TECHNOLOGY TRANSFER FROM THE INSTITUTE OF SPACE PROPULSION

STORAGE AND HANDLING OF LH_2 AT DLR INSTITUTE OF SPACE PROPULSION

ELVHyS Workshop, June 2023

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DLR

Outline

- German Aerospace Center (DLR)
- Institute of Space Propulsion
- General Aspects of LH2 Storage and Handling
- Example Filling of Storage Tank by Trailer
- LH2 Transfer Process Example at Rocket Test Bench
- LH2 Fueling Capabilities at H2 Container Test Center
- Related Projects

German Aerospace Center (DLR)

- About 10.000 employees
- 55 institutes and facilities
- at 30 locations.

- External offices in Brüssel, Paris, Tokio und Washington.

Research Activities at DLR

Aeronautics

Space

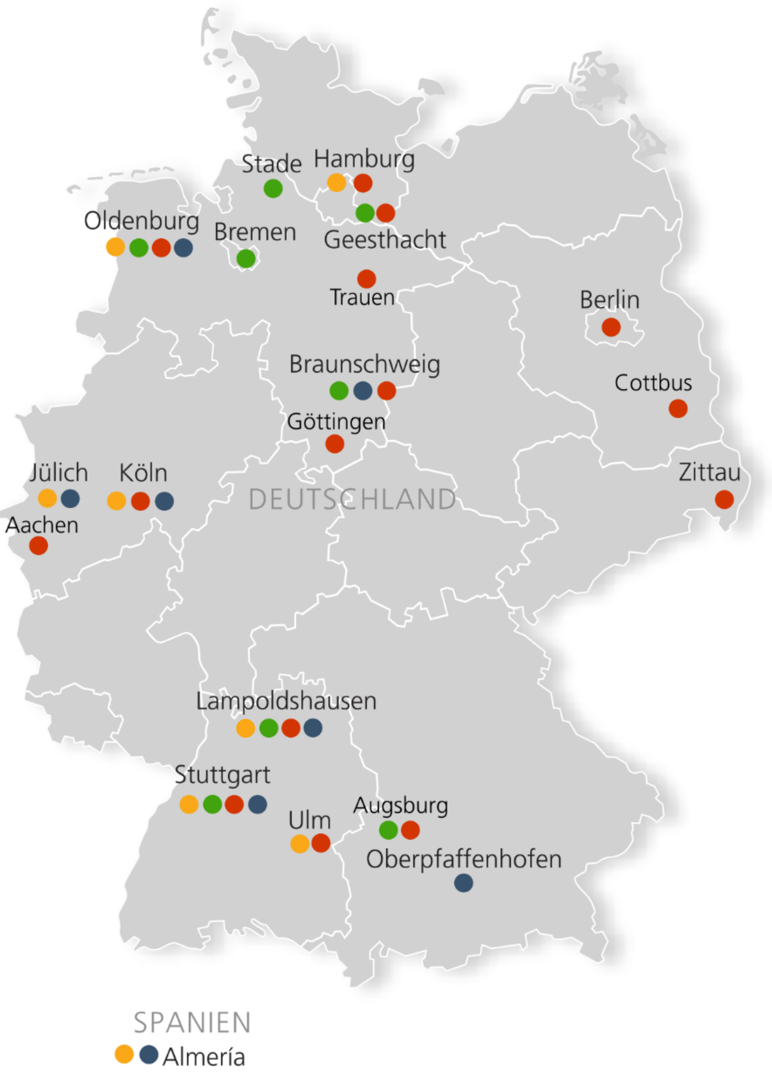
Energy

Transport

Security

Digitalisation

DLR Sites with Hydrogen Activities



Production
electrolysis & solar thermal processes

Storage & Distribution

Application

System/market analysis,
technology assessment,
sustainability

INSTITUTE OF SPACE PROPULSION

Bildquelle DLR

Hidden in the Harthäuser Forest…

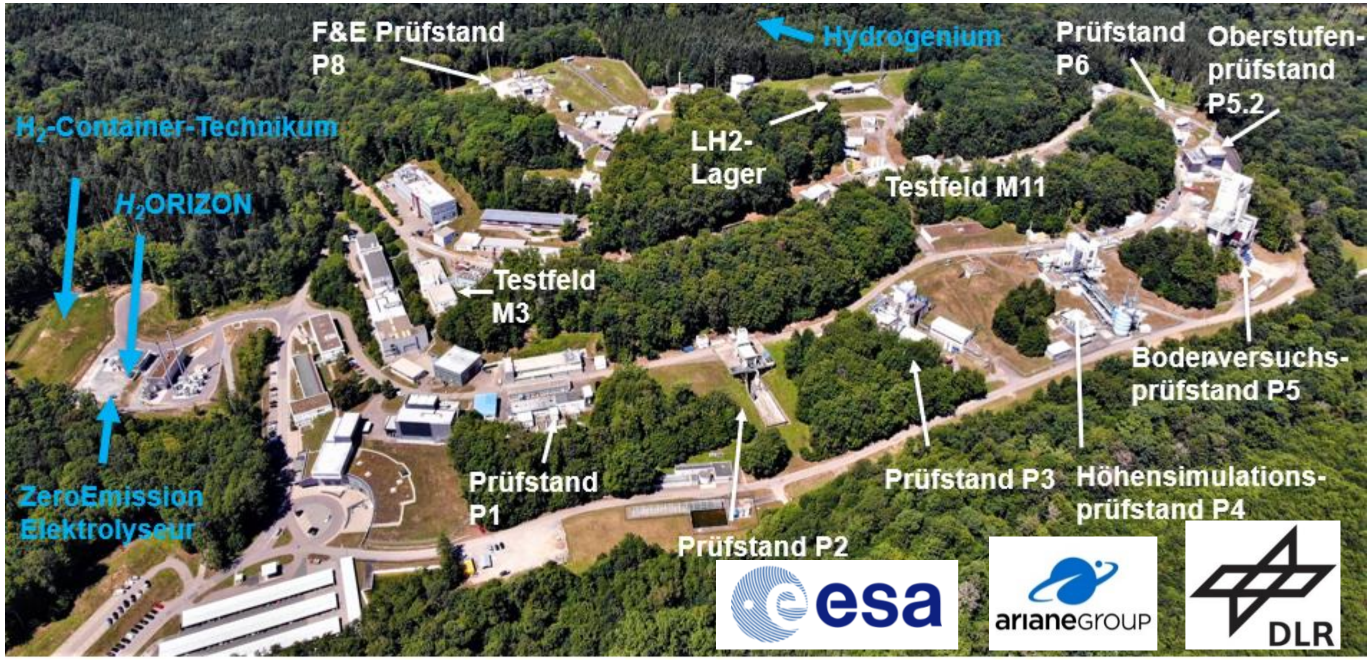
… european test center for space propulsion systems

… one of the big hydrogen consumers in the world

DLR-Institute of Space Propulsion

Site Overview

- **Founded 1959 by Prof. Sänger**
  (DLR - Institut für Raumfahrtantriebe - Die Geschichte des Standorts)
- **Operation of DLR and ESA test facilities**
- **H2 consumption about 380 t/a (mainly liquid)**
- **Operational experiences of hydrogen systems since decades**
  - Knowledge about
    - H_2-resistant materials, Components and H_2 systems
