MINIMAL

Exploration of heat management concepts for a hydrogen fuelled mid-range commercial aviation engine

Jonsson I.[1], Miltén, P. [1], Xisto, C.[1], Mauro, M.[2], Alexiou, E. [3]

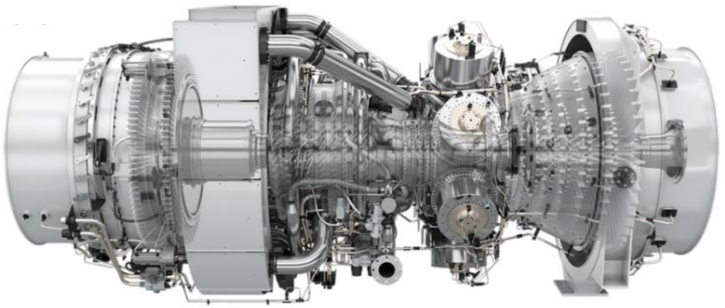
1: Chalmers University, Gothenburg, Sweden
2: Reaction Engines, Abingdon, United Kingdom
3: Aristotle U. of Thessaloniki, Greece

Date: 05.09.2023

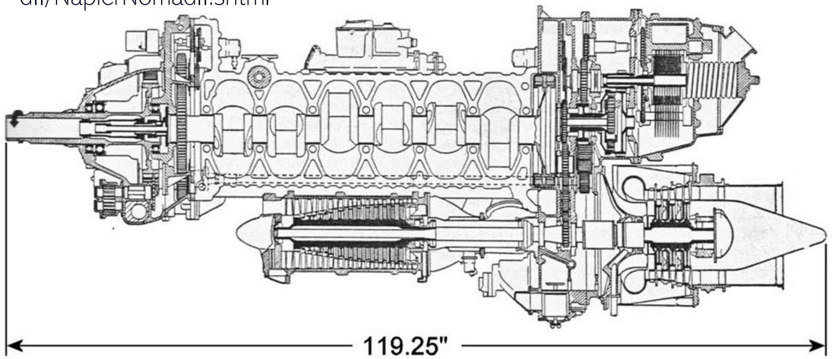
UK Research and Innovation

Funded by the European Union

Thermal Management – Background



https://www.enginehistory.org/Piston/Napier/NapierNomadII/NapierNomadII.shtml



Intercooling / Recuperation

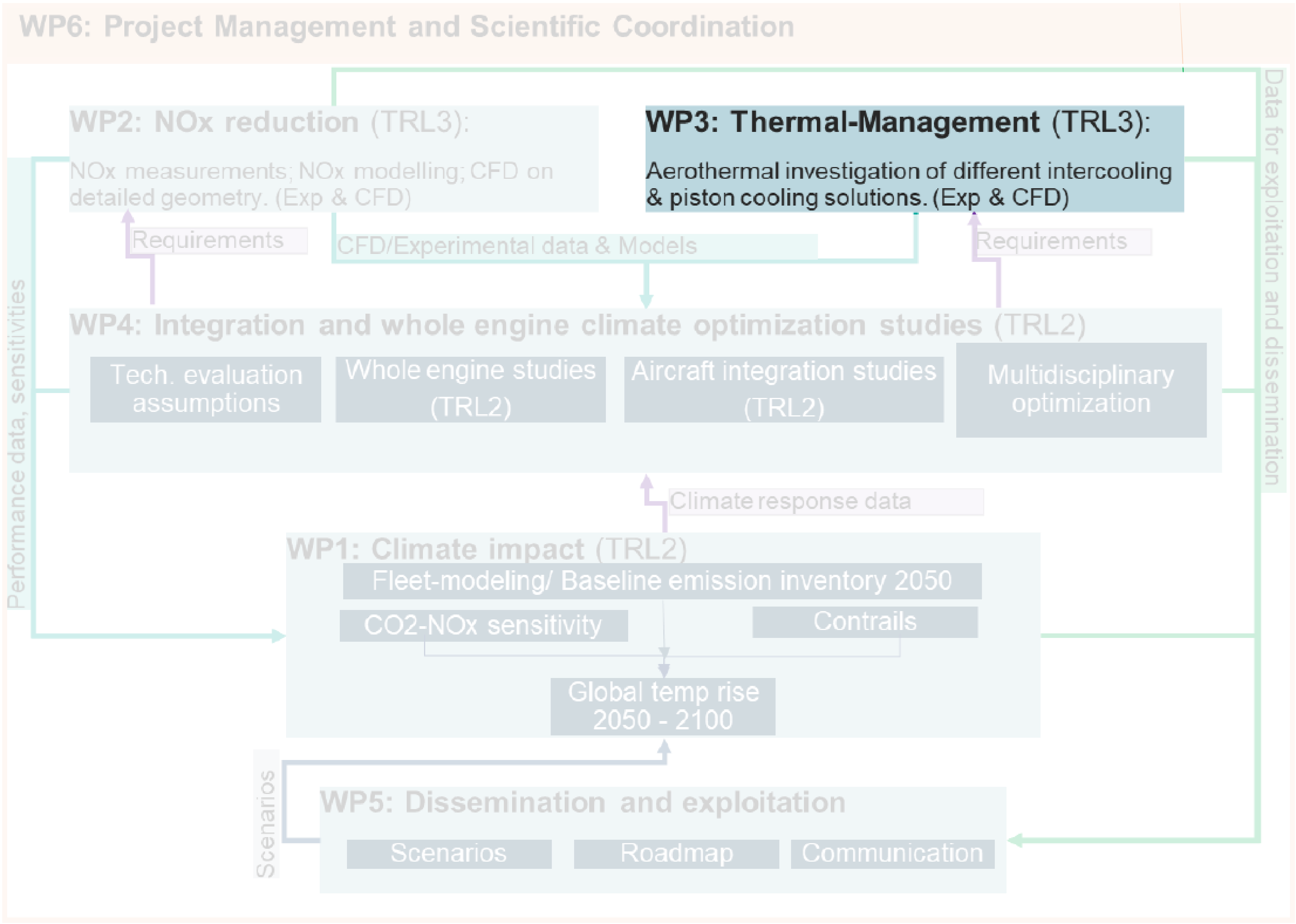
- Huge cycle benefits
- Smaller Core
- Large and heavy HX

Piston Topping

- Cycle Benefits, OPR
- Complexity
- Large and heavy piston systems

Liquid Hydrogen

- Huge, cold heat sink
- Keeps enthalpy in the system
- ~10% of lower heating value


WP6: Project Management and Scientific Coordination
WP2: NOx reduction (TRL3):
NOx measurements; NOx modelling; CFD on detailed geometry. (Exp & CFD)
WP3: Thermal-Management (TRL3):
Aerothermal investigation of different intercooling & piston cooling solutions. (Exp & CFD)
Requirements
CFD/Experimental data & Models
Requirements
WP4: Integration and whole engine climate optimization studies (TRL2)
Tech. evaluation assumptions
Whole engine studies (TRL2)
Aircraft integration studies (TRL2)
Multidisciplinary optimization
Performance data, sensitivities
Data for exploitation and dissemination
Climate response data
WP1: Climate impact (TRL2)
Fleet-modeling/ Baseline emission inventory 2050
CO2-NOx sensitivity
Contrails
Global temp rise 2050 - 2100
Scenarios
WP5: Dissemination and exploitation
Scenarios
Roadmap
Communication

