ELVHYS project overview

Federico Ustolin

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ELVHYS project No. 101101381 is supported by the Clean Hydrogen Partnership and its members. UK participants in Horizon Europe Project ELVHYS are supported by UKRI grant numbers 10063519 (University of Ulster) and 10070592 (Health and Safety Executive)

Understanding of heat and mass transfer for cryogenic and liquid hydrogen

Programme	
Time (CET)	Presentation title
09:00-09:05	Welcome (F. Ustolin, NTNU)
09:05-09:30	ELVHYS project overview (F. Ustolin, NTNU)
09:30-09:55	Simulation of sloshing-induced BOG/BOR in cryogenic fluid storage tanks (S.-M. Jeong, Chosun University)
09:55-10:15	Coffee break
10:15-10:40	Novel insulation systems for liquid hydrogen tanks (G.-W. Kim, KRISO)
10:40-11:05	Heat transfer analysis of SH2IFT bonfire tests on liquid hydrogen tanks (A. Schiaroli, NTNU)
11:05-11:30	How the quantum mechanical nature of cryogenic hydrogen influences heat and mass transfer (Ø. Wilhelmsen, NTNU)
11:30-12:40	Lunch break
12:40-13:05	Advancement in heat and mass transfer modelling (A. Venetsanos, NCSRD)
13:05-13:30	Liquid hydrogen spill and evaporation modelling (M. S. Grønli, SINTEF)
13:30-13:55	Effect of heat transfer through the tank and pipe walls on releases of cryogenic hydrogen (D. Cirrone, Ulster University)
13:55-14:25	Round table discussion (F. Ustolin, NTNU; All)
14:25-14:50	Coffee break
14:50-15:15	Behaviour of liquid hydrogen tanks exposed to fire (A. Schiaroli, NTNU)
15:15-15:40	Thermoacoustic instabilities in liquid hydrogen storage systems and novel cryocooling concepts using hydrogen as a working fluid (K. Matveev, Washington State University)
15:40-16:00	Final remarks and closure of the workshop (F. Ustolin, NTNU)

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Pre - ELVHYS

Progress / Closed gaps

Fundamental/Modelling “Release”:

- ✓ Discharge coefficients for cryo- and cryocompressed releases
- ✓ Rainout phenomena better understood
- ✓ Fundamental data for mixing of large scale releases

Fundamental/Modelling “Ignition”:

- ✓ MIE and hot surface T determined for cryogenic conditions
- ✓ Empirical tests for RPT without fast reaction
- ✓ Electrostatics of cryogenic releases
- ✓ Worst case effects for small cryogenic inventories determined via variation of ignition time and position

Fundamental/Modelling “Combustion”:

- ✓ Flame length correlations validated
- ✓ σ, σcrit and run-up distance for DDT determined at cryogenic conditions
- ✓ …

PRESLHY

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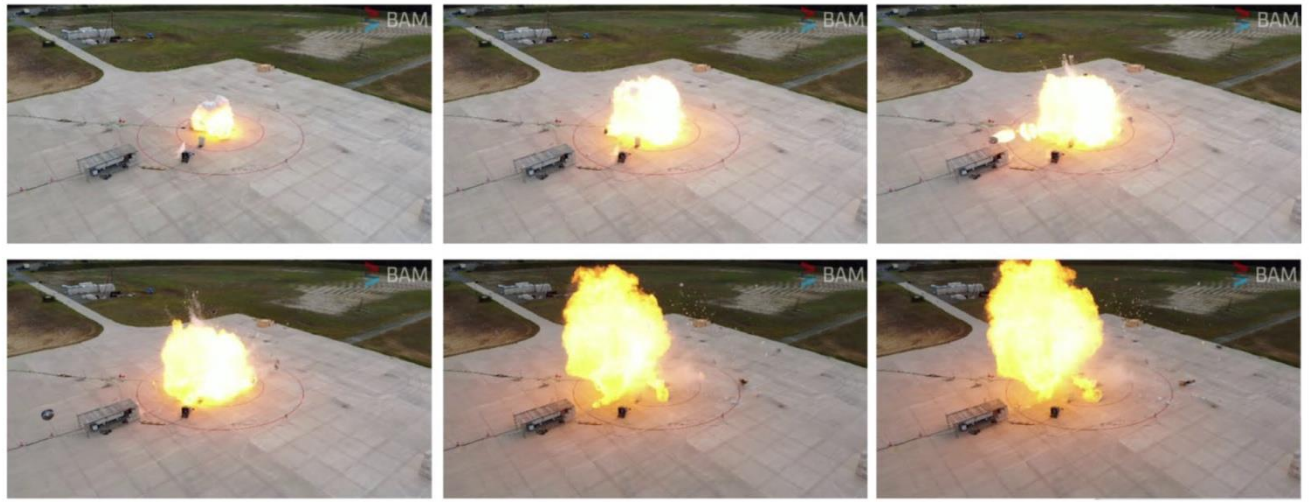
Pre - ELVHYS