    - Safety infrastructure and permissions for H_2 plants (12.BImSchV/StöV)
- **Knowledge- and technology transfer**
  - Annual hydrogen day since 2013
  - Dept. for Applied Hydrogen Technologies



Site video: www.dlr.de/ra

Test Facilities & Infrastructure

Low pressure test facilities

- High altitude simulation
- N_2O_4, MMH, H_2O_2
- Thrust range 200 - 600N

- ESA test facility
- High altitude simulation
- P4.1: LH_2, LOx, up to 250 kN
- P4.2: N_2O_4, MMH, up to 30 kN

- ESA test facility
- Ground tests
- LH_2, LNG and LOx
- Up to 4.000 kN

- Turbo pump and system tests
- ground and high altitude simulation tests
- LH_2, LOx, LNG, GNG, up to 75 kN

Low pressure test facility for upper stage and tanks

- ESA test facility
- Testing the complete cryogenic upper stage ULPM of Ariane 6 (engine with tank system)
- autarchic control
- Up to 32 tons fuel (LOx and LH_2)
- 900 seconds hot run

High pressure test facilities

- ESA test facility
- ground and high altitude simulation tests
- LH_2, LOx, LNG
- Mass flow up to 330 kg/s
- I/F-pressure up to 280 bar

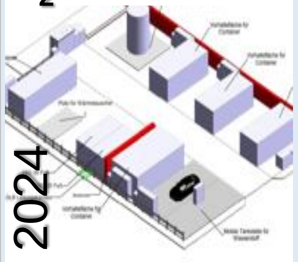
- DLR-CNES-ArianeGroup
- LH_2, LOx, GCH_4, LNG Ethanol
- ground and high altitude simulation
- Mass flow up to 12 kg/s
- I/F-pressure max. 360 bar

- GH_2 (cooled), LOx, LN_2, LNG
- Mass flow up to 1,25 kg/s
- I/ F-Pressure max. 95 bar

Test Facilities & Infrastructure

Test centres for hydrogen applications

H_2 test center



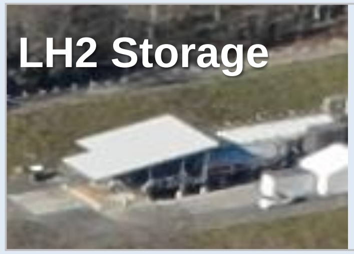
- container-based test facility
- 6 test positions for components and demonstrators
- green GH_2 (30/300 bar)~60kg/h
- 2 LH2 test positions (1000 kg/h at 16 bar)

