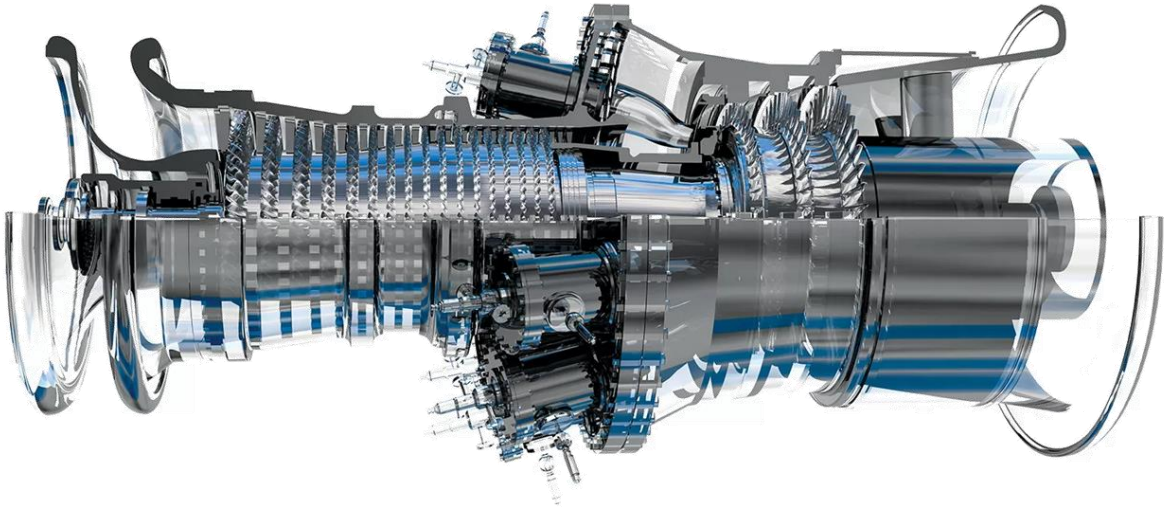
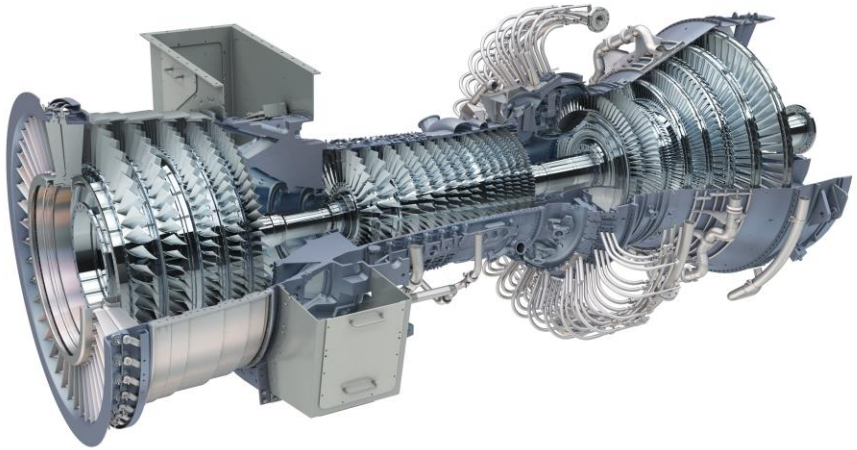
Utilization and Combustion of Carbon Free Fuels – Challenges and Opportunities

Keith McManus,
GE Research
Niskayuna, NY 12309



Heavy-duty Gas Turbine



Aeroderivative Gas Turbine

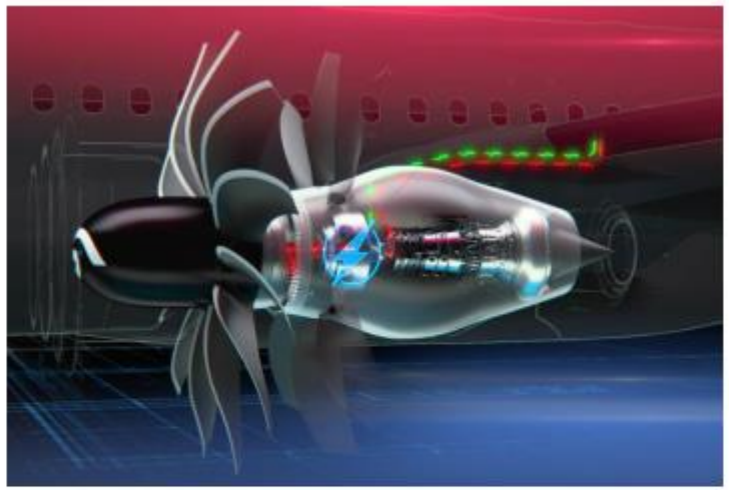
GE Aviation's breakthrough technology demonstrators

Hybrid Electric

MW-class hybrid electric propulsion system development with NASA ... builds on GE's experience with motors, generators, power convertors and power management systems

CFM RISE

GE and Safran Aircraft Engines program maturing advanced engine architectures like open fan, compact core and electric technologies for >20% better fuel efficiency vs. today's engines



Hydrogen

CFM International* developing hydrogen combustion and fuel systems for Airbus ZEROe aircraft project ... builds on 8M operating hours with hydrogen in GE land turbines

Ground and flight tests designed to show technology readiness this decade for multigenerational upgrade by mid-2030s

*CFM International is a 50-50 joint company between GE and Safran Aircraft Engines. RISE is a registered trademark of CFM.