SH2IFT Project Findings

Fundamental/Modelling “BLEVE”:

- ✓ Experiments performed and BLEVE observed at BAM
  (see van Wingerden, Kees, et al. *Chemical Engineering Transactions*, 2022, 90. Jg., S. 547-552)



Fundamental/Modelling “RPT”:

- ✓ RPT observed in BAM tests spilling LH2 on water
  (see van Wingerden, Kees, et al. "Experimental Investigation into the Consequences of Release of Liquified Hydrogen onto and under Water." (2022))

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Enhancing safety of liquid and vaporised hydrogen transfer technologies in public areas for mobile applications

Funding: 2.0 M€

Duration: 2023-2026

Coordinator: NTNU

Partners:

Website

Objective: provide indications on inherently safer and efficient cryogenic hydrogen technologies and protocols in mobile applications by proposing innovative safety strategies including selection of effective safety barriers and hazard zoning strategies, which are the results of a detailed risk analysis.

NTNU role: coordinator, consequence analysis, risk analysis

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Expected outcomes & objectives

1. Detailed risk analysis for LH2 transferring operations for mobile applications (ships, trucks, stationary tanks) fillings
2. Generic hazard distances for LH2 transferring operations in the different applications, also addressing SimOps
3. Guidelines for design of LH2 transferring facilities
4. Consensual loading procedures for LH2 transferring operations
5. Provide inputs for developing Standards, Technical Specifications, or Technical Reports at the international level

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ELVHYS – Consortium

NTNU (Coordinator)

Ulster University

DEMOKRITOS

DLR

HSE

KIT Karlsruher Institut für Technologie

Air Liquide

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ELVHYS – Stakeholder Advisory Board

- At the moment 32 organizations are included in the SAB
- The organizations are based in 8 European (Belgium, France, Germany, Italy, Norway, Sweden, The Netherlands, UK) and 4 non-European countries (Canada, China, Japan, South Korea, USA)
- Type of organizations: industries and companies (10), research centres (4), universities (10), national public institutes (3), association (HySafe), intergovernmental org. (IEA), industry org. (Hydrogen Council), rail operator (SNCF)

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ELVHYS – Collaboration with other projects

Collaborations with other projects related to LH2 and cryogenic hydrogen transfer and storage were established:

1. **e-SHyIPS** (Horizon Europe, coordinator: Politecnico of Milano, Italy)
2. **ESKHYMO** (France, 2022-2026, coordinator: CEA, France)
3. **LH2 Pioneer** (NFR, coordinator: SINTEF Energy)
4. **MF Hydra** (LH2 ferry, Norway, Norled)
5. **sHYpS** (EU, coordinator (Horizon Europe, 2022-26, coordinator: NavalProgetti S.r.l., Italy)
6. **STACY** (EIG Concert Japan, 2022-2026, coordinator: Julich, Germany)
7. **NICOLHy** (Horizon Europe, 2024-26, coordinator: BAM, Germany)
8. **HEAVEN** (Horizon Europe, 2023-26, coordinator: Rolls-Royce, Germany)
9. **DelHyVEHR** (Horizon Europe, coordinator: Engie, France)

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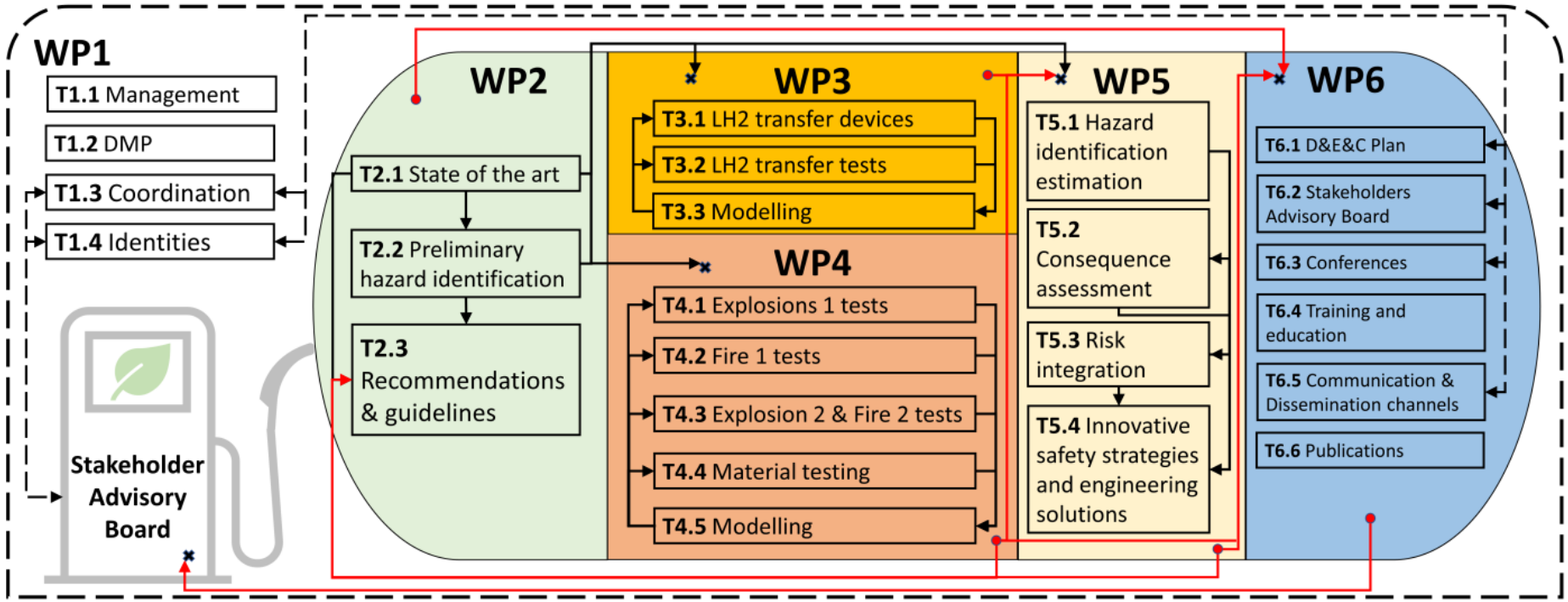
ELVHYS – Work Plan