Hydrogenium

- Large test facility with focus on LH_2 supply
- up to 4000kg/h peak at 16bar
- GH_2 up to 150kg/h Peak at 300bar
- Big and small test positions

Special hydrogen infrastructure

LH2 Storage



- LH_2 storage tank, 270m³
- LH_2 pilot tank, 55m³
- Transfer delivery rate of up to 200m³ LH_2 per day

H2ORIZON

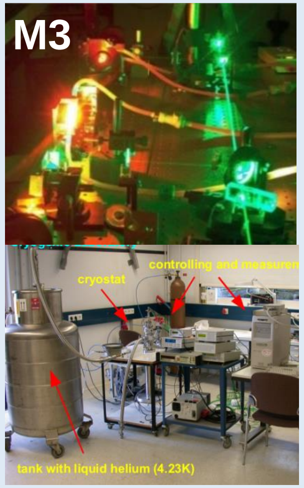
- PEM-Electrolyser research platform
- 880kW P_{el} from wind park
- 14,1 kg/h green hydrogen

ZE Electrolyser

- PEM-Electrolyser
- 2300kW P_{el} from wind park
- 35,8kg/h green H_2

Other facilities

M3



- Chemical Lab, e.g. gas and exhaust analysis, energy carrier development (ionic liquids)
- Cryogenic laboratory
- Physical laboratory
- Micro combustion chamber with LH_2, LOx, LCH_4
- Calibration lab

M11

- Green propellants
- Gel propellants
- Vacuum plant
- Scramjet research

Centralized Storages at Lampoldshausen

LH2-Tanks at Storage Area

- Storage Tank B101

270 m^3 / 0,1 bar storage pressure, 1,1 bar working pressure, max. 2,9 bar

- Pilot Tank B102

50 m^3 / working pressure 4,5 bar, max. 6,5 bar

Filling of tanks by trailer.

