EASA Workshop –H2 technologies

| 12/17/2024 / Köln / MTU Aero Engines- Nicolas Yernaux

MTU PROPRIETARY INFORMATION

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Abbreviations

A/C	Aircraft
ATEX	Atmosphere Explosives
CAT	Catastrophic
CTE	Coefficient of Thermal Expansion
EPT	Electrical Power Train
EPU	Electrical Propulsion Unit
FADEC	Full Authority Digital Engine Control
GH2	Gaseous Hydrogen
H2	Hydrogen
HFS	Hydrogen Fuel System
SW	Software
HFS-CS	Hydrogen Fuel System – Control System
HFS-SC	Hydrogen Fuel System – System Capsule
HSS	Hydrogen Storage System
SW	Software
TAT	Turn Around Time
TC	Type Certificate

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Design Philosophy and Assumptions

Underlying design philosophy:

- Certification and Safety requirements stay at equivalent level with introduction of Hydrogen as a Fuel
- Transitions times from Idle to Take-off shall be kept similar
- Introduction of Fuel cell technology shall be manageable in similar ways for the pilot as A1 today
  - *I.e.: indication of H2 massflow and remaining quantities shall remain and have similar accuracy*
- Introduction of Hydrogen Fuel System shall be manageable for airport operations and TAT in similar ways as todays

Technology Assumptions:

- Any H2 conditioning system to perform the H2 distribution is part of Hydrogen Fuel System

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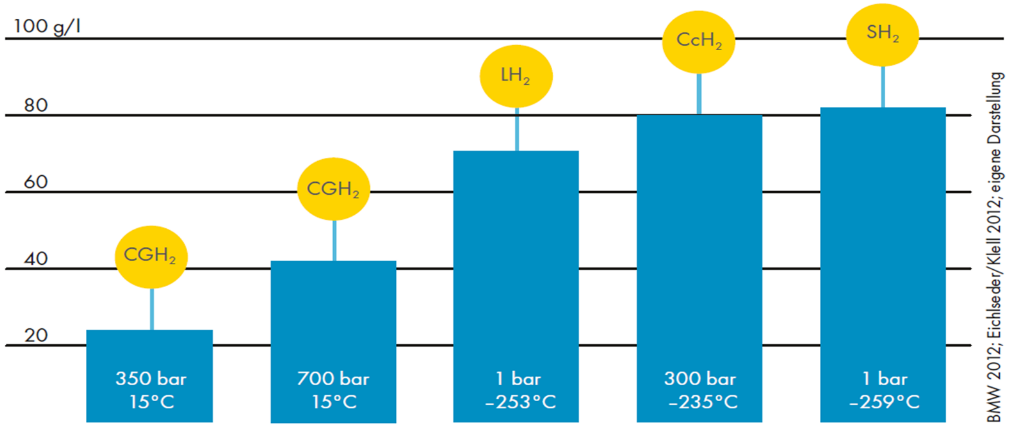
Hydrogen storage possibilities

	Liquid	Compressed Gaseous	Cryo compressed
Typical storage temperature	< 10 bars	~ 700 bars	50 – 700 bars
Typical storage pressure	20 K	Room temperature	25 – 110 K
H2 density (pressure dependent)	< 70 kg /m3	< 40 kg /m3	< 80 kg /m3
Pros	High LH2 density High gravimetric index	Easier conditioning No active extraction system	Highest LH2 density
Cons	Cryo temperatures	Low density High pressure equipment low gravimetric index for HFS	Cryo temperatures High pressure equipment Low gravimetric index for HFS



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System needs

- Feed GH2 at the required temperature and pressure to the Fuel Cell System
- High reliability / availability of the system as loss of hydrogen feed capability shall not be CAT at Take off
- High massflow rates required for tank filling to comply / fit with TAT
- LH2 availability at the airport

