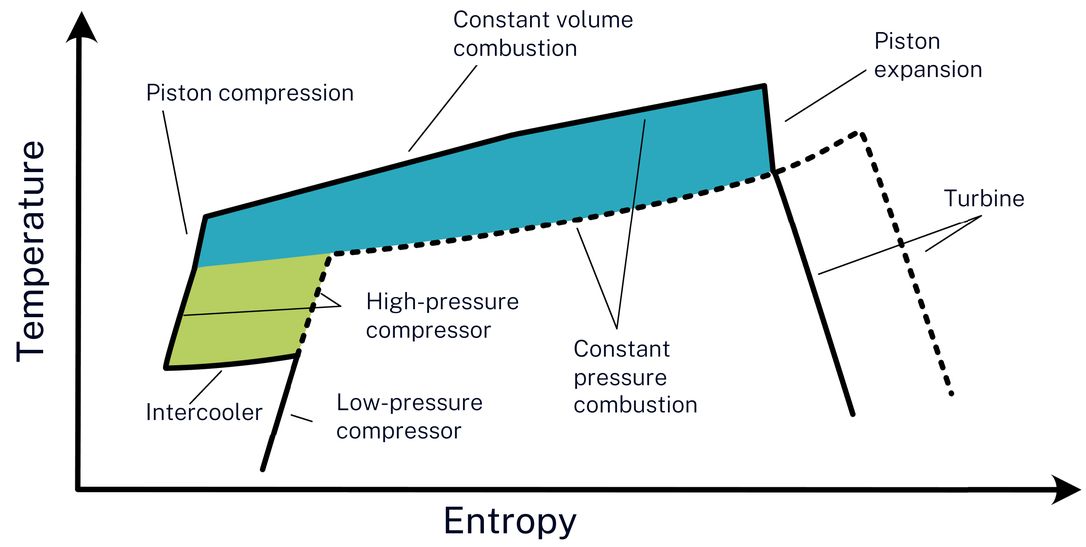
# Minimum environmental impact ultra-efficient cores for aircraft propulsion

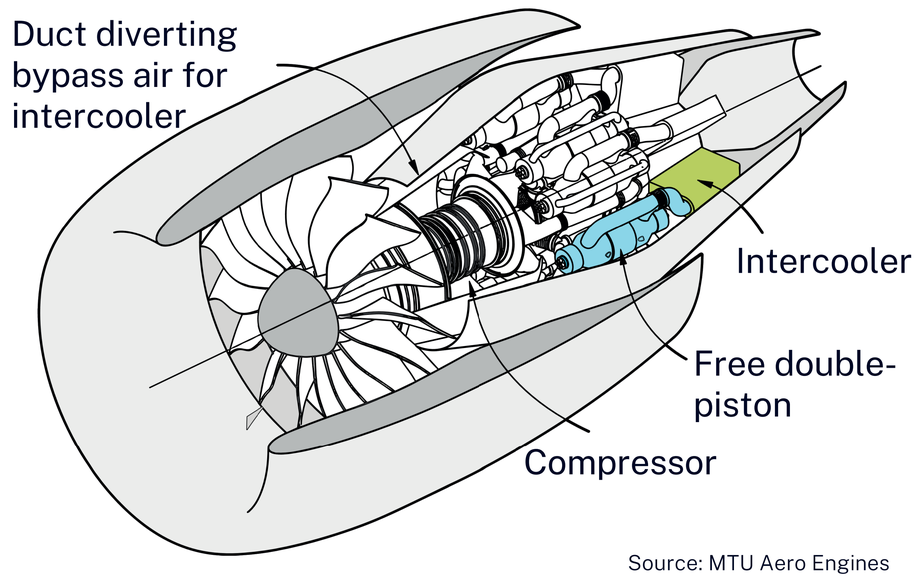
MINIMAL

## Key Outcomes

- Climate optimum Composite cycle engines to TRL2
- Mature low-NOx hydrogen opposed-piston combustor to TRL3
- Mature LH2 intercooler to TRL 3