- WP1 (NTNU) - Project Management & Coordination
- WP2 (AL) - From industrial background and strategy to findings application
- WP3 (DLR) - Cryogenic hydrogen transfer facilities performance
- WP4 (HSE) - Fires & explosions from cryogenic hydrogen transfer facilities
- WP5 (NCSRD) - Risk Analysis for selected cryogenic hydrogen transferring operations
- WP6 (UU) - Dissemination, exploitation, communication

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ELVHYS – State of the art on LH2 transfer and preliminary analysis

The main activities in WP2 in the first half of the project were:

- **Task 2.1** - LH2 transfer ecosystem, infrastructure description and regulatory challenges (AL)
  - **Sub-Task 2.1.1** LH2 transferring applications and associated feared events (AL): completed
  - **Sub-Task 2.1.2** Description of LH2 transfer equipment and protocols for LH2 transferring operations (AL): completed
  - **Sub-Task 2.1.3** Overview of existing RCS and identification of gaps (AL): completed
- **Task 2.2** - Preliminary major accident hazard identification for LH2 transfer operations (AL)
  - **Sub-Task 2.2.1** Overview of risk analysis methodologies (AL): completed
  - **Sub-Task 2.2.2** Preliminary major accident hazard identification and severity assessment (AL): completed
  - **Sub-Task 2.2.3** Research programme and expected results (AL): completed

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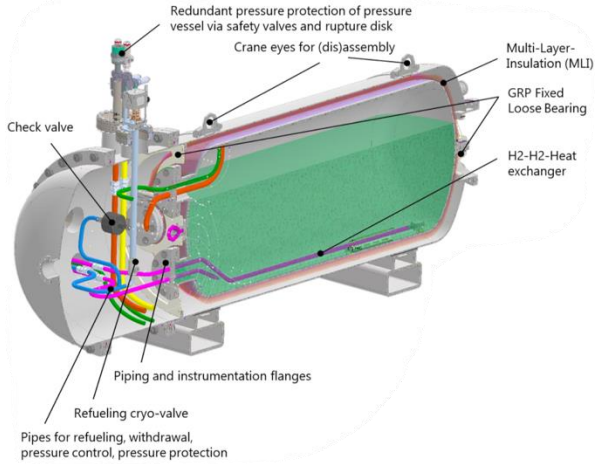
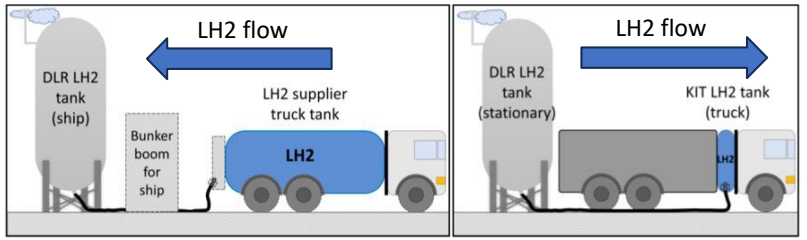
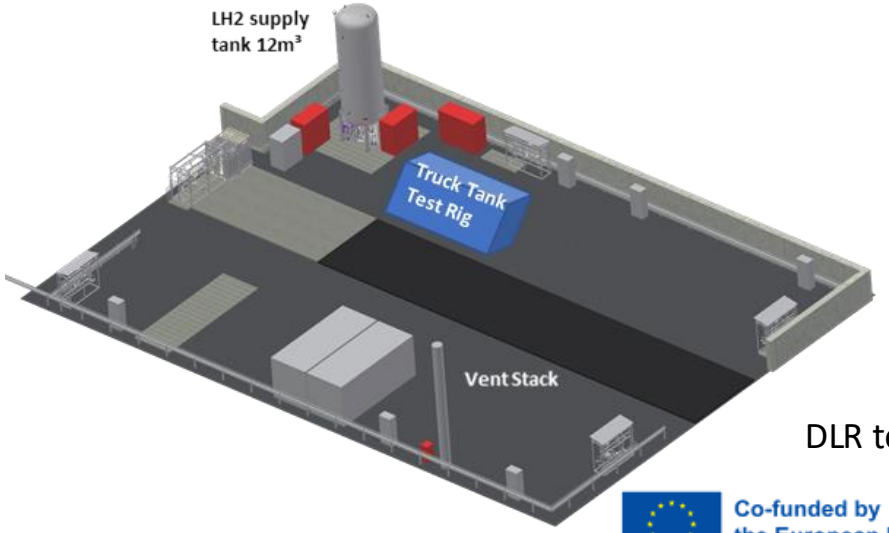
ELVHYS – Experimental activities (1/6)