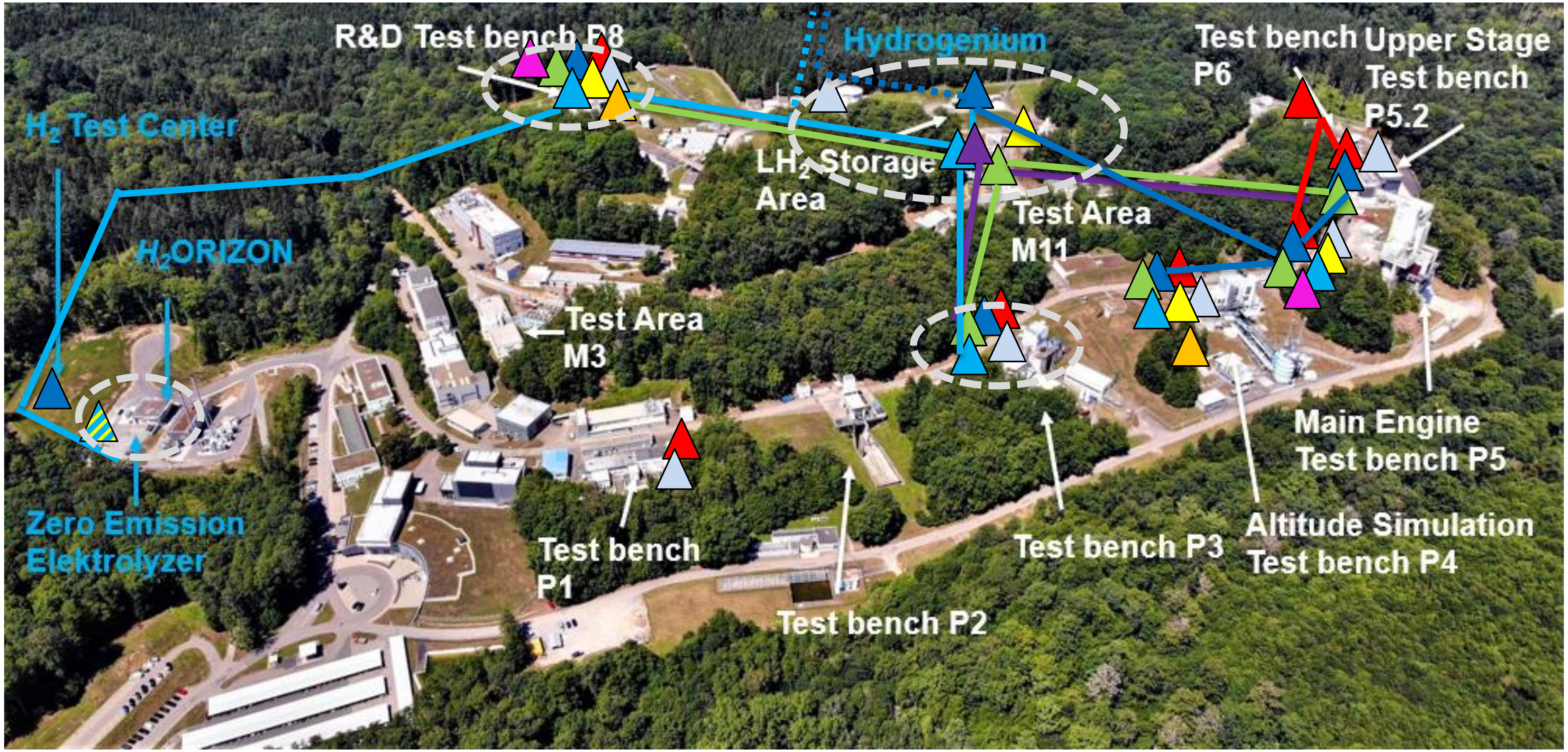
- Transfer of LH2 to test benches

or to evaporator to provide GH2 for consumer.

Overview and Extension of Main Media Supply Systems

	Piping	Tank
GH_2		
LH_2		
GN_2		
LN_2		
GOx		
LOx		
LNG		
GHe		
Water		

H_2 „sources“
(Production and/or
Refilling area



General Aspects of LH2 Storage and Handling

- Low temperature: storage of liquid hydrogen requires insulated tank
  - Typical design: double walled, vacuum insulated, additional insulation in space between inner and outer vessel, e.g. multi layer insulation, perlite, glass bubbles.
  - Inner vessel has to withstand mechanical stresses, due to temperature gradient, and defined max. working pressure; structural material has to be adequate for H2 operation.
  - Outer vessel: protection against outside conditions, vacuum tight.

- Transfer:
  - Pressurization of tank with (1) evaporator or (2) pressurized gas, or
  - LH_2 pump (currently still expansive and high risk of failure, usually restricted operation range, thus maybe not suitable for application with wide range – aircraft with high consumption at start and low in normal operation)

General Aspects of LH2 Storage and Handling

- Safety of components and system
  - design and manufacturing according norms and standards, e.g. Pressure Equipment Directive (PED)
  - grounding and lightning protection to avoid unintended ignition
  - commissioning, leak tests stepwise starting with inert media (e.g. GN_2, water), inert cryogenic media (e.g. LN_2), and finally with LH_2

- Operational Safety
  - avoid over-pressure due to boil off -> safety valves for normal operation; exhaust valve for operation with high evaporation rates (cool down)
  - every possibly separated piping segment has to be equipped with safety valve
  - avoid explosive atmosphere at critical areas by releasing evaporated H2 via vent or flare stack

General Aspects of LH2 Storage and Handling

- Purging:
  - LH2 infrastructure must be clean, dry and inert bevor filling process !
  - Purge gas GN_2

  - Removal of not wanted rest gases (air) and humidity
  - Removal of dirt (e.g. after modification or repair work)

- Methods
  - Flow through
  - Pressurization and venting
  - Pressurization, venting and evacuation

General Aspects of LH2 Storage and Handling

- Conditioning:
  - Preparation of piping, tank, etc. for filling with cryogenic media.
  - Bring system after run back in inert state.

- Objective:
  - gases (expect of GH2 and GHe) will freeze, and can block or destroy plant.
  - avoid any contamination for end user.

- Purge gases to eliminate N_2: GH_2 or GHe
  - Advantage GH_2: price, availability
  - Advantage GHe: lower risk; no warm up for purging

Filling of Storage Tank by Trailer

- Air Liquide coupling extended with adapters from Air Product and Linde
- The unloading station is an EX protection zone
- Weather protection by a roof for the tank and the pipeline
- Additional protection by Teflon cap and welded protection tube

Preparation for Transfer

- Trailer in parking position secure locked
- Grounding
- Connection of flexible hose
- Positioning of catch bin below locations with no or worse insulation, to catch condensate

Example of Transfer Duration

- Arrival LH2 Trailer: 10:30 h
- Start purging: 10:45 h
- Start filling 50m³ Tank: 11:20 h
- Switch to 270m³ Tank: 12:31 h
- End of filling: 12:31 h
- End of purging an warm up: 13:45 h

Duration: 3 h 15 min

Transfered LH2: 2400 kg

LH2 Transfer Process Example at Rocket Test Bench

- P5 test bench for low pressure cryogenic testing facility for lower stage engines under sea level conditions

- Vulcain engine test with liquid oxygen and hydrogen
- LOX 300kg/s @ 17 bar
- LH2 50 kg/s @ 5 bar