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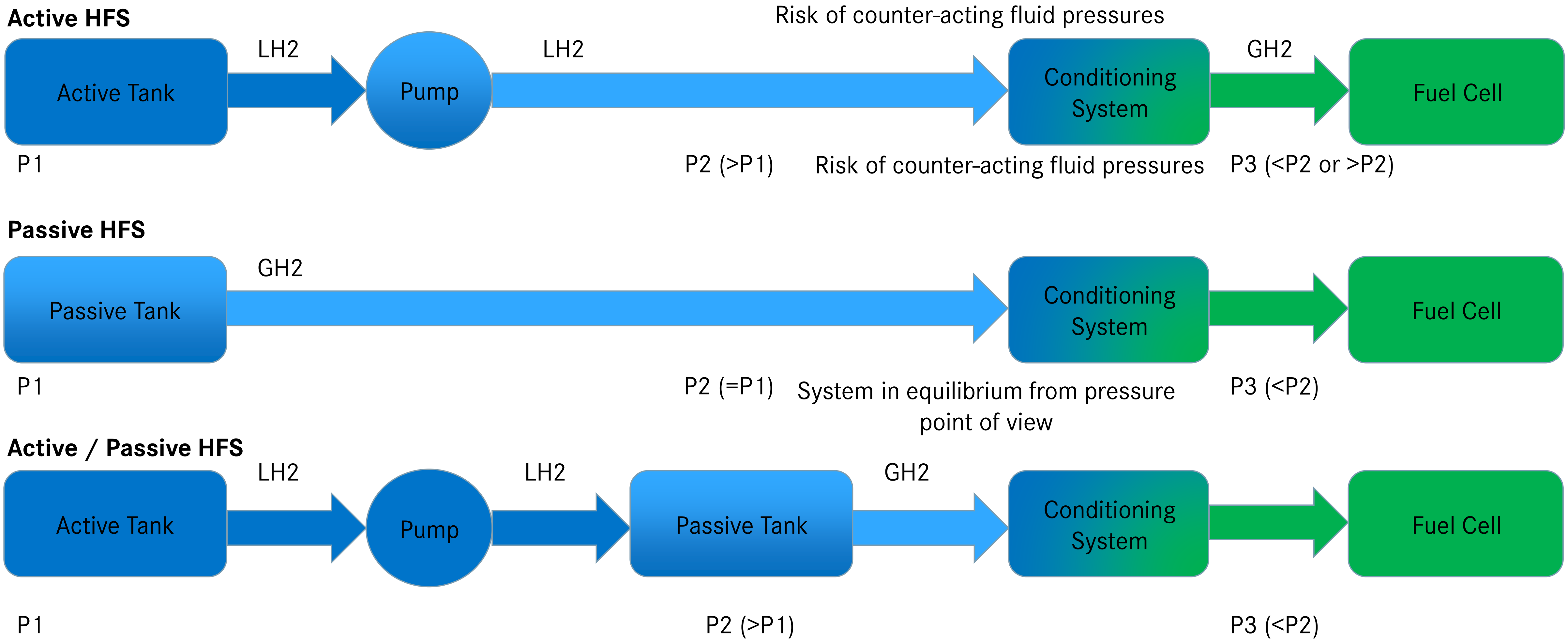
Hydrogen extraction principles



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HFS operating principle

Main operating principles available for Liquid Hydrogen Fuel Systems:

- Active system or Passive system or combination therefore

	Active HFS	Passive HFS	Active / Passive HFS (2 Tanks: 1 Passive / 1 active)
Pro	Low pressure tank Increased H2 density	System is always in equilibrium (highest pressure at source) Reliable and comparably simple extraction under all A/C conditions	Improved gravimetric storage index with very large HFS
Cons	Non equilibrium in the system (extraction risk) Use of cryo pumps (high reliability pump) Additional heat transfer into inner tank	Tank weight is impacted by tank pressure	Non equilibrium in the system (extraction risk) Cryo pumps are needed between the tanks By-pass of the Passive tank may be needed from safety point of view Very complicated and complex extraction

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Tank technologies

- Steel
  - High resistance toward fire, possibility to sustain fire (e.g. external) for 15 minutes (fire proof system)
  - Crack propagation speed are much lower than for aluminum, allowing much more failure tolerant design
  - Sizing of the HSS for A/C life is achievable with virtually no weight impact versus the sizing static load cases
- Aluminum
  - More thermal stress toward the structure due to elongation coefficient of the aluminum
  - Sizing for aircraft life comes with a high weight impact versus the sizing static load cases
  - Poor fire resistance
  - Difficult to weld Aluminum with Stainless steel (i.e.: pipes, valve connections, etc.)
- Composite
  - No weight advantage but high RC cost disadvantage
  - Leak tightness over A/C life considered very tricky especially when using steel pipes and valve connections

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Hazards

What are the Hazards linked to Hydrogen:

- **Cryo hazard due to low temperature**
  - Risk on humans, surrounding materials due to change of material mechanical properties and or CTE shock.
- **Leak of gaseous hydrogen:**
  - Flammable fuel => needs to be treated with similar approach as with A1 today (isolation valves, definition of released energy amount).
- **Ignition through sparking:**
  - Concerning the tank system there is a fundamental difference versus A1 today because there is no Oxygen in the fuel tank (fire triangle). Concerning pipes and the Flying Fuel Cell system, similar methods apply as of today with A1.

