Cryogenic Tests of an Airborne Liquid Hydrogen Tank for a Manned Aircraft In the HEAVEN Project

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Project cofinanced by :

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Powering aircraft with liquid Hydrogen :

When the dream goes to HEAVEN

Cryogenic Hydrogen Tech Aircraft

DLR H2FLY WE BRING HYDROGEN TO AVIATION Air Liquide PIPISTREL elringklinger ayesa

HEAVEN : A liquid H2 tank with a fuel cell

- **Objectives**
  - Demonstration of a manned flight powered by a Fuel Cell supplied by a LH2 Tank.
  - A step towards a commercial aircraft
- **Challenges**
  - Put the LH2 tank onboard an existing aircraft called “HY4”
  - Interface the tank with the aircraft and the existing powertrain system (fuel cell fed with HP GH2)
  - Sufficient performances to be able to fly
  - Safety assessment in order to obtain the Permit To Fly for a manned flight

Not just a tank : a comprehensive cryogenic system

Many operational functions to perform

- Cool-down/warm-up, refueling/defueling, pressurization, FC feeding by LH2 vaporization, standby, etc…

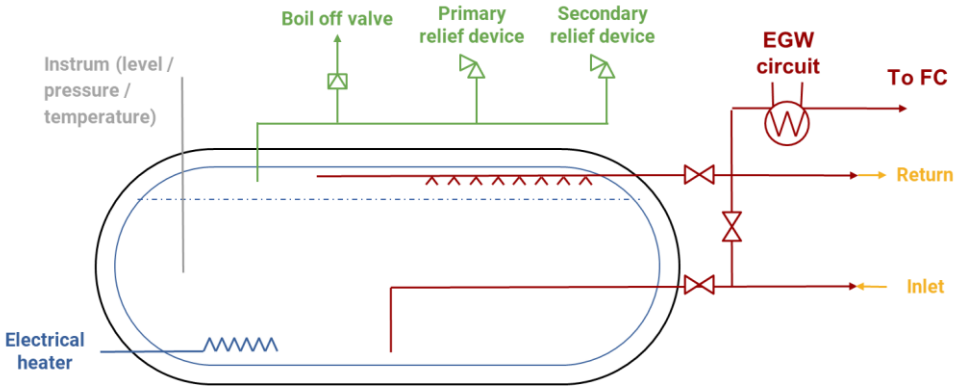
Performances of the LH2 Tank

- aluminium vessels, vacuum insulated, operates at 6.3 barA
- 16 kg of usable LH2; gravimetric index 11%
- can feed up to 100 kW Fuel Cell

All safety analyses performed according to ARP4761 guidelines in all operations

Ground refueler

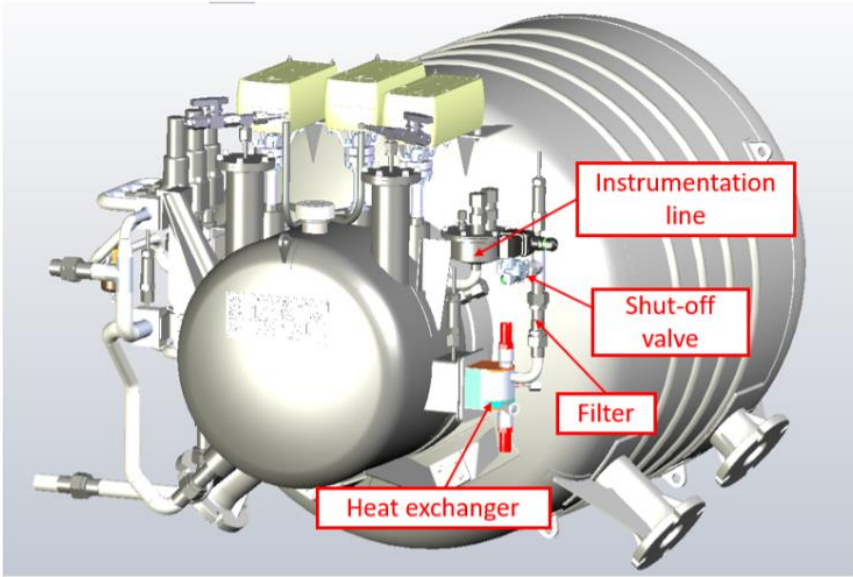
- Interface between LH2 trailer and aircraft