- Local storage tank 600m³ @ 7 bar

Preparation of vulcain 2 engine at test bench P5

LH2 Transfer Process Example at Rocket Test Bench

- European Research and Technology Test Bench with cryogenic propellants

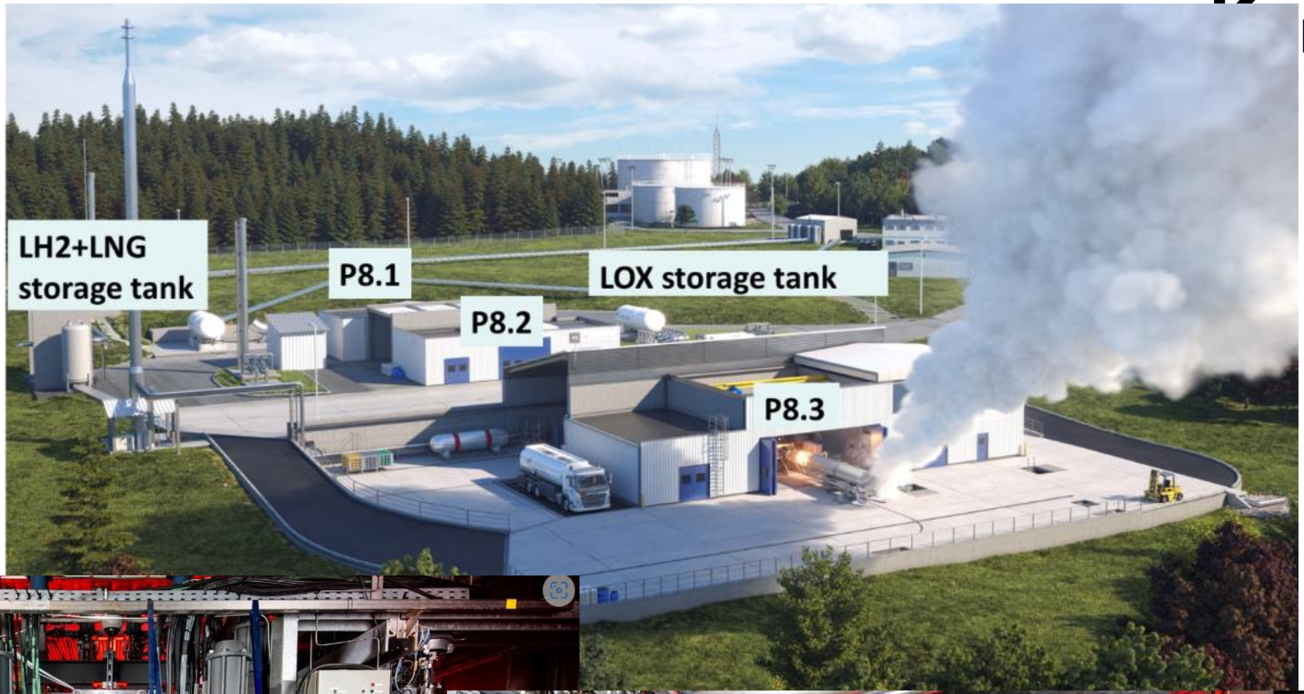
P8.1/2

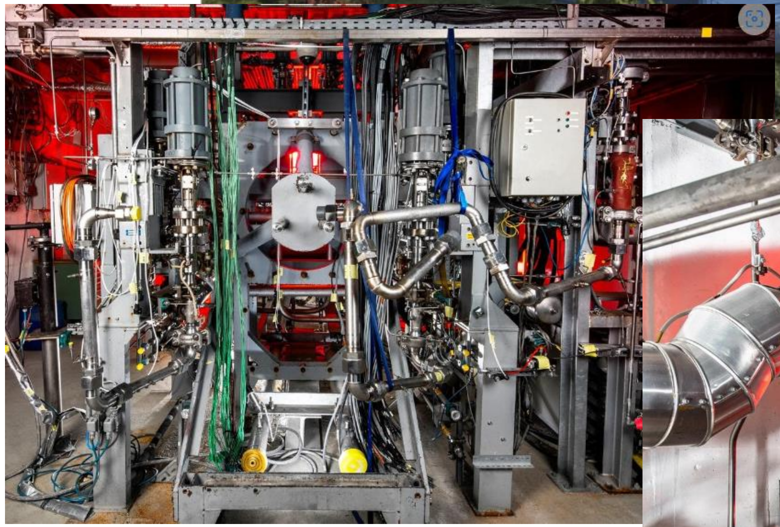
- high pressure cryogenic facility for sub-scale testing, high-altitude simulation capacity
- LH2 12 kg/s @ 300 bar

P8.3

- Turbo pump, power pack and engine test capability with cryogenic propellants
- LH2 20 kg/s @ 14 bar