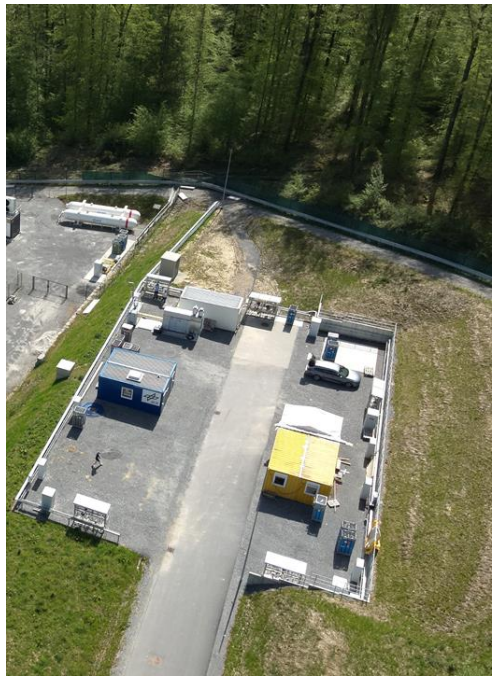
Nr.	Phenomenon investigated	WP	Location	Performed by
1	LH2 transfer operations from a giving to a receiving tank	3	Lampoldshausen (Germany)	DLR



LH2 tank (images courtesy of KIT)







DLR test facility (images courtesy of DLR)

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ELVHYS – Experimental activities (2/6)

Nr.	Phenomenon investigated	WP	Location	Performed by
2	Oxygen enrichment and condensed phase explosions	4	Buxton (UK)	HSE

UPDATE: this experimental campaign was concluded last week at HSE. The data analysis will start soon, and the results will most likely be presented at the next workshop.

Experimental release of LH2 previously performed at HSE (Hooker et al., 2012)

Aerial view of HSE test pad during the tests(images courtesy of HSE)

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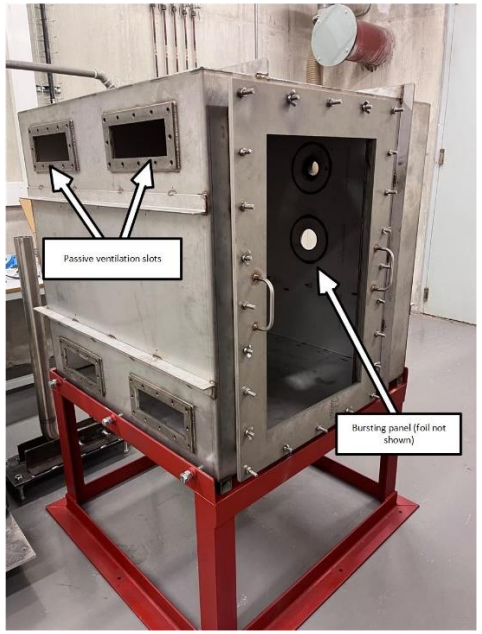
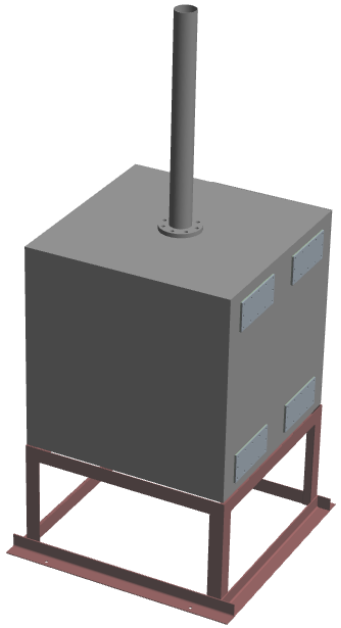
ELVHYS – Experimental activities (3/6)

Nr.	Phenomenon investigated	WP	Location	Performed by
3	LH2 Leakage into cold room/tank connection space considering barriers and obstacles	4	Buxton (UK)	HSE

UPDATE: this experimental campaign was concluded last week at HSE. The data analysis will start soon, and the results will most likely be presented at the next workshop.