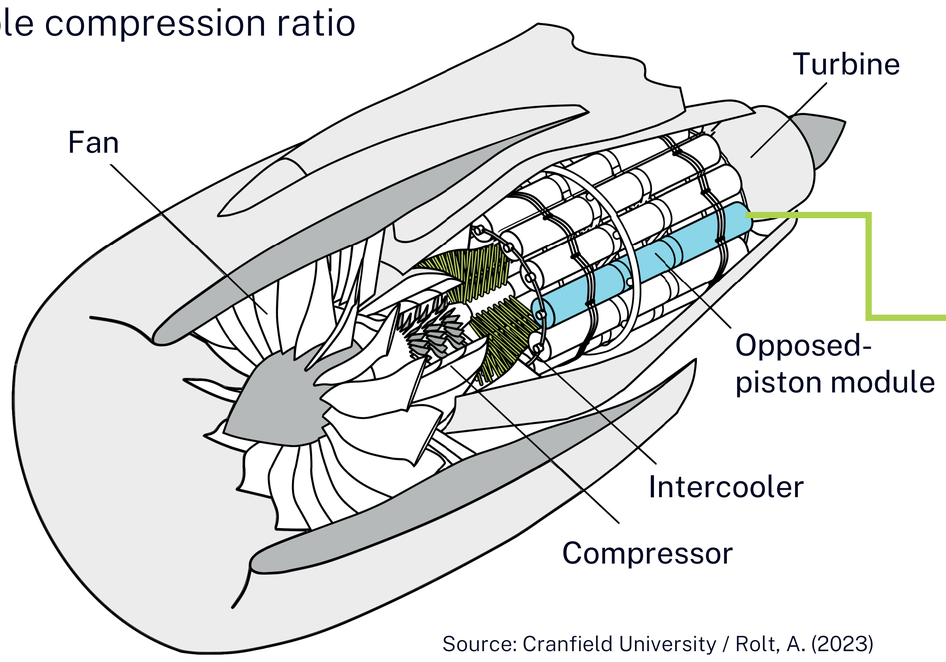

CCE free double-piston




Source: MTU Aero Engines

## Low-NOx opposed piston combustion

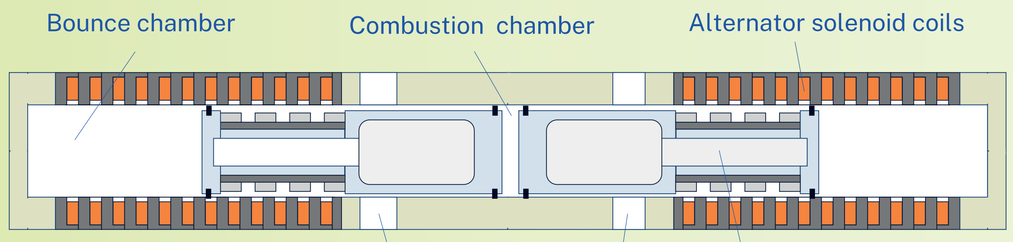
- Hydrogen Premixed Charge Compression Ignition (PCCI)
- Exhaust gas recirculation (EGR) or Steam Injection
- Variable compression ratio




Source: Cranfield University / Rolt, A. (2023)

CCE free opposed-piston

**Opposed Free Piston – Schematic Cross-section**



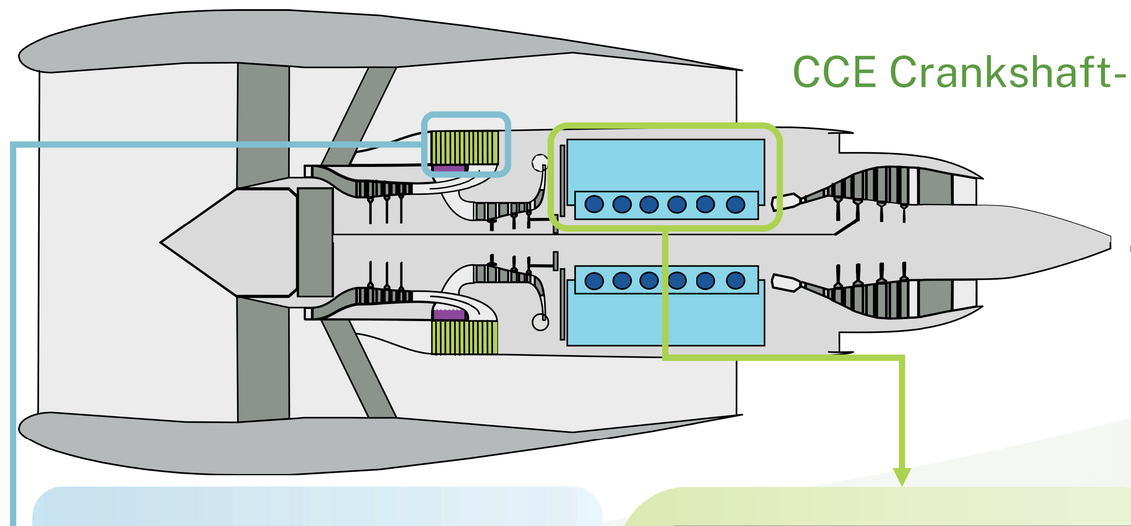

Source:
Cranfield University / Rolt, A. (2023)

