Hydrogen at Test Site at DLR Institute of Propulsion

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Hydrogen at Test Site at DLR Institute of Propulsion Background

- Hydrogen is the most promising fuel propellant of chemical space propulsion motors and therefore space launch systems
- **Since 1990** the operational experience of liquid hydrogen fueled rocket stages is continuelly extended in Western Europe and in Lampoldshausen
- The dimensioning of test facilities, hydrogen safety systems and safe operations is still today a challenge
  - Space limitations for testing large rocket subcomponents
  - New technologies for measurement command and control of test processes
  - Testing is almost a step towards the limits of system

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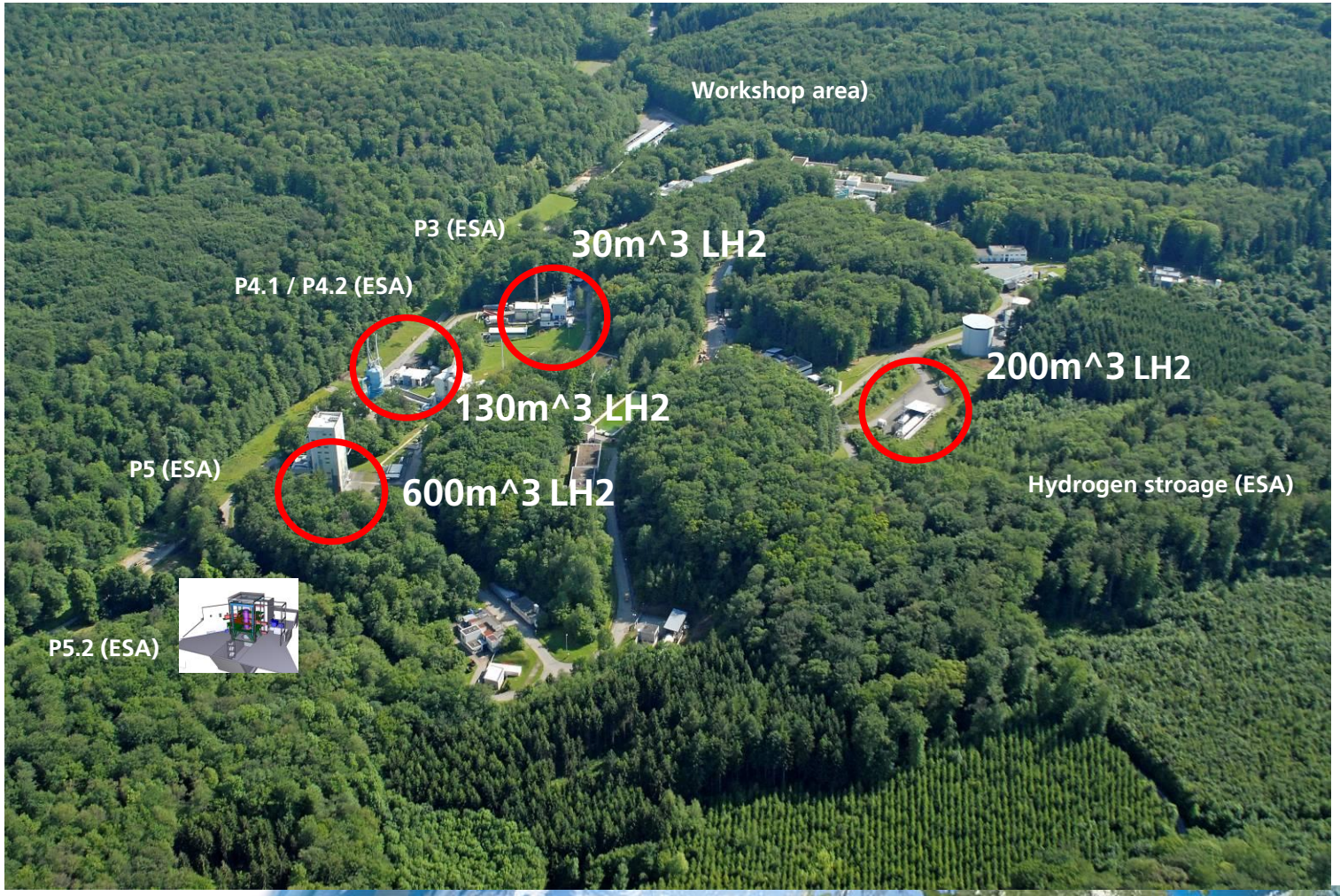
Test Site Center LH2 Storages for Rocket Engine Testing



