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Deliverable 2.7

Operational training materials for HyResponder

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Summary

The unique operational training facility in hydrogen safety previously built at ENSOSP must be upgraded to enable new training practices due to the risks of Liquid hydrogen (LH2) and Liquid Nitrogen (LNG).

The state of the art in hydrogen safety provides some information to improve the training for responders, including written materials and consolidation of relevant engineering tools.

HyResponder will capitalize on the previous investment in the unique facility, using it to train trainers and identifying how its use can be maximised beyond the project.

Keywords

LH2, Cryogenic, LNG, New tool, Upgrade, Virtual reality

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Introduction

The HyResponder project will use practical approaches to achieve educational goals. There is a threefold training approach in HyResponder: educational, operational and virtual reality. The operational training, is carried out on the unique operational installations (European Hydrogen Safety Training Platform: EHSTP) of the ENSOSP site. This training is complemented by training using virtual reality software and virtual tactical rooms.

Within HyResponder, previously developed training materials will be developed and extended to train the trainers of responders. Thus, the existing ENSOSP platform must be upgraded to achieve this objective and to integrate the LH2 educational tool. It is planned to set up a comparative tool based on the reproduction of LH2 and LNG leaks.

Every effort will be made to replicate a realistic scenario for responders and/or demonstrate the core principles, whilst working within the constraints of what is feasible and indeed available with new technologies associated with LH2.

The operational training platform

Location

The EHSTP is located at the ENSOSP, 1070 rue du lieutenant Parayre 13798 Aix en Provence – France.

