Composite Cycle Engines with Opposed Free Piston Cores to Minimise Climate Impact

MINIMAL

Key Features

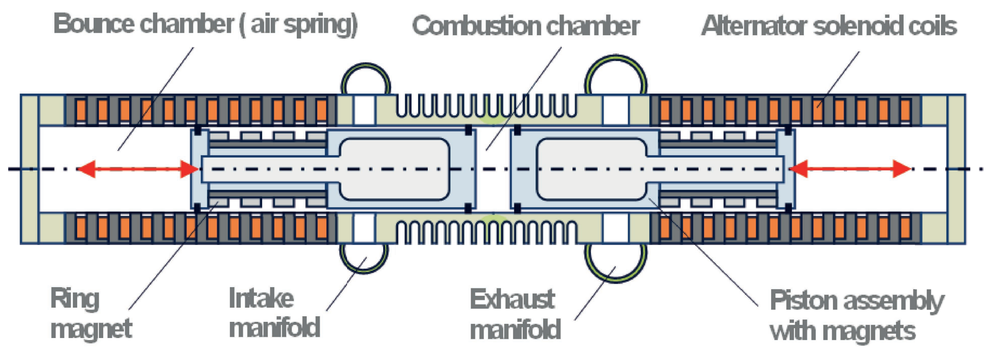
- **Rolls-Royce** models SAF-fuelled composite cycle engines (CCE)
- **Cranfield University** models a CCE run on liquid hydrogen (LH_2)
- Constant volume combustion will increase thermal efficiency
- Electric power generated by the free piston core may be used to help drive the fan or to power a distributed propulsion system
- Single-cylinder test rig at Cranfield investigates alternative modes of hydrogen fuel injection and ignition to minimise NOx emissions

Advantages of the OFP core configuration

- Opposed piston engines have no cylinder-heads and heat losses
- No mechanical transmission components or poppet valves
- Oil-free air-riding bearings for the pistons and linear alternators
- Variable compression ratio to optimise off-design performance

Opposed Piston Engines

- Initial diesel versions were used for marine propulsion
- Junkers made the Jumo series of aero engines in 1930s
- Opposed free piston (OFP) engines have recently been developed by Mainspring Energy and Libertine FPE



Schematic cross-section of an opposed free piston cylinder

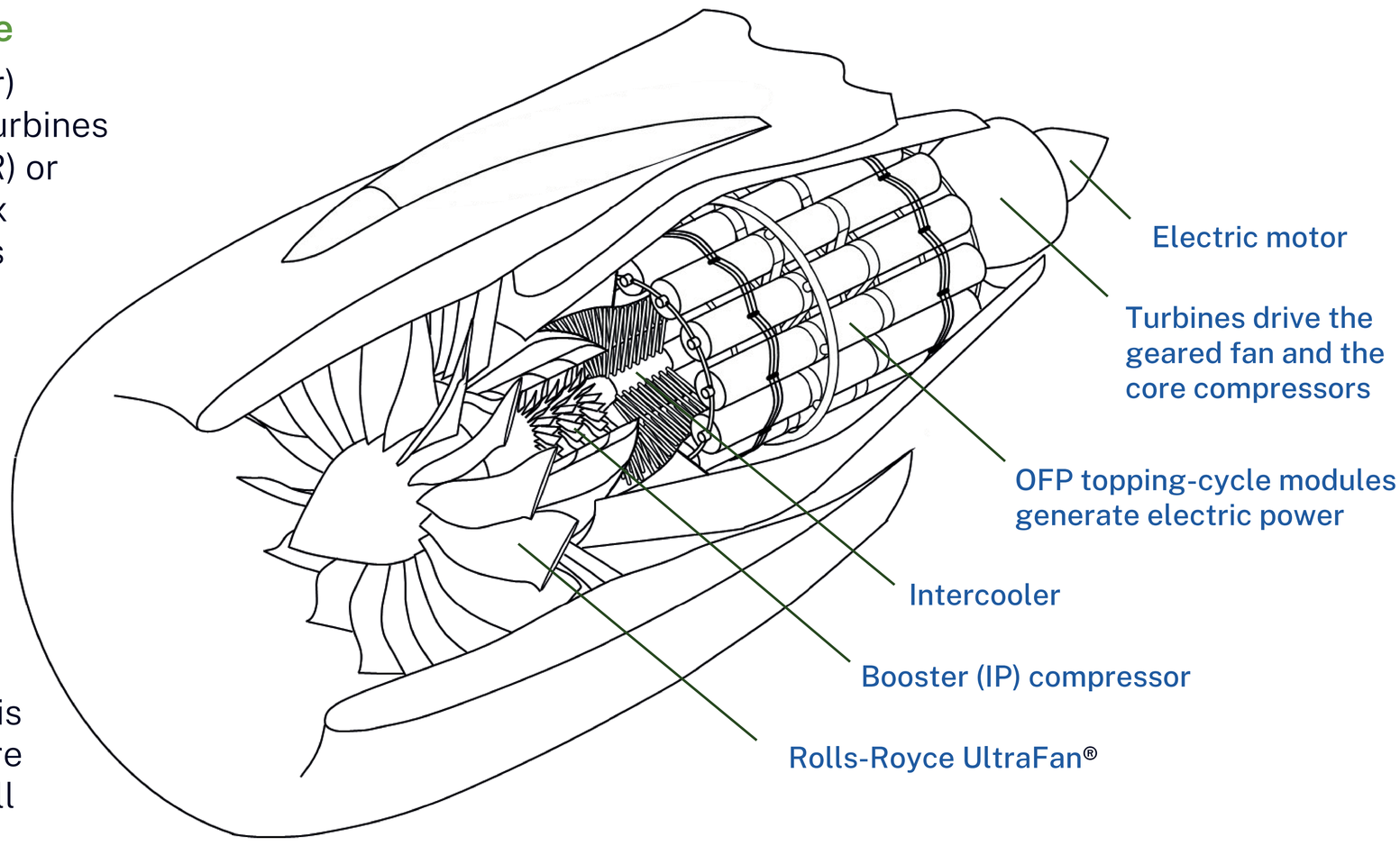
Turbofan engine designs are sized for small, medium and large commercial aircraft