- Local storage tank 11m³ @ 6bar



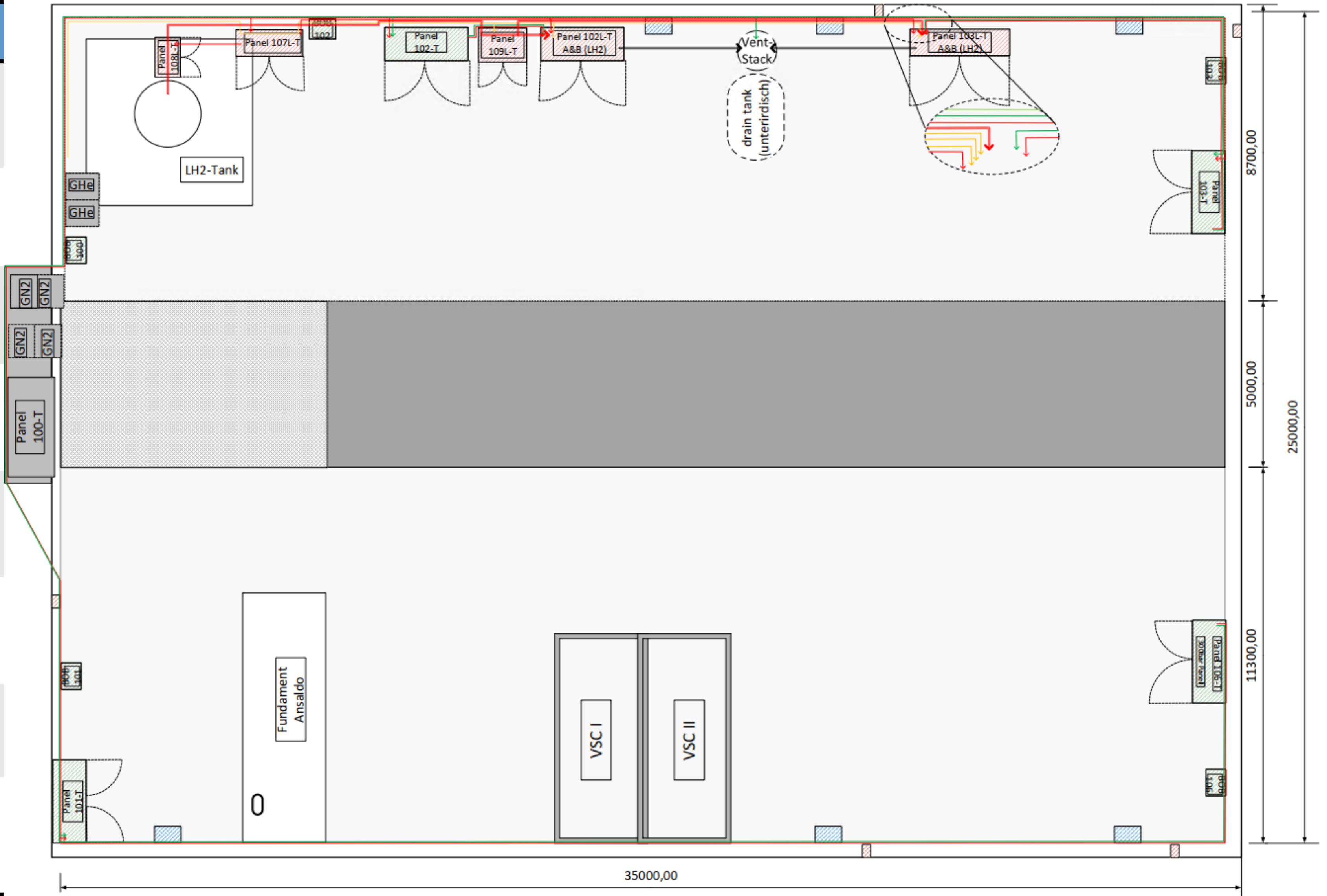


P8.2 test cell

High pressure cryogenic lines

LH2 Fueling Capabilities at H2 Container Test Center

Media supply	
GH2 (green)	4 test positions: 30bar, > 60$\frac{kg}{h}$ TBC
	1 test position: 300bar, 30$\frac{kg}{h}$
LH2	2 LH_2 test positions: <16bar (TBD), approx. 1000$\frac{kg}{h}$
GN2	Purging 5bar, 65 $\frac{kg}{h}$
	Command pressure 7bar, 30 $\frac{kg}{h}$
LN2	Available instead of LH2 if needed
GHe	Purging for LH_2 specimen 6 bar, 60 kg/h
	Quick Discharge of 2m³ test specimen 6 bar, 114 kg/h