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Hazards mitigation

Cryo risk mitigation

- Limit the cryo temperature inside the tank and tank capsule, only distribute H2 at room temperature
- Ensure that all components within the tank and tank capsule are compatible with Cryo temperatures

Mitigation of propagation of hydrogen within the aircraft

- All hydrogen supplying / containing equipment shall be double shrouded:
  - Any leak resulting from a first failure would be:
    - contained within a shroud
    - Detected through pressure change
    - Discharged from the shroud outside of the aircraft through a passive system

Mitigation of propagation of hydrogen within the aircraft

- Ensure fault current cannot be propagated to electrical components
- Use specific sensors (ATEX compliant)

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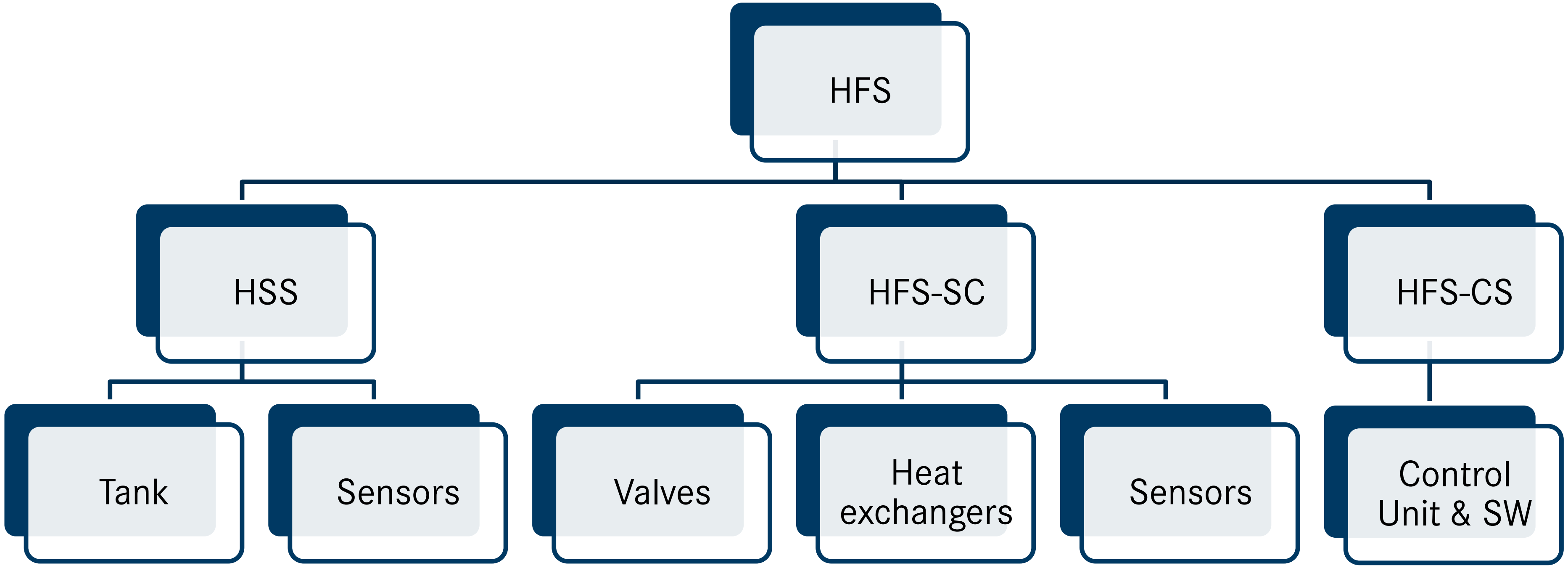
System breakdown

How can a Hydrogen Fuel System (HFS) breakdown been seen:

- A Tank with sensors holding the Hydrogen – Hydrogen Storage System (HSS)
- A System Capsule (HFS-SC) to pre-condition the Hydrogen for a safe distribution
- A Control System (HFS-CS) managing the system and communicating with other aircraft systems



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System interface and interaction to propulsive system