Thermal Management of Hydrogen

Mature, Down-select & Optimise thermal management solutions

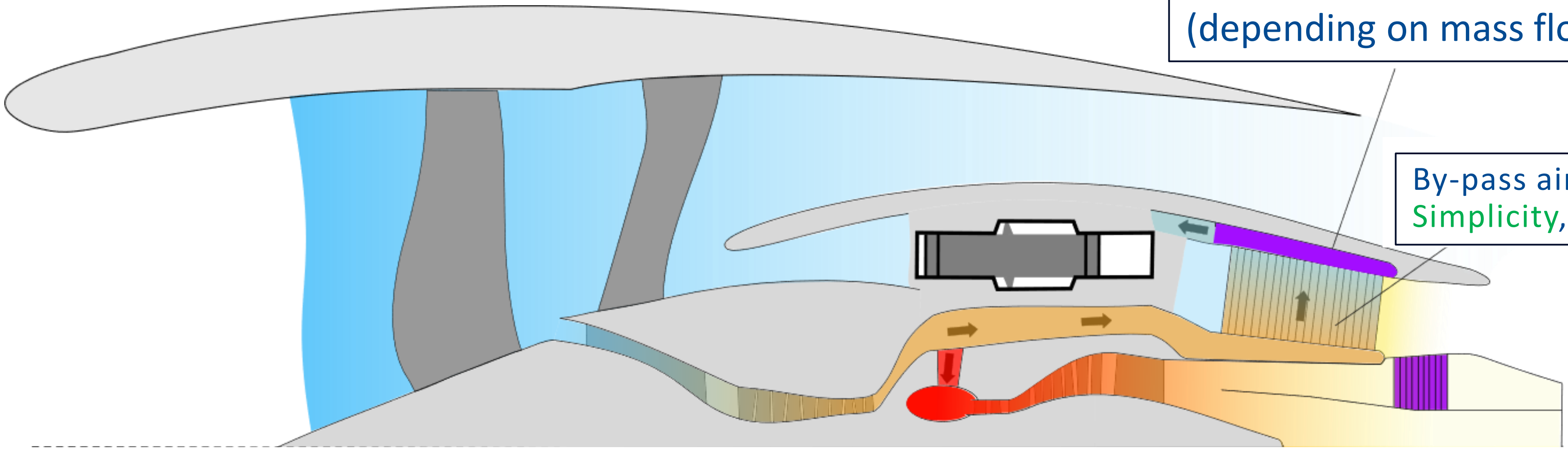
Objectives

- Define thermal management requirements and specifications (T3.1, T3.3).
- Develop conceptual design tools for heat management components (T3.1).
- Mature LH_2 enhanced intercooling concept to TRL 3 (T3.2).
- Down-select and optimize compact high performance thermal management solutions tailored for the specifications of the candidate CCE concepts (T3.3).

Intercooling - Form Factor

Using fuel as thermal sink, single loop:
Simplicity, low weight, thermal authority (depending on mass flow constraints), **risk**

By-pass air as thermal sink, single loop
Simplicity, low risk, thermal authority, weight



One of many concept of location of HX in the core

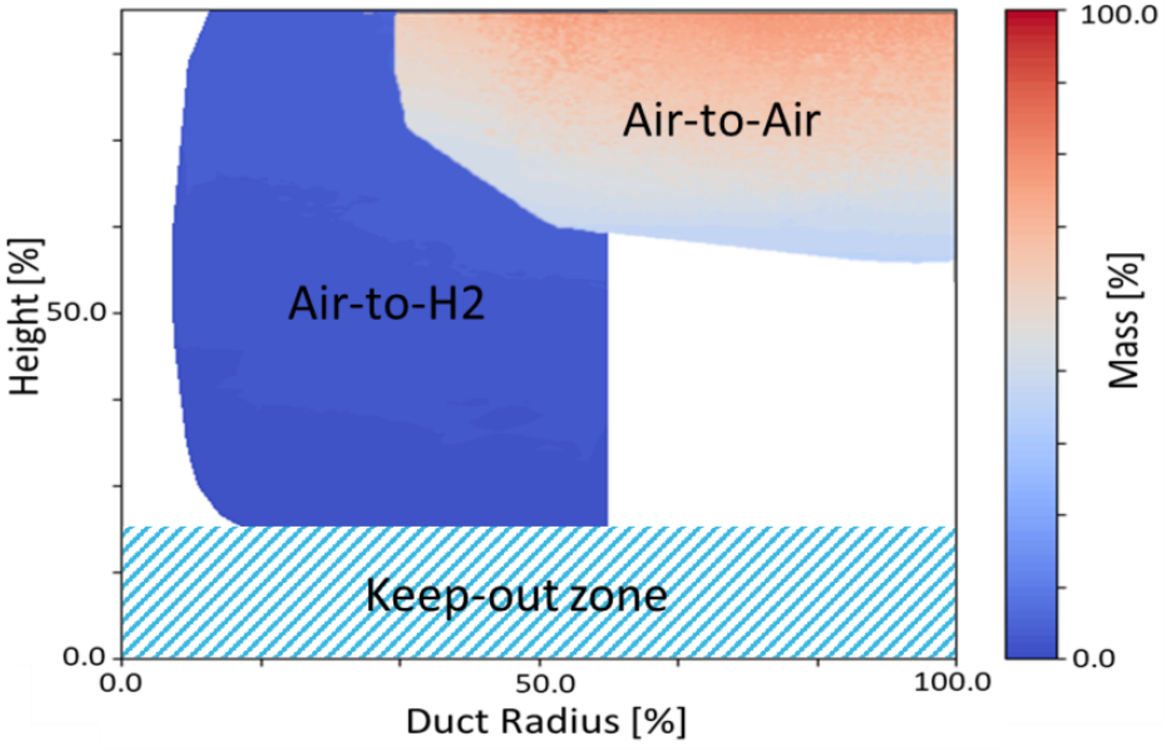
Using Both
Safety, thermal authority, comprehensiveness, more flexible, possible redundancy and risk containment, complexity, weight, cost, failure modes