GPS Coordinates: 43.507590, 5.359310

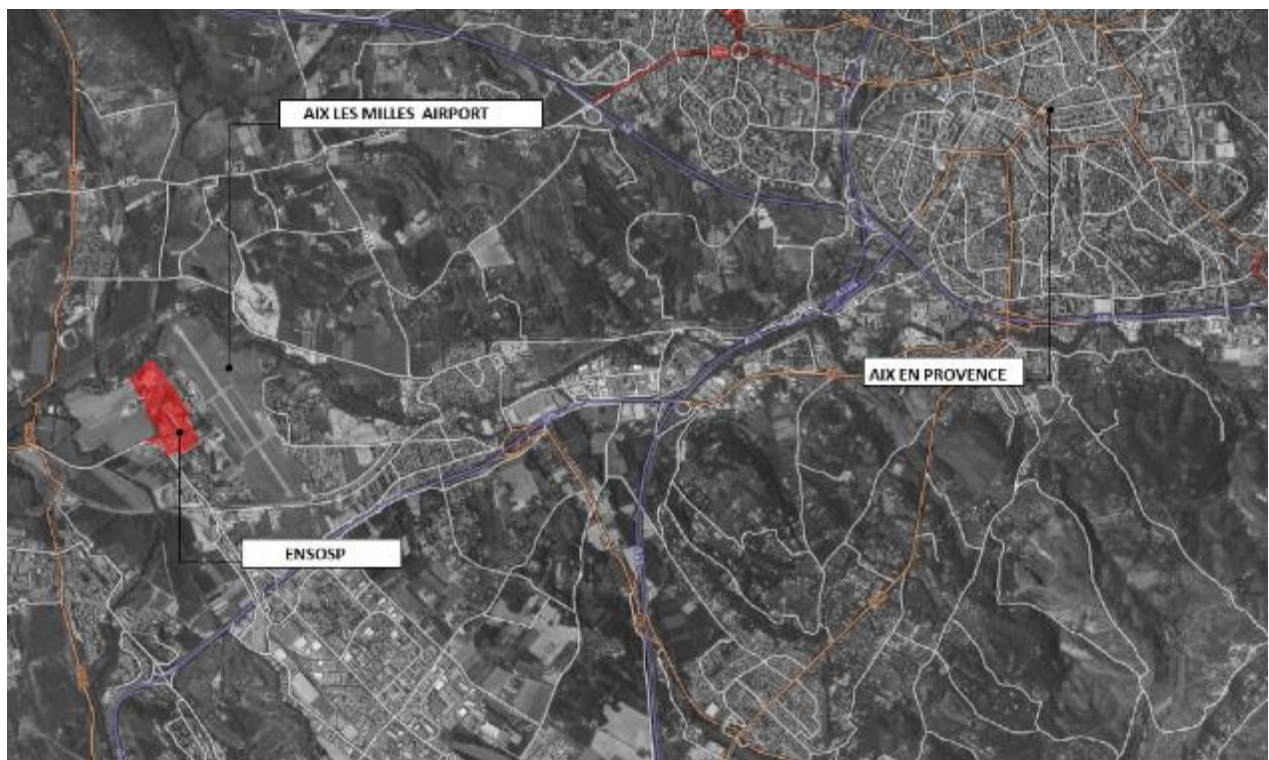


Figure 1 location satellite view

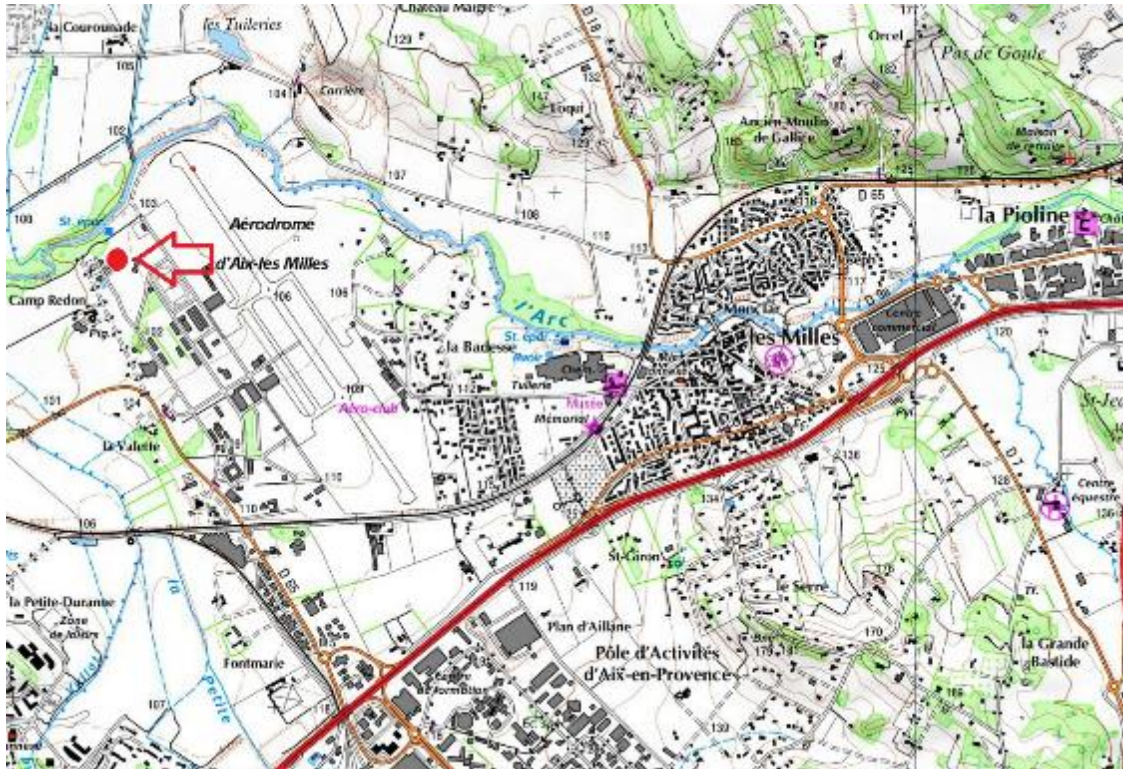


Figure 2 location map view

Description

The EHSTP which is 2500m² wide is built on an area of 6000 m². It is divided into 10 operational exercises which can be combined in several scenarios.