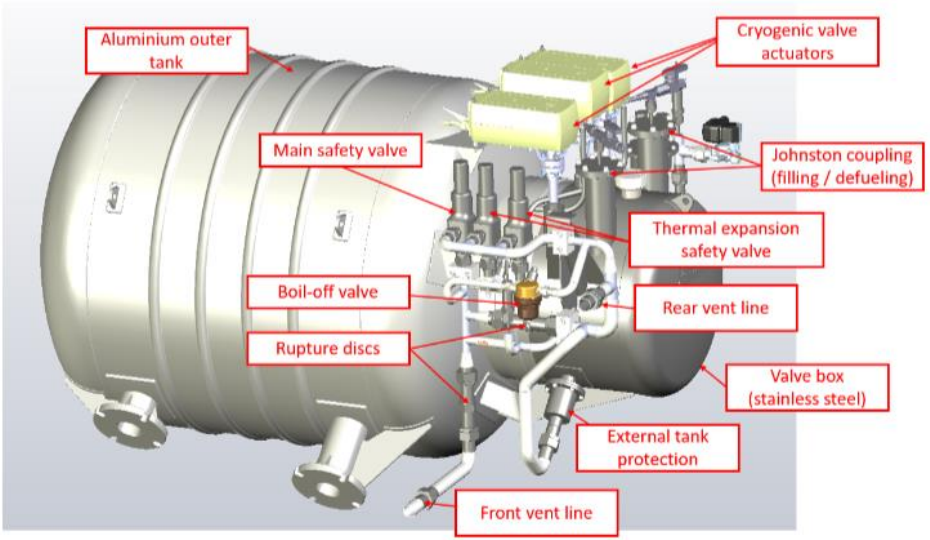


Key design features of Heaven LH2 tank

Aluminium inner and outer tank -> mass reduction
Titanium neck -> mechanical and thermal optimization
Welded stainless steel plate HX for vaporization -> reliable and compact
Electrical heater for tank pressurization -> light and reliable

The tank was Entirely designed, manufactured and tested in ALAT's premises





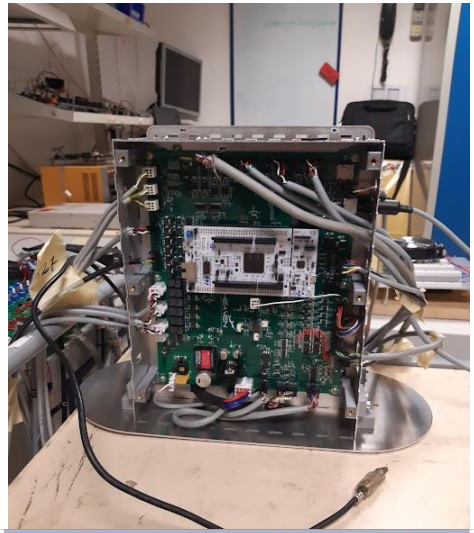
A dedicated control/command system

Developed internally at ALAT

Fully automatic system : it maintains a constant pressure in flight whatever the flow rate required by the fuel cell