Intercooling - Design tool

- Creating feasible HX configuration maps
- Reaction Engines: ATOM: In-house design tool

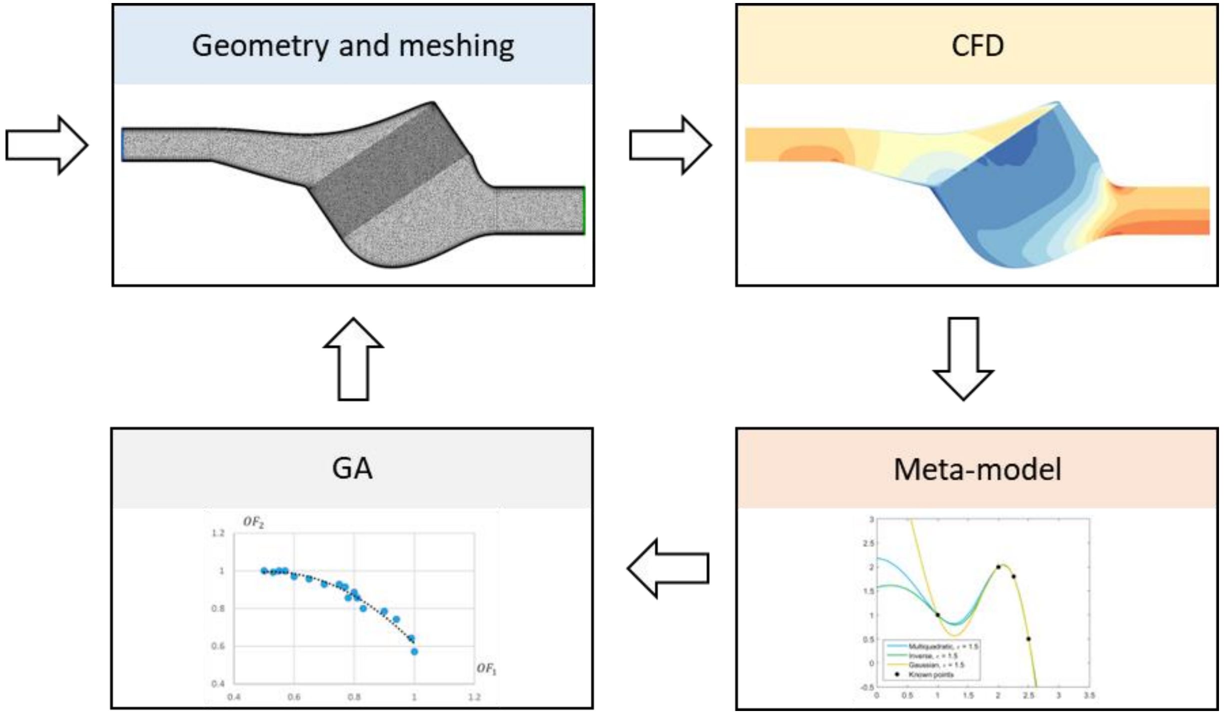
Example:

- Low aspect ratio, involute spiral, high DP tubes configuration
- Other types HX - Turning HX (CTH)