Leak zone:

1A: Gaseous H₂

1B: Gaseous Methane

1C: LPG

Explosion zone:

2: variable concentration explosion mock barrel (H₂, Methane)

Dismantled trailer:

3: Dismantled long cigars mock trailer (H₂)

FCH Car:

4: FCH car fire (roof and bottom TPRD)
LPG)

Multi-energy car (hybrid):

5: variable release modes (H₂, Methane,

Reffuelling station:

6: H₂ leak

On wheels trailer:

7: H₂, methane Leak

FUEL Cell container:

8: H₂, methane Leak, technical failure

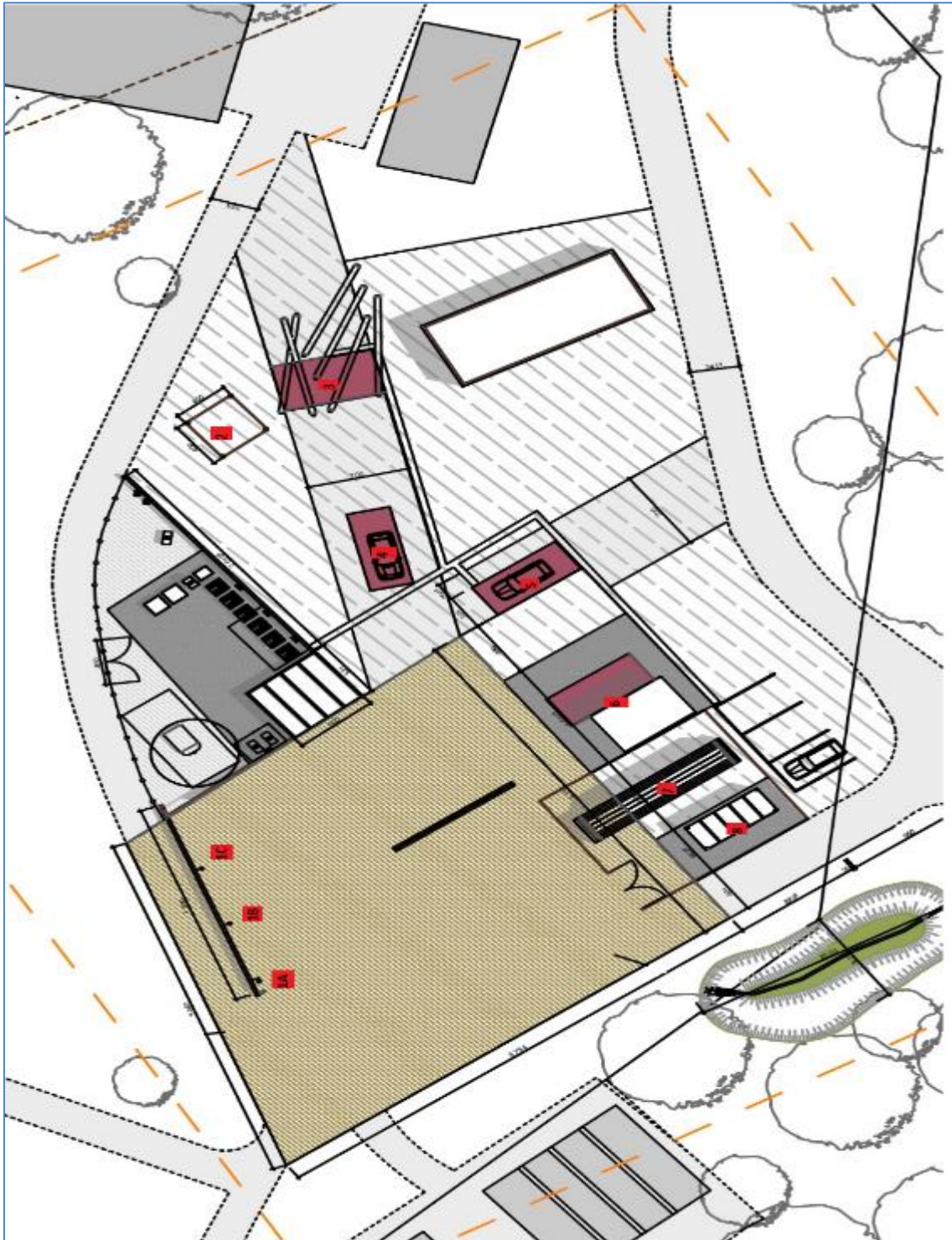


Figure 3 EHSTP

New Tool to compare LH2 and LNG phenomena

A scenario is primarily defined by reviewing the existing training offering and making minor updates to the current platform and expanding the operational platform to incorporate LH2 activity based on the scenarios identified in WP1.