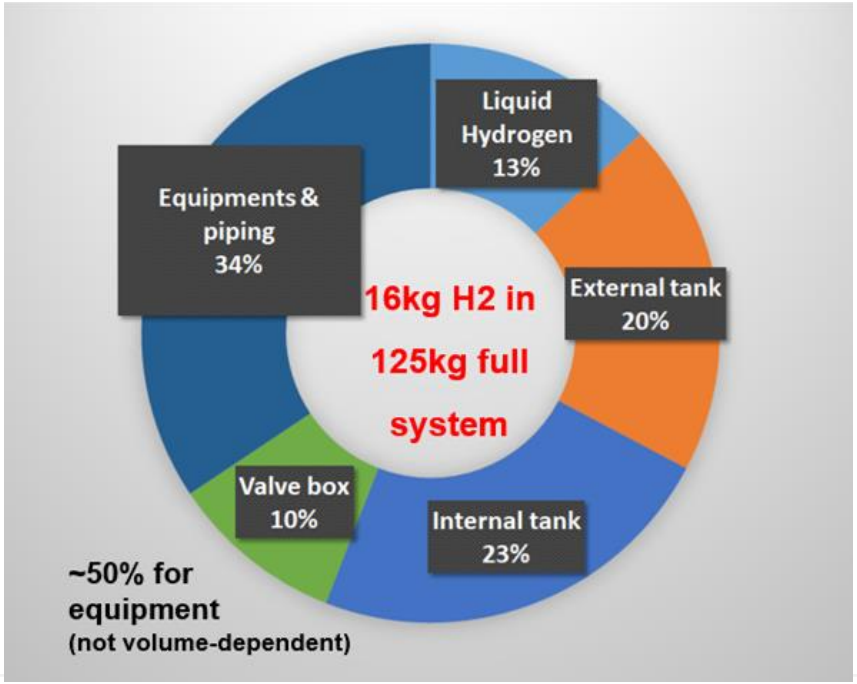
Key informations only are sent to the pilot that can switch off the tank at anytime

All operational and safety functions are analogic



A few words about the gravimetric index (GI)

Heaven tank mass breakdown



GI = mass of liquid / total mass of the tank full of LH2

GI of HEAVEN tank : 11% but 50% is not volume dependent
-> Storage vessel = 54 kg (GI=23%)

-> in the future, with bigger tanks :

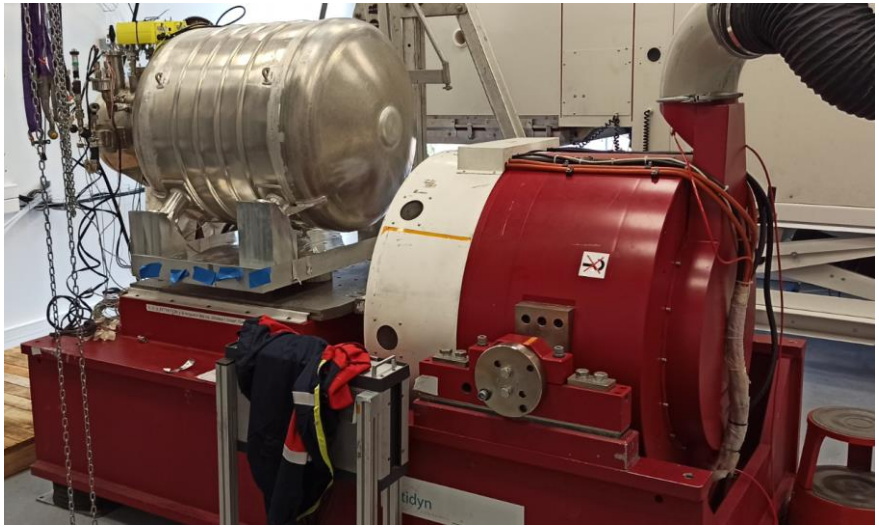
- Valve box will not be much bigger
- **GI can be higher than 20%**

Tests before flight

Before flight, a lot of tests have been performed to demonstrate that the tank :