HSE experimental setup (images courtesy of HSE)

LH2 indoor testing at HSE (images courtesy of HSE)

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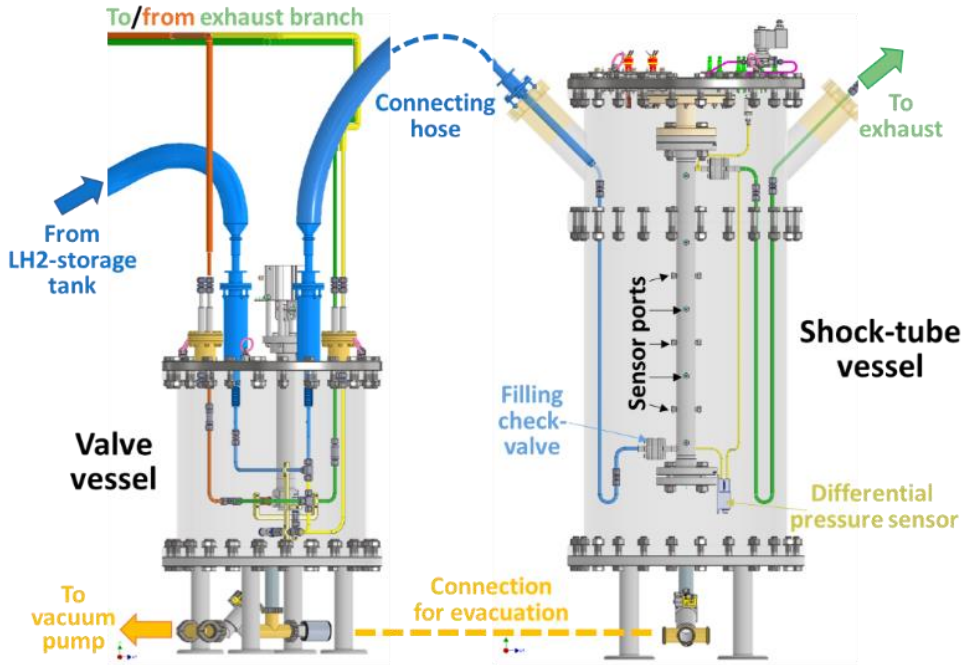
ELVHYS – Experimental activities (4/6)

Nr.	Phenomenon investigated	WP	Location	Performed by
4	Boiling Liquid Expanding Vapour Explosion (BLEVE) tests with a shock tube	4	Karlsruhe (Germany)	KIT

HYKA safety vessel V220 at KIT



ELVHYS experimental setup (images courtesy of KIT)