Accident scenarios specific to LH2

The different scenarios identified are:

- Liquid spreading
- Cryogenic cloud
- Liquid storage in fire
- Road accident and overturning of a liquid hydrogen trailer
- Release on a connection between the liquid hydrogen trailer and the storage
- Ignited release

⇒ How to intervene, what equipment, how to communicate, with whom to communicate?
For a safe, appropriate and effective intervention?

Educational objectives of the new tool

So what do we want to feel by the simulation to prepare the responder for the LH2 risk?

- Liquid spreading: ***what kind of behavior, from liquid to vapor, cold embrittlement of equipment, cold burn***
- Cryogenic cloud: ***limited visibility for intervention, anoxia risk, safety features frozen, containment of the cloud***
- Release: ***leak detection means***
- Deflagration due to flammable cloud ignition: ***feel overpressure/energy***
- Ignited high pressurized release: ***flame length, radiative heat fluxes, invisible flame***
- ***Difference between immediate and delayed ignition***
- More generally: ***what are the safety features on LH₂ applications – for what – where***

In fact, the new tool must reach 2 principal goals:

- Enable creation of a cryogenic cloud,
- Activate ignition just on the leak or remote ignition.

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Many solutions exist:

	Option 1 LH ₂	Option 2 Subcooled H ₂	Option 3 H ₂ + Cryo-N ₂ (LIN)
Description	LH ₂ released	Gaseous H ₂ cooled and released + probably Cryo N ₂	H ₂ released for ignited scenarios LIN released for liquid spreading and cryogenic cloud
Requirements	LH ₂ tank required	Heat exchanger for cooling H ₂ LIN	LIN
Advantages	« Real » conditions	No LH ₂ Gaseous H ₂ already on-site LIN easy to provide No increase of H ₂ amount on-site (permitting aspects)	All is already available at ENSOSP No LH ₂ Gaseous H ₂ already on-site LIN easy to provide Easy to perform a non-scheduled demonstration No increase of H ₂ amount on-site (permitting aspects)
Drawbacks	Manage LH ₂ handling Cost of the LH ₂ tank Timing for LH ₂ tank receipt LH ₂ cost LH ₂ supply (Mouthon, ENSOSP, on-site liquefier...) Timing to perform a non-scheduled demonstration if required Additional safety features required Permitting document due to LH ₂ and associated additional H ₂ amount	Manage heat exchanger Heat exchanger cost	- Tbd...

Figure 4 – Different options

*

Main equipment

Product	Provider	Use	Quantity
Ranger Euro-Cyl 600 L	Chart (via Cryopal) (delivery: 9 weeks)	Storage and pressurized LIN jet	2
Solenoid valve	tbd	Generate automatically and remotely pressurized LIN jet	1
Cryogenic equipment (flexible, O ₂ detector, cryo-gloves)	Cryopal	Safety	1
Cryogenic vessel Arpege 70 L	Cryopal	Auxiliary storage for pool spillage	1
Reverser	Schweyer (info@schweyer.fr)	Spill automatically and remotely LIN for pool	1
Inox retention pit	tbd	Contain the LIN pool	1
LIN filling	Air Liquide		450 L

Safety equipment

Equipment & procedure module, handling the appropriate equipment, feel the thresholds of devices

- Individual protection clothing + individual detectors (O₂ for anoxia, multi-gas explosimeter)
- Intervene and act: leak hunting on H₂ dispenser with several devices (e.g. acoustic detection, thermal IR camera...)
- Pedagogic materials: virtual visit of a LH₂ refuelling station (video(s)), library of safety features – real or virtual, library of detection devices – real or virtual