Variant OFP CCE designs may include

- Aftercooling (after the HP compressor)
- Secondary combustion ahead of the turbines
- Cooled exhaust gas recirculation (EGR) or water/steam injection to minimise NOx
- Various thermal management systems to preheat liquid hydrogen fuel
- Export of electric power for distributed propulsion systems

Performance targets

- More than 10% reduction in SFC
- Over 10% reduction in fuel burn (allowing for a small weight increase)
- NOx emissions comparable with more conventional turbofan engines, which is challenging given the high temperature cycles, so combustion experiments will explore NOx mitigation strategies



High bypass ratio composite cycle turbofan with multi-cylinder OFP core and gas generator

Experimental programme at Cranfield to research efficient low-NOx modes of hydrogen combustion

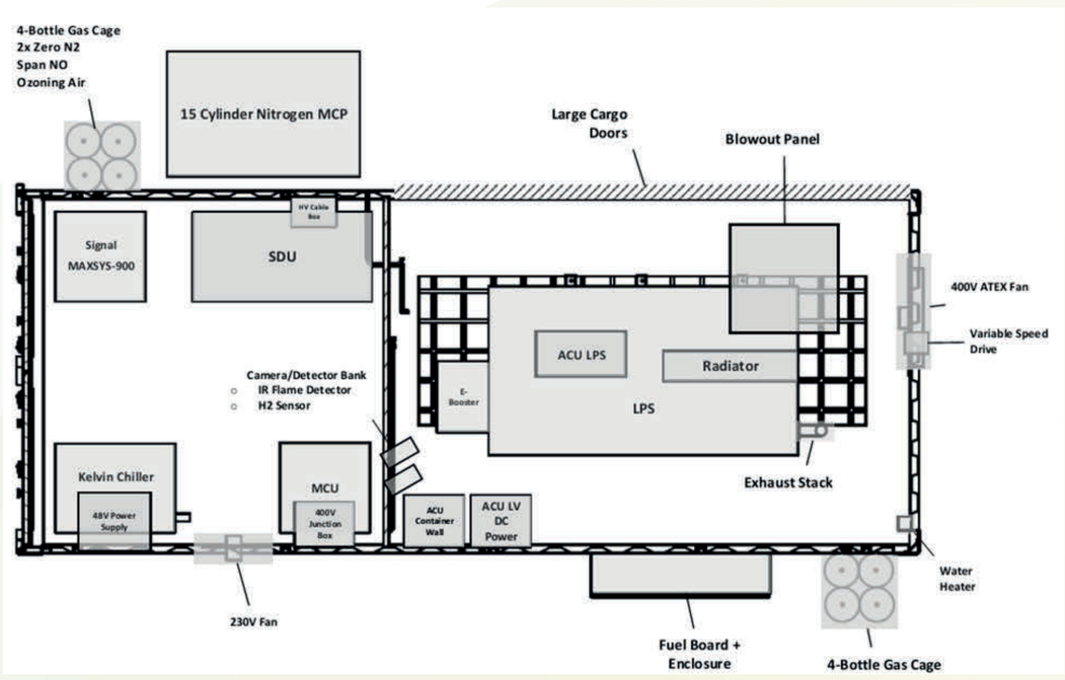
Single-cylinder Research Engine at Cranfield University

- The single cylinder research engine is provided by Libertine FPE Ltd.
- Libertine FPE is a UK-based SME: https://www.libertine.co.uk

The single cylinder research engine installed in its containerised test cell

Hydrogen combustion experiments

- Spark ignition with transition to compression ignition
- Tests simulating CCE core module conditions including EGR and premixed charge compression ignition (PCCI)



Test cell layout for gaseous hydrogen combustion experiments

Contact
Dr. Andrew Rolt
Cranfield University, UK
e-mail: a.rolt@cranfield.ac.uk

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