Maturing Intercooling Concepts

- Intercooling integration
- Detailed CFD studies

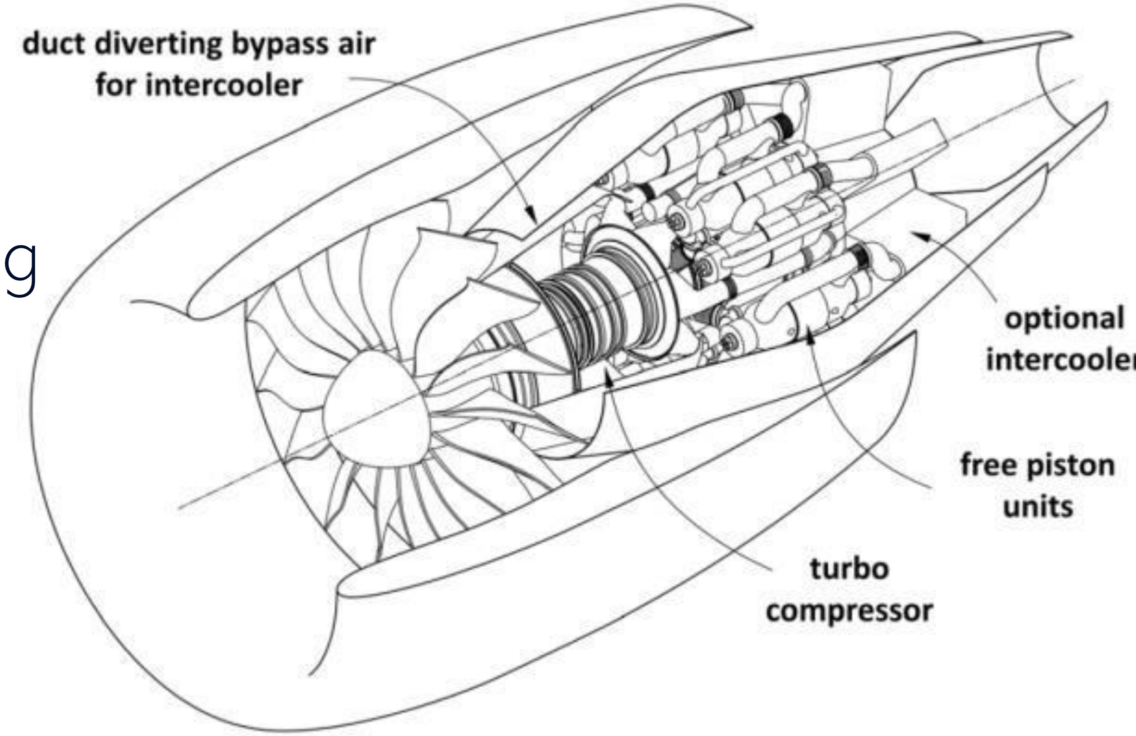


- Experimental Verification TRL3

- 2.5 Stage Compressor
- Large-scale
- Stable Operation;
- Aerothermal Investigation;
- Designed for heat-management integration studies;

CCE components - Thermal Management

- Novel piston configuration
- Cooling requirements
- Similar approach as for intercooling
- [COCO 0D-1D model] → Surrogate Models → CFD → Experiments - TRL3.



Kaiser, S., Schmitz, O., and Klingels, H. (January 13, 2021). "Aero Engine Concepts Beyond 2030: Part 2—The Free-Piston Composite Cycle Engine." ASME. *J. Eng. Gas Turbines Power*. February 2021; 143(2): 021002. https://doi.org/10.1115/1.4048993

Additional Thermal Management

Additionally, heat management concepts having a direct impact on non-CO2 emissions such as intercooling with LH2 will be matured to TRL 3. The selection of technologies includes:

- The direct use of core air for cooling and lubrication.
- The use of cryo-cooling concepts for LH2 heat-management
- Phase-change cooling concepts, such as hybrid nucleate boiling

Final Remarks

WP in conceptual stage:

- Various intercooling strategies have been identified and a modelling tool capable of performing optimisations has been developed.
- Air-to-Air HX potentially capable of delivering the desired cooling at the cost of mass and volume; an Air-to-H2 HX offers mass and volume saving opportunities but with potential thermal authority limitations depending on the cycle characteristics, eg: H2 mass flow.
- An additional fluid might be required to mitigate the H2 related risks.
- Mixed solution might provide a suitable solution but a more complex system

Thank you !

Presenter: Isak Jonsson
Organisation : Chalmers

The MINIMAL project is receiving funding from the European Union's Horizon Europe research and innovation programme under grant agreement No: 101056863

Cranfield University is being funded by UKRI (IUK), Project No: 10040930 under the Horizon EuropeGuarantee