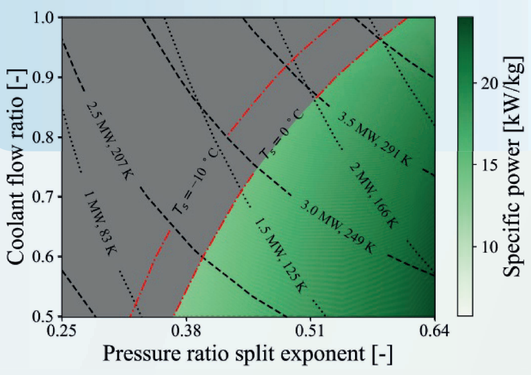
**Cranfield University's Single-cylinder Test Rig from Libertine FPE**


Source: Libertine FPE (2025)

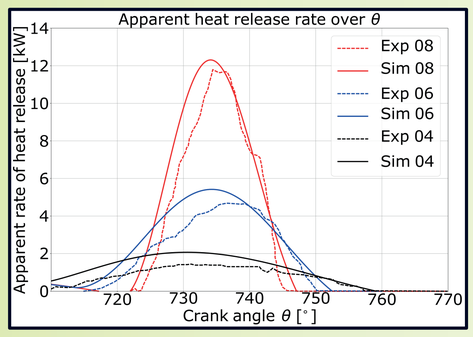
## Integration for minimum climate impact

CCE Crankshaft-based

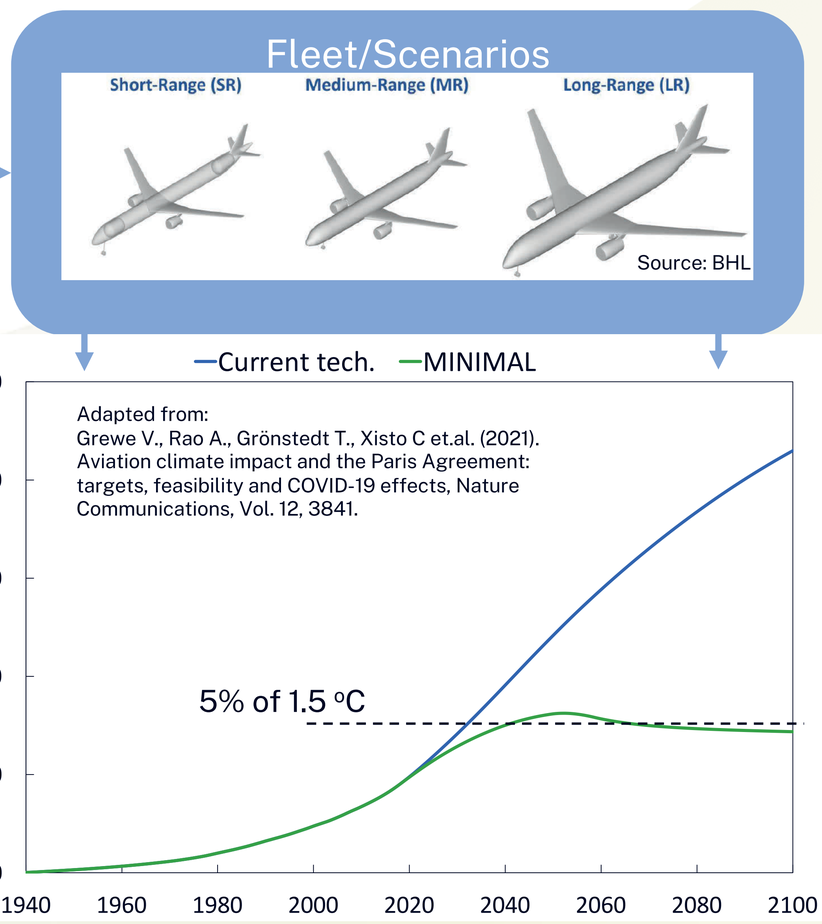





Performance & Design




Performance, Design & Emissions




**Contact**
Carlos Xisto
Chalmers University of Technology
Gothenburg, Sweden
e-mail: carlos.xisto@chalmers.se
Tel: +46 31 772 14 58

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