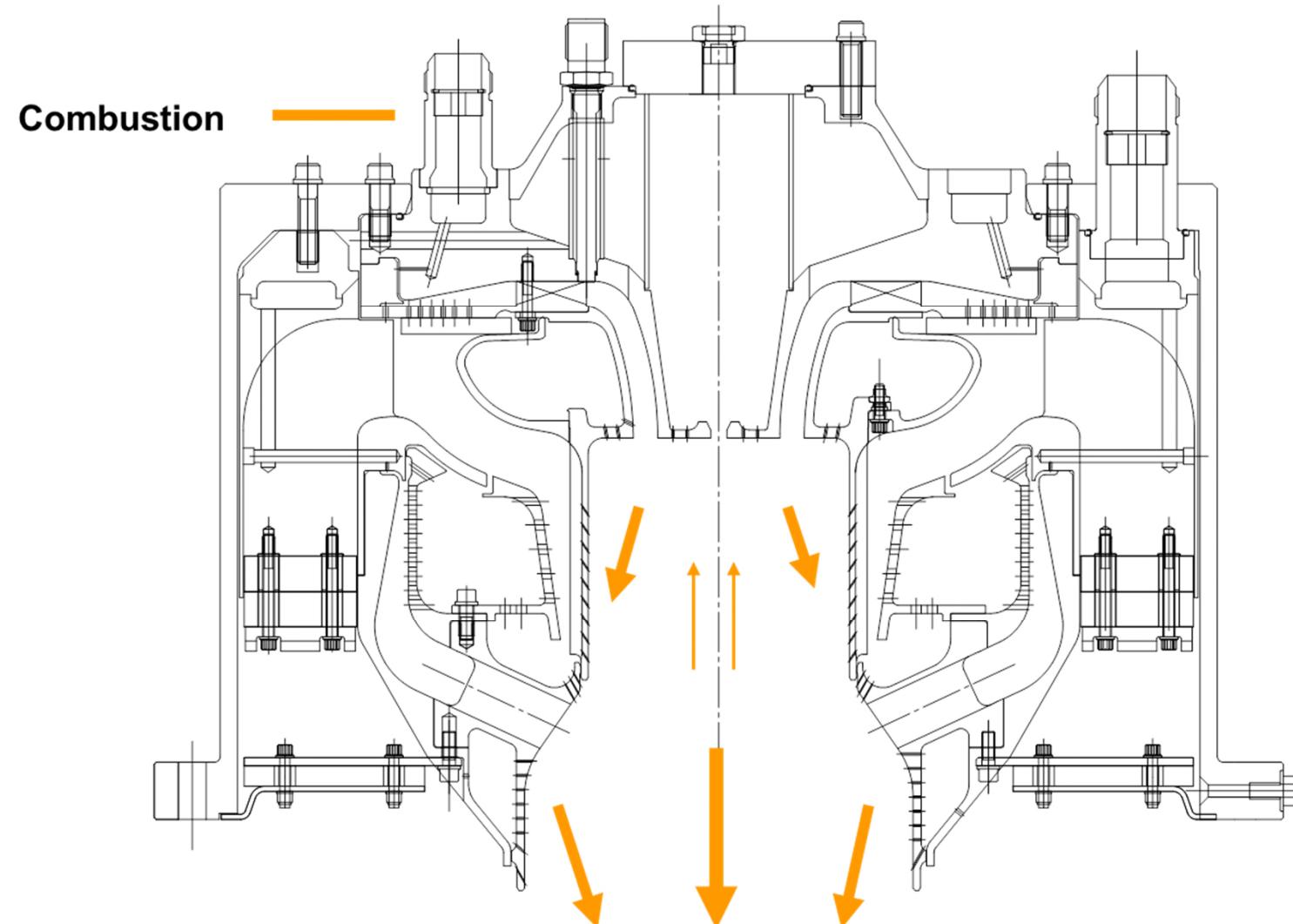
Air/Fuel Mixture 



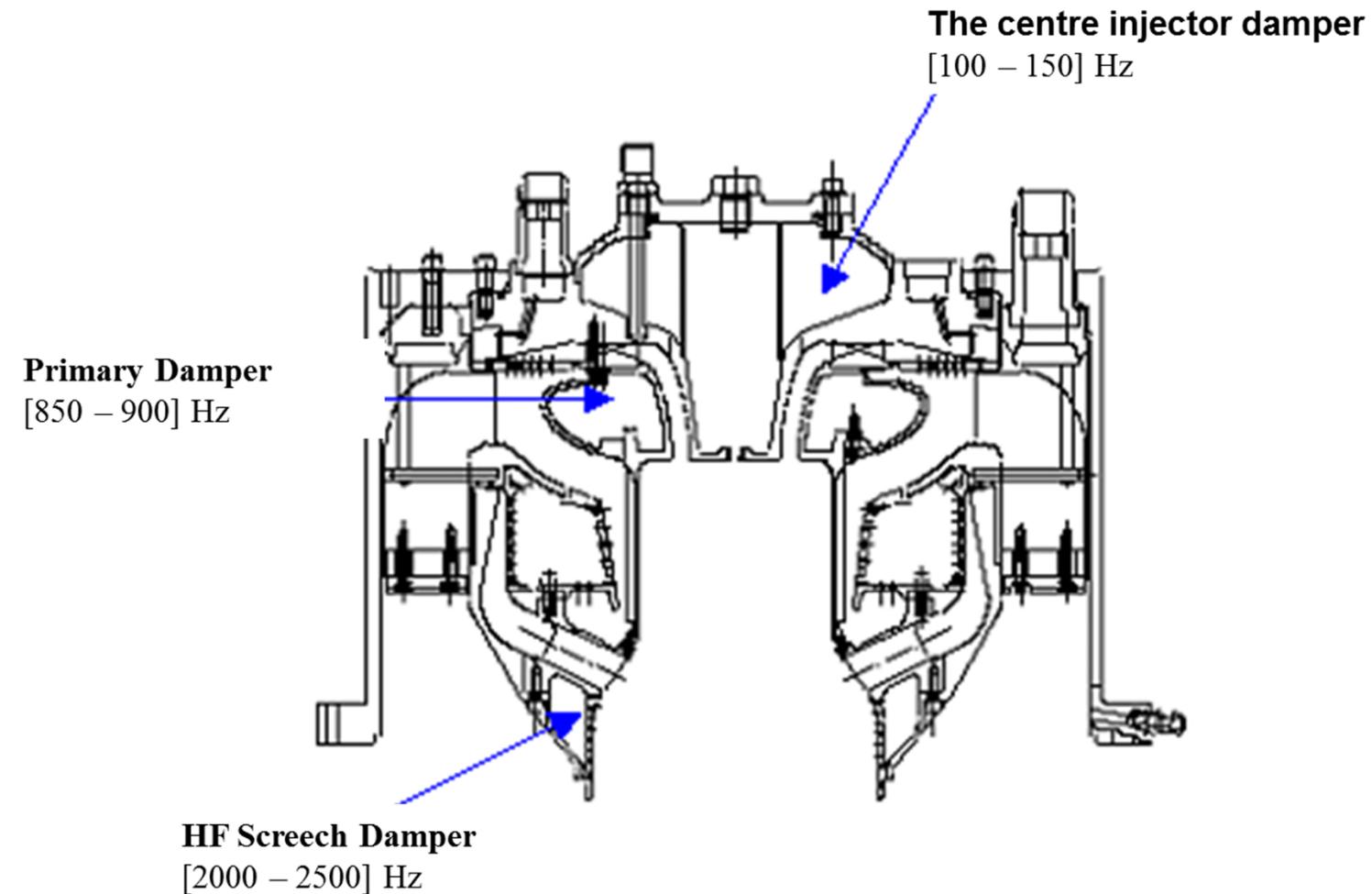
Industrial Trent – MarkIII DLE (66MWe)



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Questions?

Thank You!