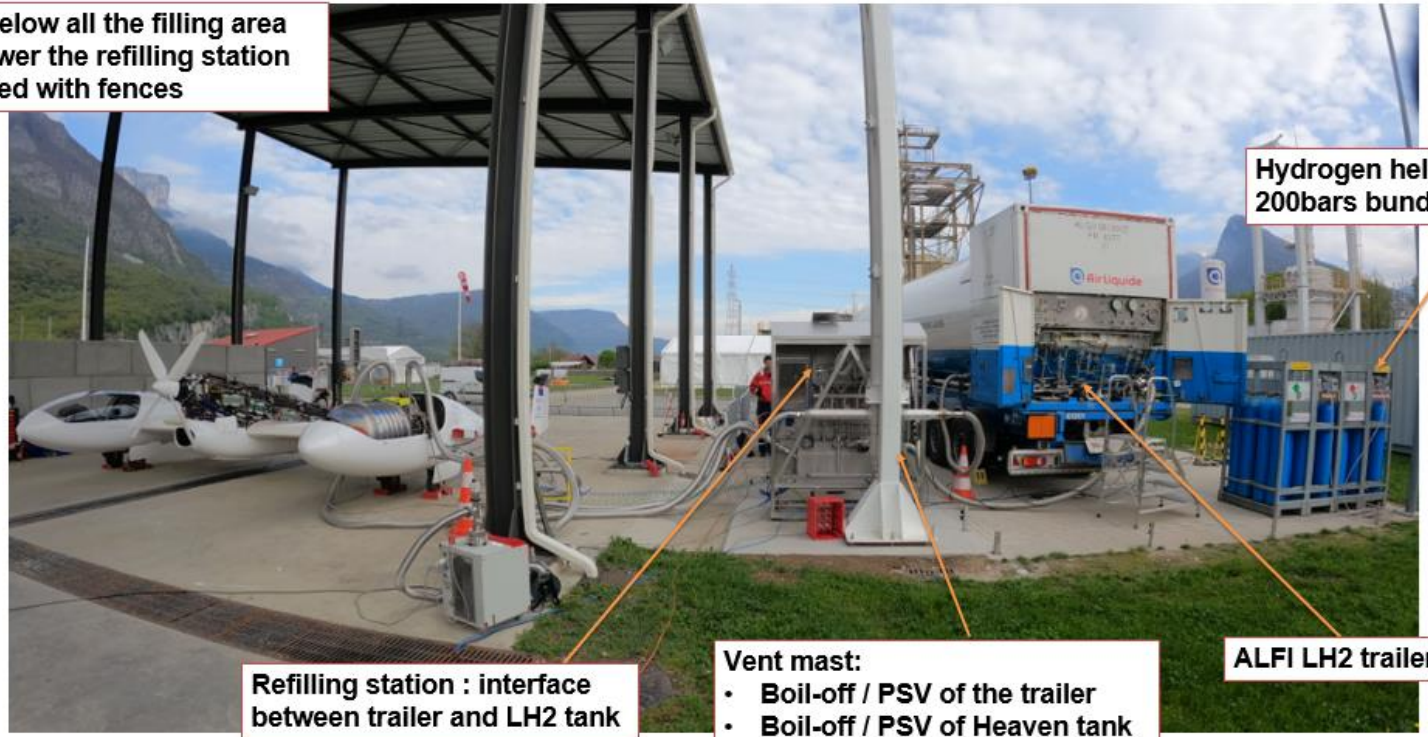
- Can supply the FC at required flow rate (2.4g/s) at a constant pressure during a typical flight profile
- Has a sufficient time to boil-off (10 to 20h after filling before boil-off valve opening)
- Can withstand aeronautical environment without leak / mechanical integrity deterioration
- Generates no glitch by its control/command

All the tests was performed on ALAT facilities



Overview of the refilling area during coupling tests at ALAT

- Concrete below all the filling area
- 230V to power the refilling station
- Area secured with fences



This test area and the associated equipments will also be used in the future to test other LH2 tanks

Flight tests

https://www.youtube.com/watch?v=-qnLkFaX8uo

- Tests performed at Maribor airport - Slovenia in September 2023
- Permit to test fly granted by slovenian civil aviation authorities
- 6h of flight tests performed in total, including a 3h flight

World first LH2 flight with a fuel cell and pilots on board

Conclusions

A world premiere : a manned electric aircraft powered by LH2

- A 4 year project that led to the world first LH2 flight with a fuel cell and pilots on board
- Perfect coordination with H2FLY (head of project) and Pipistrel (aircraft maker)
- The tank behaved as expected
- Authorizations and operations at the airport went smoothly
- All functions for future aircraft implemented and tested

This HEAVEN tank can be replicated or adapted to other aircraft

It paves the way to LH2 powered Aircrafts