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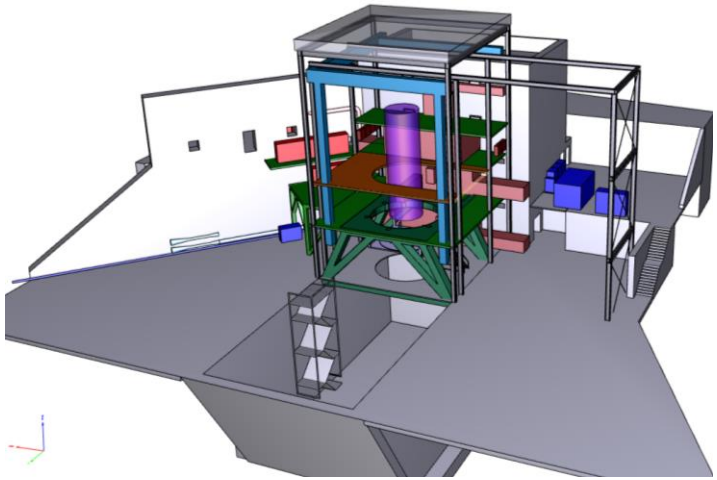
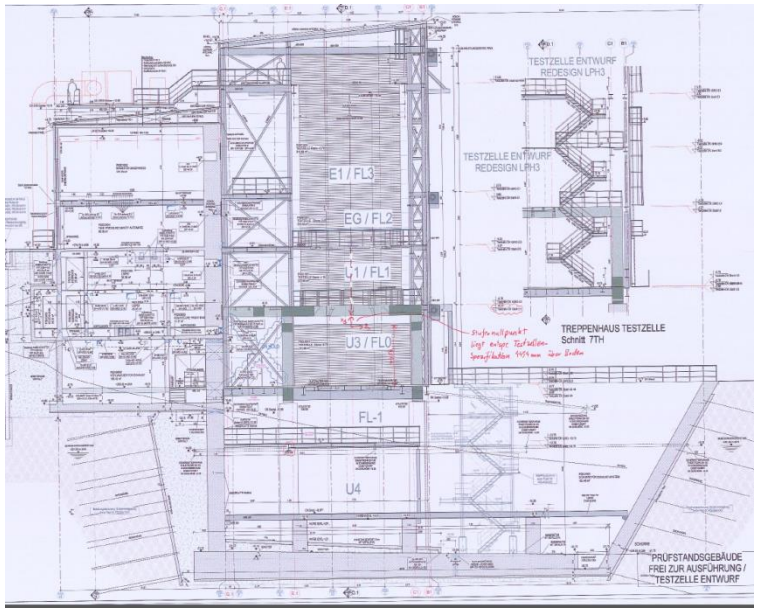
Actual Project P5.2 (A6 Upper Stage Test Facility)





- In Lampoldshausen a new test facility P5.2 was designed to test A6 ULPM upper stage
- chute will recover residual LH2/LOX in case of stage break down
- P5.2 concept based on max use of test site existing infrastructure → Connect to fluid net