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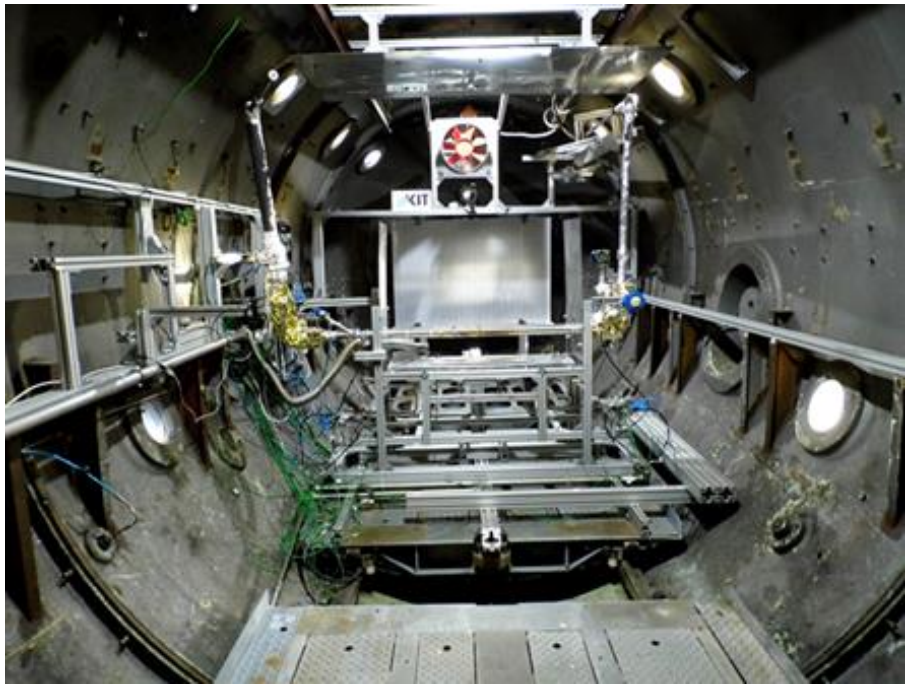
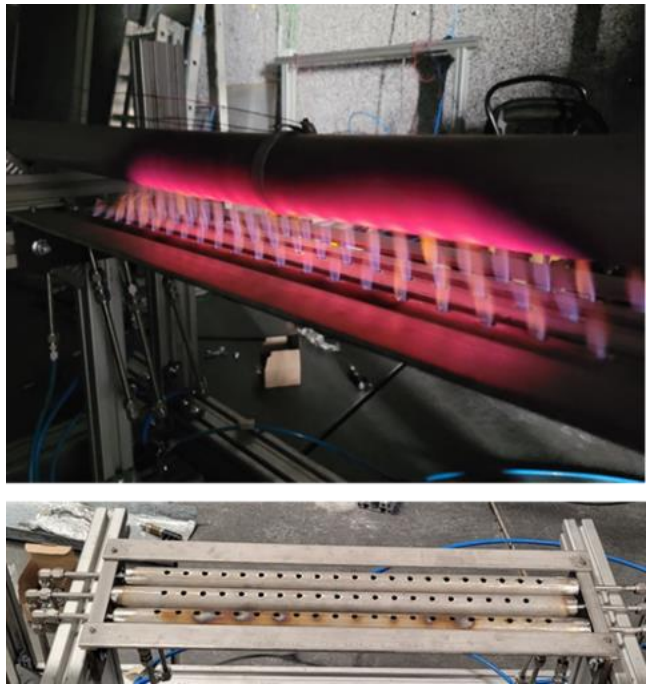
ELVHYS – Experimental activities (5/6)

Nr.	Phenomenon investigated	WP	Location	Performed by
5	Fire tests of short LH2 transfer line elements	4	Karlsruhe (Germany)	KIT



Inside HYKA H110 safety vessel A1 at KIT



ELVHYS experimental setup (images courtesy of KIT)

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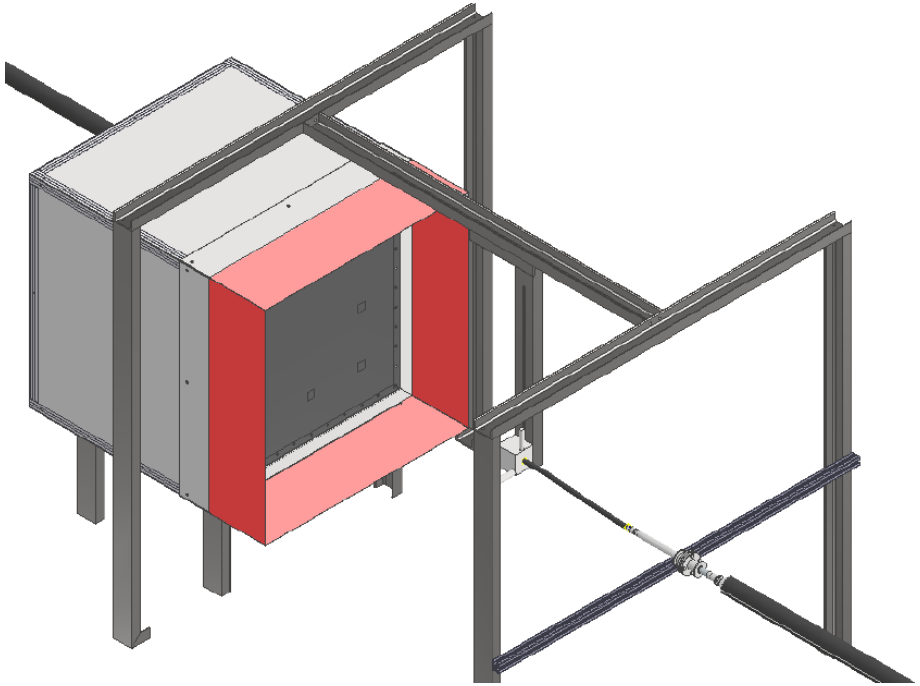
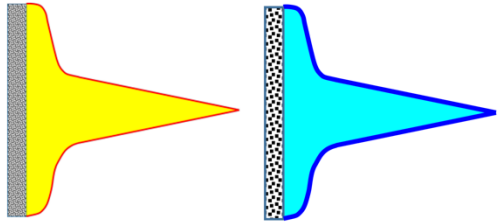
ELVHYS – Experimental activities (6/6)

Nr.	Phenomenon investigated	WP	Location	Performed by
6	Material testing against unignited and ignited LH2 jets	4	Karlsruhe (Germany)	KIT