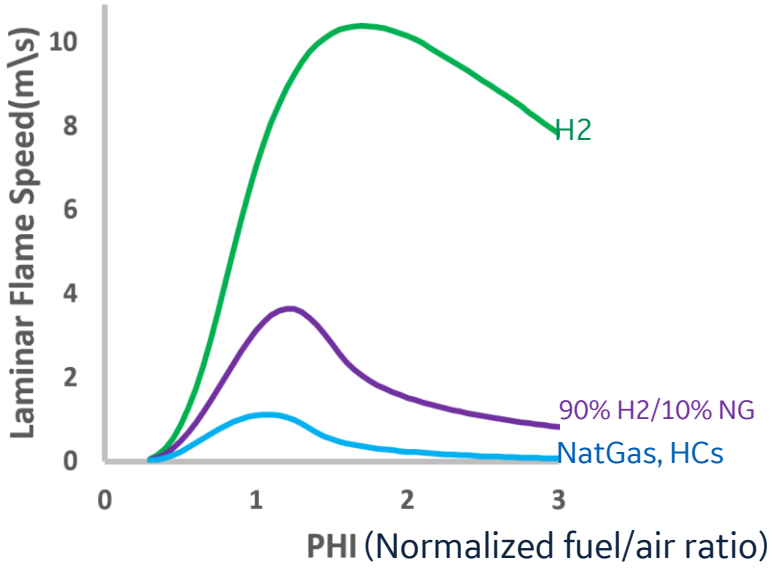
H2 Combustion

Fundamental change in burning properties

Flame speed is 10x Natural gas

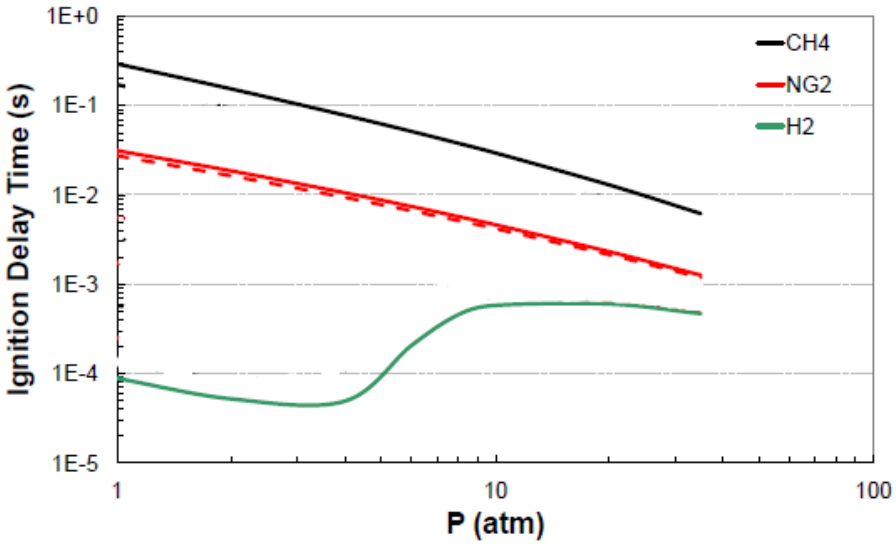
Flashback / Durability

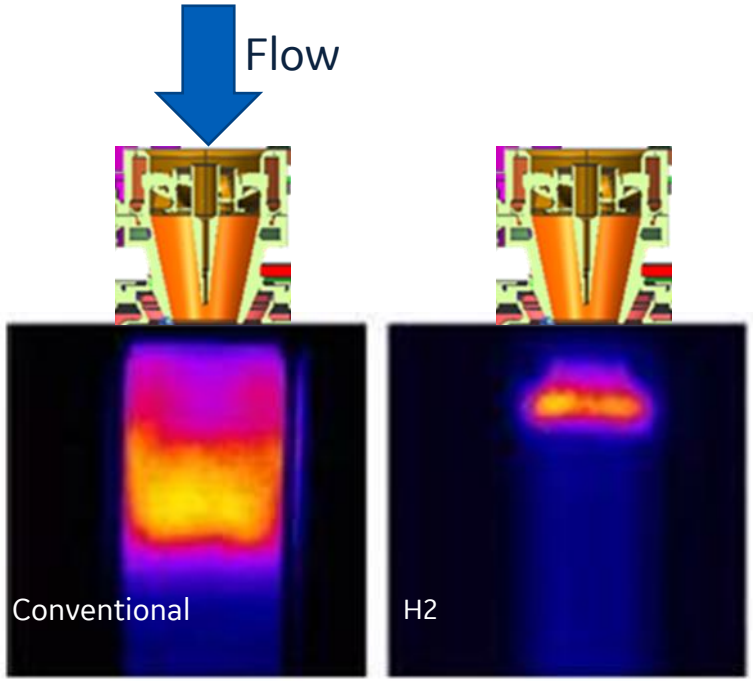
Operability / LBO



Ignition delay time is 10x lower

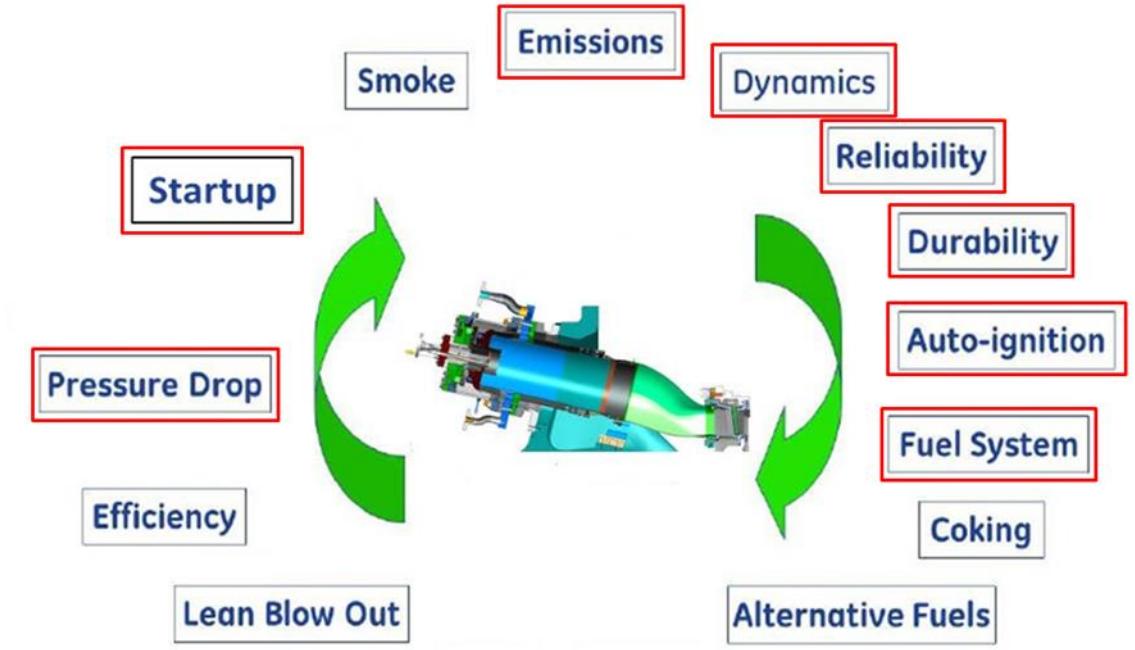
Auto-ignition



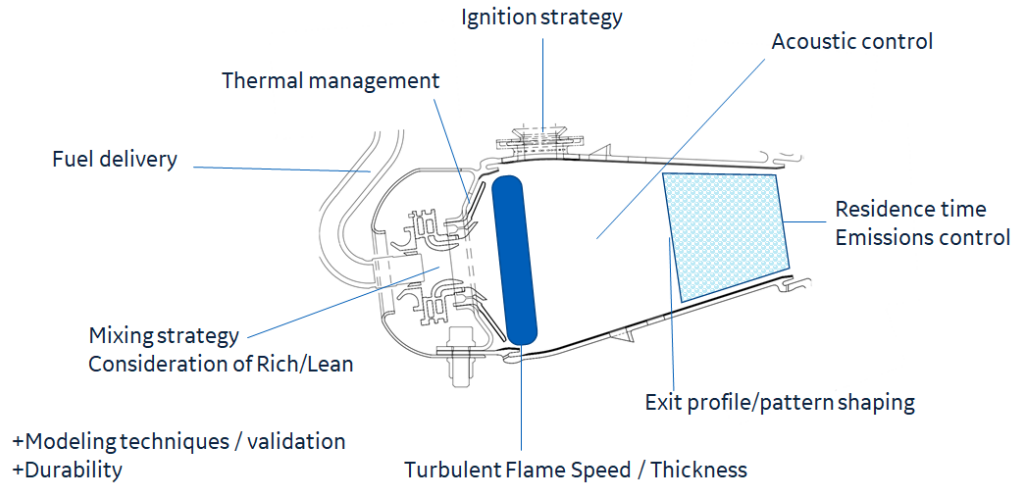


Compact flame structure

H2 Combustor Design



Combustor Requirements



Aerothermal design considerations

Fuel delivery
- Assumed gaseous at fuel nozzle
- Injection plane, orifice qty

Fuel-Air Mixing
- Rich Burn:
  - Primary/Secondary Swirl number
  - Pressure Drop
  - Flowsplits
  - Mixing length
- Lean Burn → Micro mixer

Flashback/Auto-ignition risk

Emissions → NOx production

Operability
- Blowout (LBO)
- Ignition system architecture (type & location)

P4 Dynamics (Combustion acoustics)

Combustor durability

HPT → combustor exit profile/pattern

<u>Need new Rules and Tools for Robust Combustor Design</u>