→ Hot run firing a cryo stage at ambient conditions in 2019

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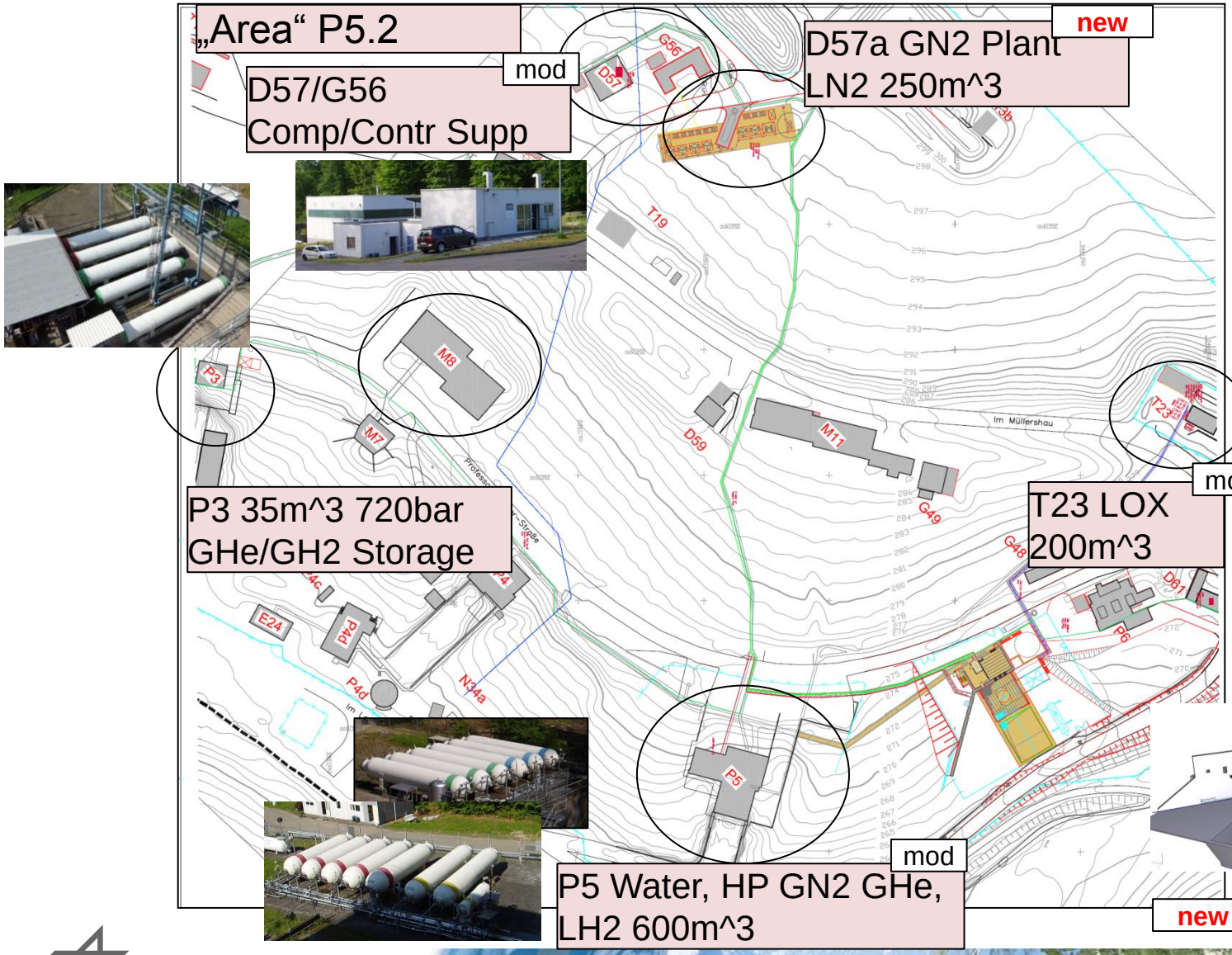