Tank size maybe part of the fuselage and tank diameter may be closed to fuselage diameter → Positive impact on gravimetric index

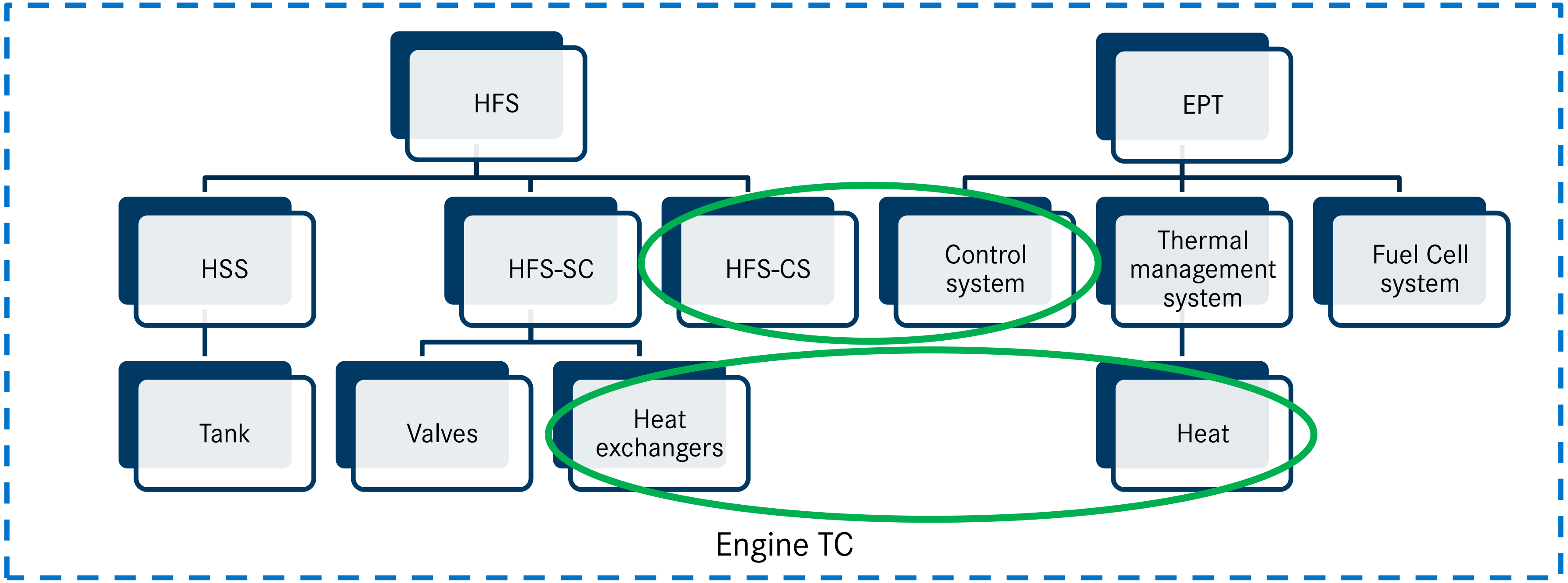
Tank volume depends on flight mission to achieve

Tank size is closely linked to the aircraft design

Conditioning system is independent of mission and fuselage diameter but is linked to aircraft power

Conditioning system interfaces with engine for transient behavior and thermal exchanges