Animation of ignited and unignited LH2 jets

Free field test site of ITES-KIT (campus south) with installed experimental rig for impingement and its 3D model (images courtesy of KIT)

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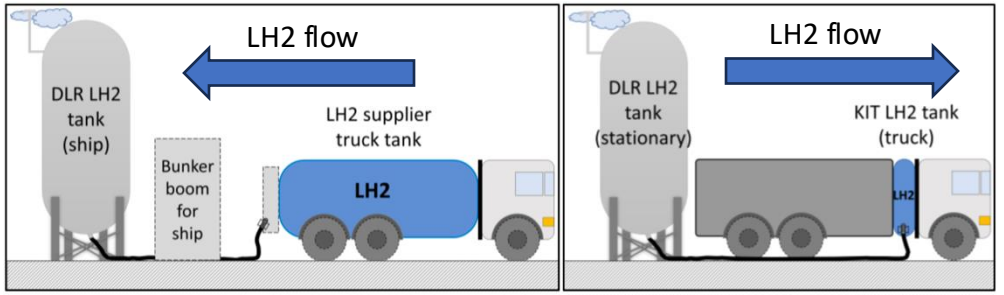
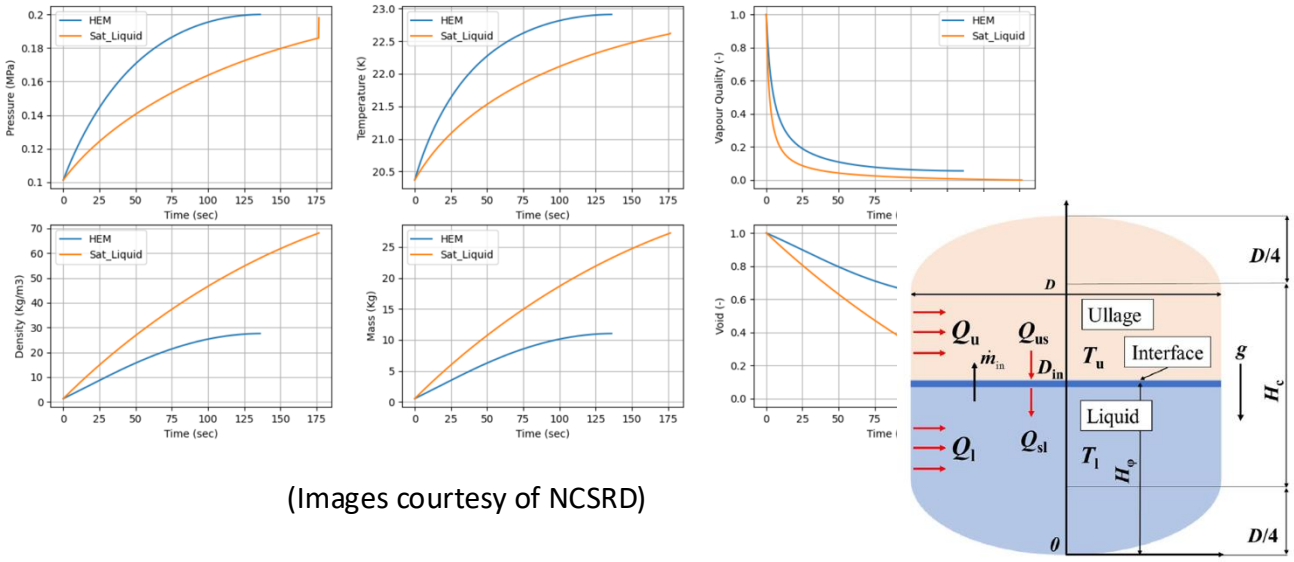
ELVHYS – Modelling activities (1/2)

Cryogenic hydrogen transfer facilities performance

- NCSR “Demokritos” partner is leading this activity.
- Modelling is carried out in parallel with the tests to first support the experiments and then validate the models.
- NCSRD aims to further develop DISCHA engineering tool previously developed to simulate LH2 releases.
- KIT and NTNU are also involved in the modelling activity of LH2 transfer operations.





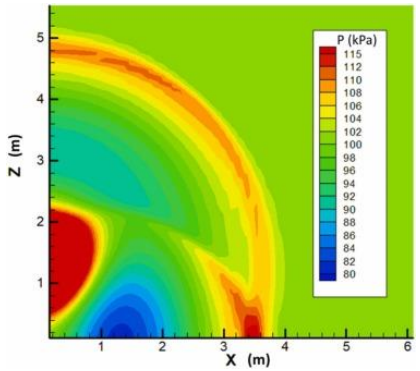
(Images courtesy of NCSRD)

(Wang H.R. et al., 2022)