Area P5.2:
Fluid Supply Network

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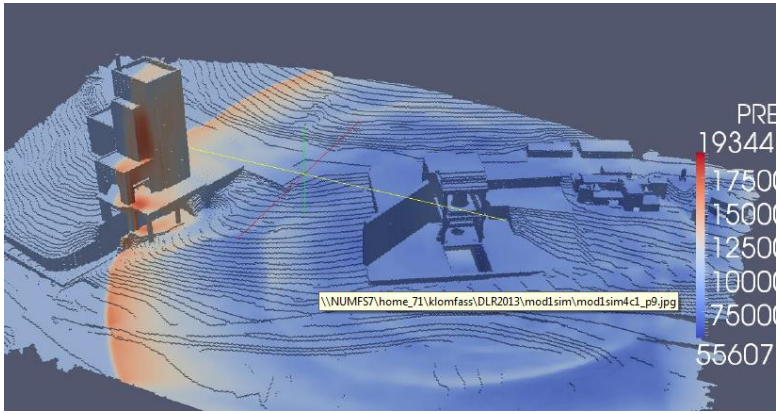
A6 Upper Stage Test Facility Hydrogen Studies

- **A safety study** in the course of concept engineering contained a study of blast expansion **either at atmosphere or at vacuum (confined) conditons**
  - The worst case scenario considered was a rupture of 70m^3 LH2 tank structure where a sudden release and exposure of big quantity of LH2 to ambiance was assumed.
  - The study of blast expansion has been performed at EMI in Freiburg where computational tool Apollo has been applied
  - In parallel with FLACS Gexcon
  - The yield of the blast depends on the amount of ignitable (premixed) hydrogen gas



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Operation of Test/Near Term Engineering Activities

- Today the safety devices and equipment of the test cell is adressed in the design (design challenges):
  - Devices to restrict the amount of of free premixed hydrogen/air gas clouds
    - Application of gow plugs near test specimen (regular space arrangement)
      - Effect in case of ignition to the test specimen (LH2/LOX stage)
  - Detection of small intern/extern hydrogen leakages (maybe by remote visusal methods)
  - Device for detection of hydrogen leakages upstream/downstream of a onboard check valve installed at the filling line I/F to the stage within 5 min (remote controlled)
- Safe operation of LH2/LOX upper stage
  - Avoidance **of sudden boil off** situations inside the LH2 liquid body inside a tank
  - High flowrate release **of LH2 via flare stack**
    - **possiblity to release LH2 to the flare (2h of 30l/s LH2 release (2.1kg/s))**
  - Simulation of flow considering heat transfer, chem reaction and multiphase flow at the flare stack tip

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Unkowns and Interrests

- How many **LH2 can be expected to be converted from liquid to gaseous phase** when suddenly released to atmosphere ? (initial conditions for explosion and detonation)
  - Combined Physical processes (heat transfer, rupture of liquid body,mixing with air) not determined.

- In case of complete rupture of LH2 and LOX tank: what can be expected to happen **after release inside the pool/chute**
  - Secondary effects and **controlled** burn down inside the chute
    - Mixture LH2/OX (icing?)/N2 icing
    - Operation of water??
    - Artificial ignition sources
    - Control devices for observation after rupture of tank

    - DLR propose a subscale test (1:4-5) to simulate such sudden release and pool evaporation behaviour of LH2 with LOX (~15m3 LH2, 5m^3 LOX)

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Technologie Request/Transfer of Technologies

- Accurate Measurement of flow of LH2
  - Calibration center in Europe for hydrogen calibration/ where is it?
    - In times of good perspektives of hydrogen it should be possible to realise it on institutional level at least!
- Accurate Measurement of temperature in LH2 range based on European technology
- Decrease/avoidance of GHe for operation of LH2 processes

- DLR will errect a fuel cell station as an electrical power production unit in cooperation with industry
  - First on basis of natural gas later use of GH2 waste gas
  - Storage of wind mill generated electricity

- Erection of GH2 fuel supply station is considered with industry

- Every year in Feb there a Hydrogen Day is organised by DLR Institute of Propulsion in order to promote the technologie