Performance, Conditioning and control system and is closely linked engine design



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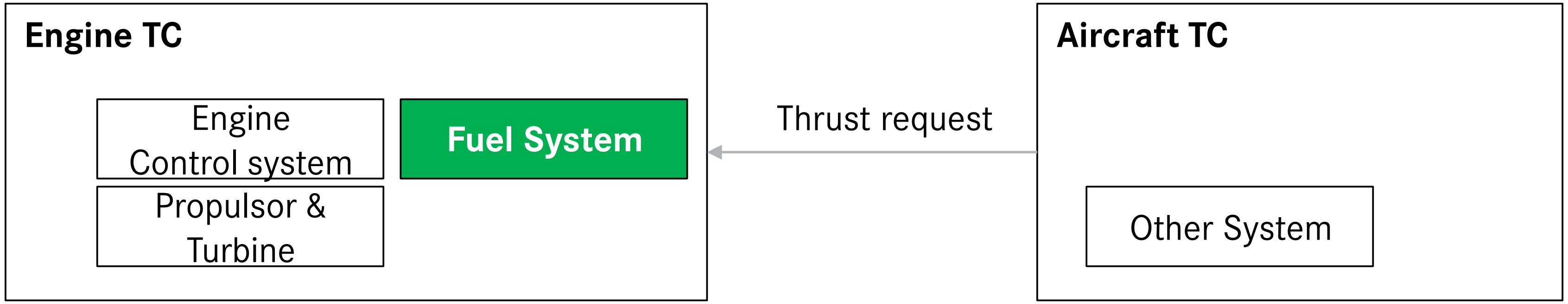
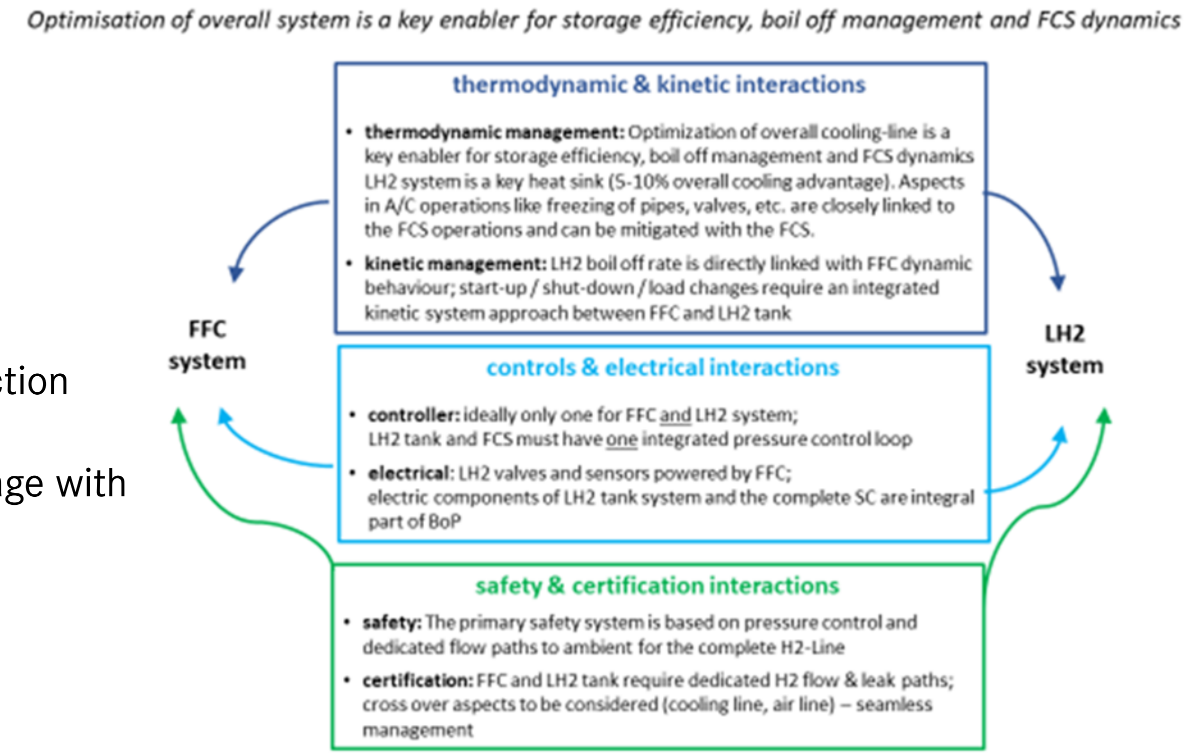
Certification proposal



Why HFS should be part of an Engine TC:

- Strong entanglement between EPT and HFS
  - Heat sink
  - pressure provision
  - common controls between EPT and HFS
  - EPU ramp up (controls) is linked to H2 extraction function
- Both EPT and HFS can be used in different Airframer Fuselage with minor modifications
  => One baseline HFS TC adapted for multiple Airframer



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MTU recommendation

System equilibrium offers a high stability within the distribution of hydrogen

The conditioning system (or tank capsule) shall be as close as possible to the LH2 Tank

Double shrouded pipes and equipment allow a controlled evacuation of hydrogen leak outside of the aircraft

MTU sees a very strong link between:

- The Electrical Powertrain Control System (equivalent to a FADEC) and the Control system of the GH2 generation
- The Thermal system and the conditioning system of the Hydrogen Fuel System
- The EPU performance and the HFS performance

MTU recommends to bring the Hydrogen Fuel System and Electrical Power Train under the Engine Certification

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