Hydrogen Supply

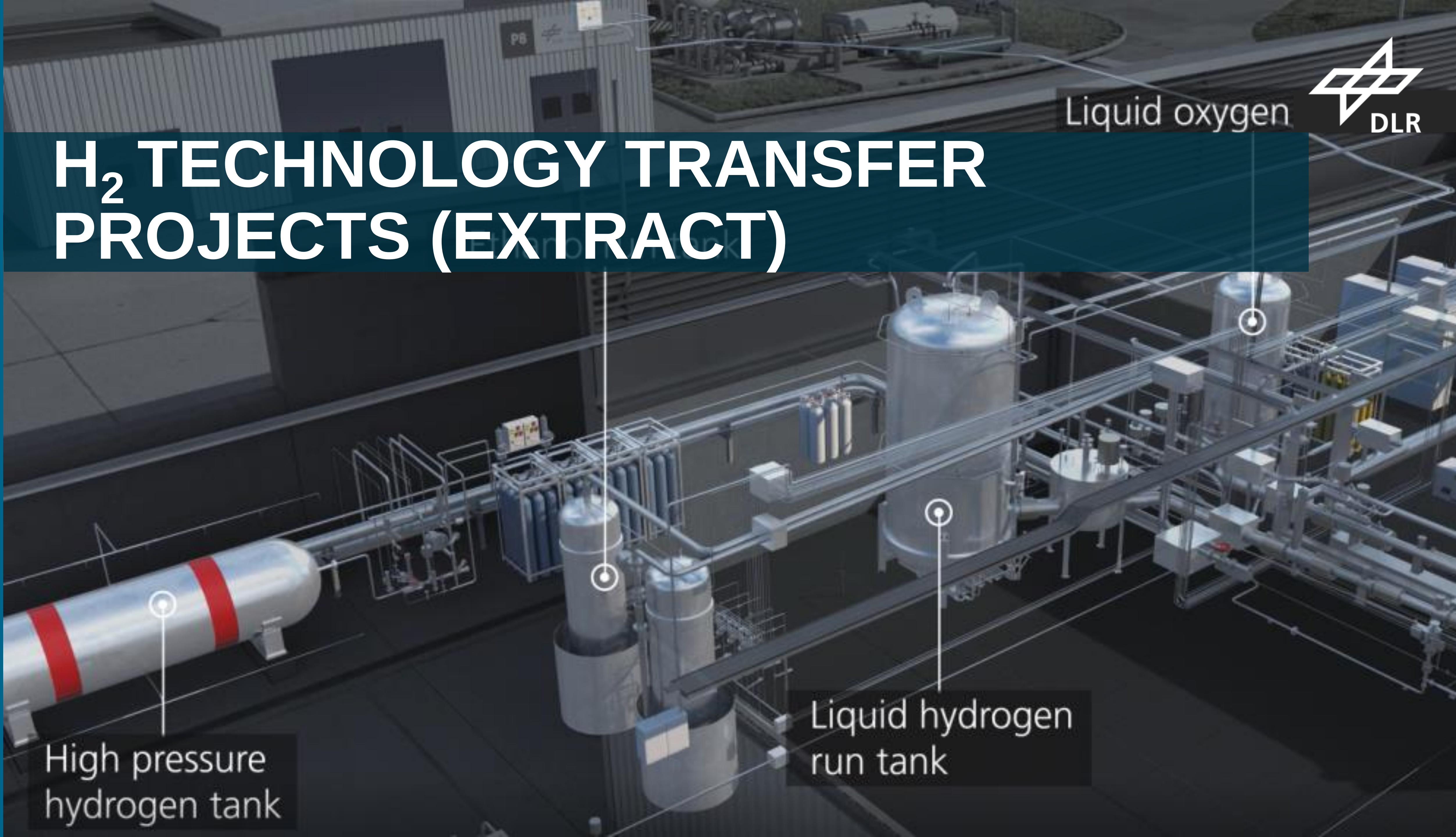
100% green hydrogen (gaseous)

- From electrolyser (30bar) (directly connected to windpark)
- Supply for technical center at no wind
  - 2 bottles with 12m³ at 300bar as buffer
  - Transfer from central storage via pipeline

Liquid hydrogen (delivered)

- LH_2 supply tank 12m³
- Interface for discharge DN25
  - about 1000kg/h at max. 16bar
- max. test specimen size: 2m³
  - Quick discharge with He in 5min