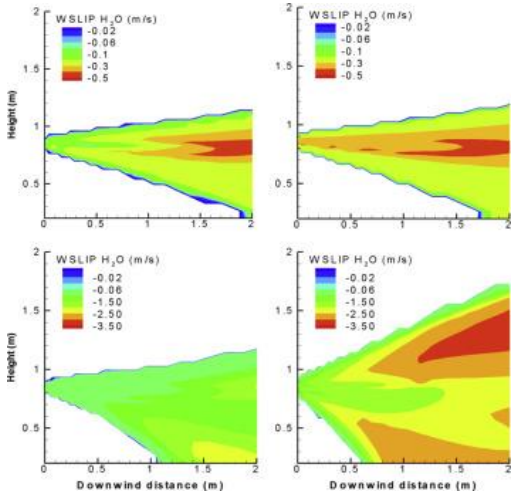
ELVHYS – Modelling activities (2/2)

Fires and explosions from cryogenic hydrogen transfer facilities

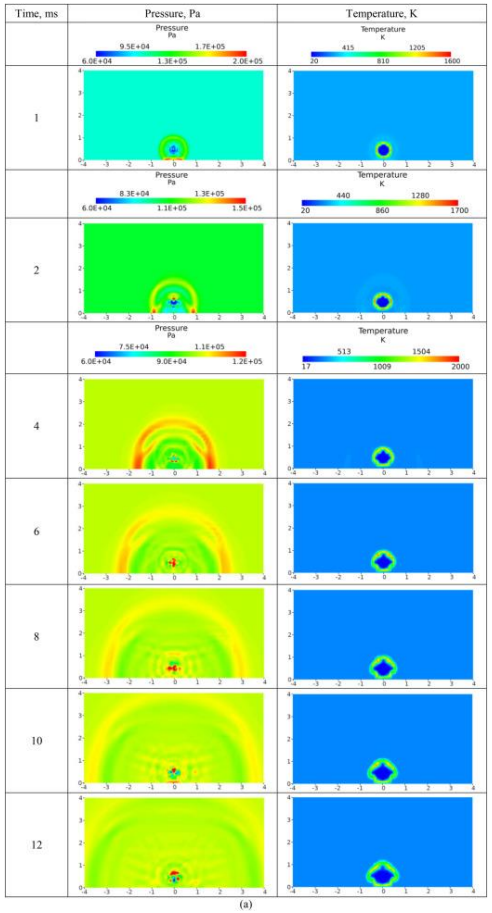
- NCSRD partner is leading.
- Partners involved in modelling of WP4 physical phenomena: HSE, KIT, NTNU, UNIBO, UU.
- Physical phenomena that will be modelled are:
    1. BLEVE
    2. Unignited and ignited LH2 releases
    3. Fire resistance of LH2 components
    4. Jet fires
    5. Pressure Peaking Phenomenon (PPP)



(Ustolin et al., 2021)



(Giannissi and Venetsanos, 2018)

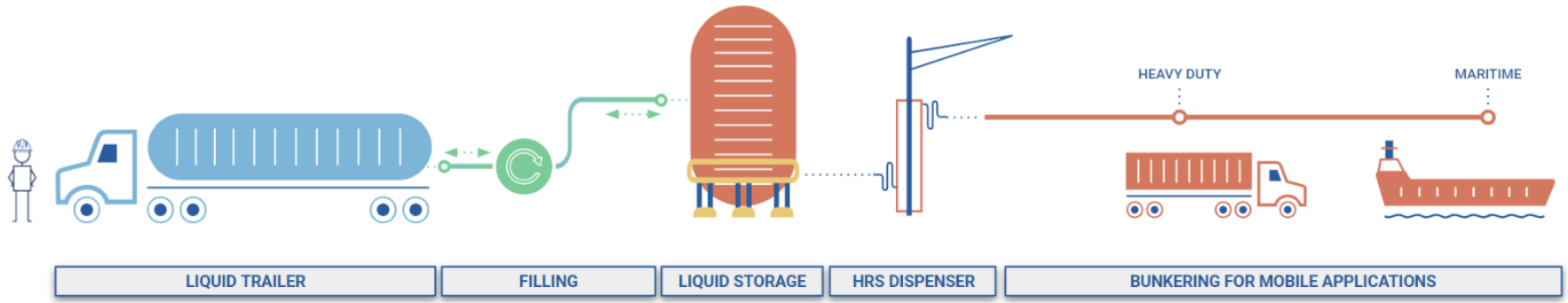


(Cirrone et al., 2023)

ELVHYS – Risk Analysis

Risk Analysis for selected cryogenic hydrogen transferring operations (WP5)

- NCSRD partner is leading this activity supported by AL, DLR, KIT, NTNU, UNIBO, UU. The tasks of this risk analysis are:
  - **Task 5.1** – Hazard identification and damage state estimation
  - **Task 5.2** – Consequence assessment
  - **Task 5.3** – Frequency assessment and risk integration
  - **Task 5.4** – Innovative safety strategies and engineering solutions



(Image courtesy of Air Liquide)

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Thank you for your attention

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