Auxiliary equipment

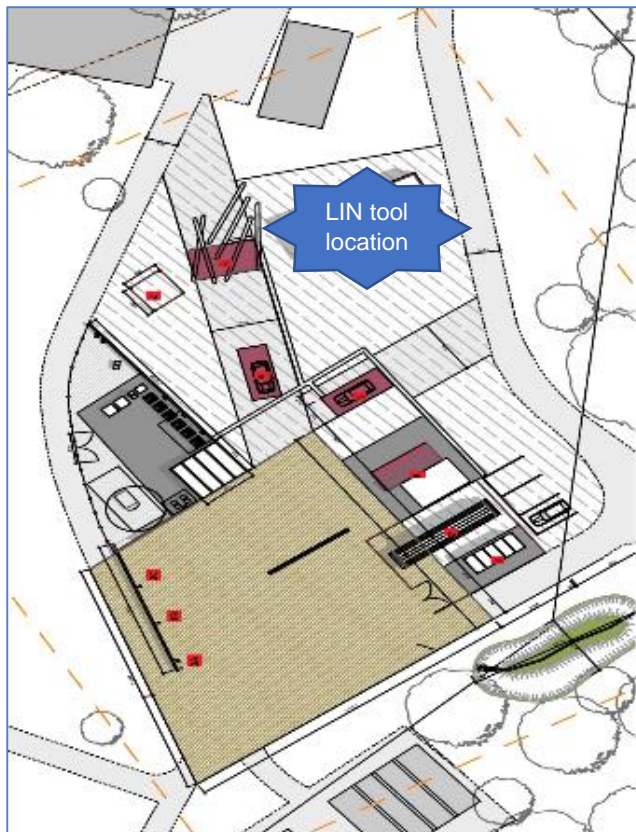
- Leak detection devices for « Safety equipment & procedure » module
- Igniter for flange leak ignition for « Ignition, flame & deflagration » module
- Subcontract for operational platform PID drafting

Proposal

The third option [Gaseous H_2 + Liquid Nitrogen] is favored for the following reasons:

- ∴ Safer
- ∴ Easier to handling
- ∴ More flexible
- ∴ Less expensive
- ∴ More realistic in terms of set-up taking into account the schedule requirement

Potentially additional media to complete the platform... to be defined regarding objectives and requirements of the training, and the remaining budget (2 locations available)



Cryogenic module:

- Vaporization & dispersion of a cryogenic liquid
- Behavior of the cryogenic cloud
- Containment of the cloud in order to protect targeted areas, taking into account weather conditions

Simulation with liquid nitrogen:

- LH2 pool dispersion
- LH2 jet release and dispersion



Figure 5 New tool location

This solution can be supplemented by virtual reality in the event of a scenario that cannot be simulated in reality.

December 2021 update

On 2021, December 16th, equipment has been purchased and implemented on the platform.

In details, this new tool is composed by:

- 2 cryogenic tanks
 - o Simulation of a liquid hydrogen leak with liquid nitrogen
- 1 thermal camera
 - o Necessary to see the level of liquid in the tank and also useful for observing hydrogen flames on other simulators
- 4 infrared thermometers
 - o Necessary to see the temperature of liquid and gas and also useful for observing hydrogen flames on others simulators
 - o 4 thermometers allow up to 8 observers
- 2 oxygen detectors
 - o Safety of the trainers and the trainees
- 4 pairs of cryogenic gloves, 2 cryogenic aprons, 2 pairs of cryogenic overboots
 - o Safety of the trainers
- Gate, path to the platform and concrete slab to move the tanks to a safe area



Figure 6 The two LIN tanks simulating a liquid hydrogen leak



Figure 7 Zoom in on one of the LIN tanks

Conclusion

The technical choice for a new tool must reproduce the LH2 and LNG phenomena in the platform. The 3rd option with H2 and LIN allows a library of safety features to train the trainers. If a situation cannot be simulated, virtual reality (CRISE module) will allow these simulations to be completed. Details of the new unique facility at ENSOSP are given.