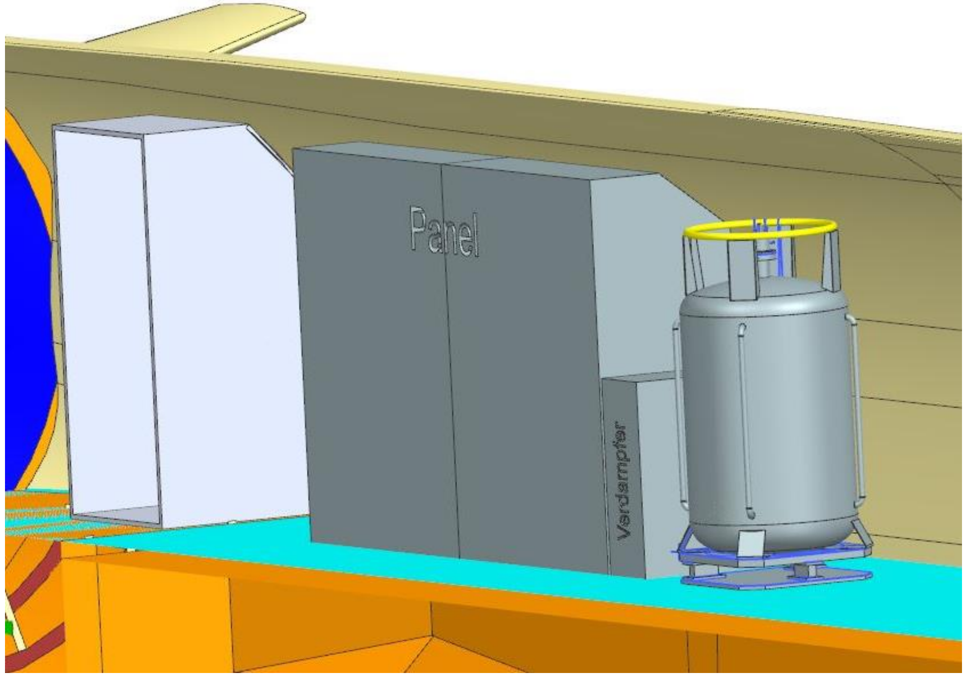
H_2 TECHNOLOGY TRANSFER PROJECTS (EXTRACT)



Hydrogen Aviation Lab
Ground demonstrator for usage of liquid hydrogen in a common airplane (A320)

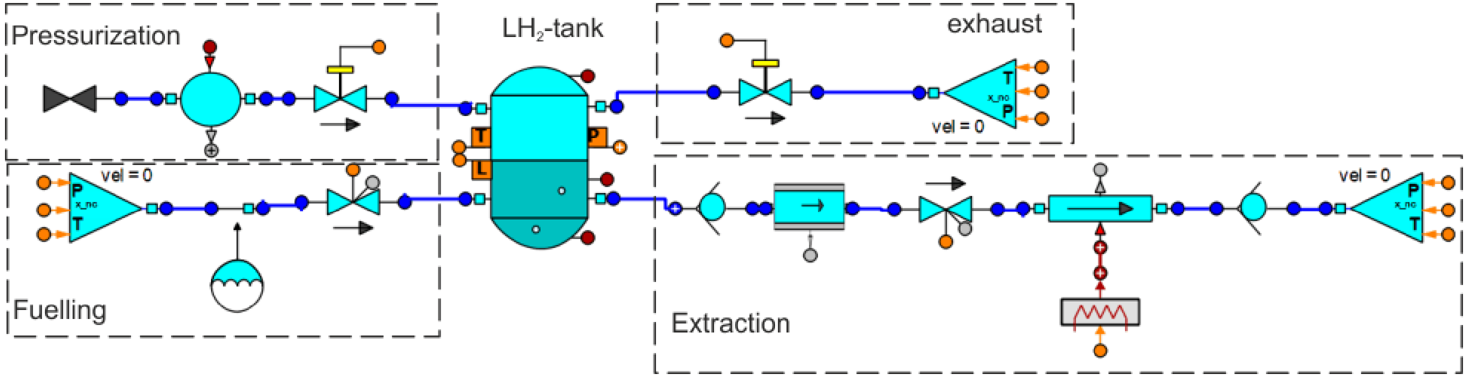
Partner

- Lufthansa Technik (LHT)
- Zentrum für angewandte Luftfahrtforschung (ZAL)
- German Aerospace Center (DLR)



Scope of DLR Lampoldshausen

- Design und Erection of the complete H_2 system on board until fuel cell interface
- simulation of system behavior for various scenarios (filling, taxiing, flight)
- Optimization regarding to
  - safety
  - efficiency
  - Boil-off



Dornier 228 Flying Fuel Cell (Do228FFC)

Emission free flight demonstrator Dornier 228

Partner

- MTU Aeroengines
- German Aerospace Center (DLR)

Overview

- Hydrogen powered fuel cell
- unilateral electrical propeller engine (> 500 KW)
- Development of a complete power train with cooling line suitable for aviation
- Planned maiden flight 2026

Scope of DLR Lampoldshausen

- Planning and Erection of an LH_2 ground filling station for the flight field in Oberpfaffenhofen

Beispiel einer Tankanlage

Foto: Walther Präzision: Hydrogen Refueling Technology

Thank you for our attention!

Contact

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