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TABLE OF CONTENTS

Introduction

HyResponse project pilot sessions will use two practical approaches to reach the educational goals. One is operational, and realized on the operational facilities (European Hydrogen Safety Training Platform (EHSTP)) which are under construction on the ENSOSP site, and the other use is virtual using virtual reality software and virtual tactical rooms..

Task 5.2 of Work Package aims to elaborate elaboration the virtual training exercises based on the work performed in WP2.

Part 1 and 2 are based on "CRISE vitual training systems, simulation and services" developments (MARANNE, 2015).

Flowcharts are provided by AREVA

1 Pedagogic scope and concepts

1.1 Andragogy principles

During the development of the HyResponse educational materials and VR exercises the pedagogic concepts of andragogy, i.e. the adult learning theory, have been taken into consideration . (Knowles, 1984). The andragogy focuses on a self-directed learner. It requires less didactic and more hands-on approaches with real-life applications and is based on previous and acquired experience. According to Malcolm Knowles there are four principles applicable to adult-centred learning:

> *1. Adults need to be involved in the planning and evaluation of their instruction.*
>
> *2. Experience (including mistakes) provides the basis for learning activities.*
>
> *3. Adults are most interested in learning subjects that have immediate relevance to their job or personal life.*
>
> *4. Adult learning is problem-centered rather than content-oriented* .

Besides, an adult learner brings into the continuing educational arena a rich array of experiences that will affect the learning styles and assimilation of knowledge. All these principles are highly relevant to the education, experience acquisition and dissemination activities of the HyResponse project.

An attainment of the first principle is an organisational matter, and the implementation of the HyResponse training sessions will require an active participation of trainees in the evaluation of all the educational materials produced in order to improve them (Verbecke et al., 9-11 september 2013). It is expected that the HyResponse audience will understand why the programme is important to their learning and life situations. The trainees will be able to apply the knowledge they gain during the training to their own job situations and professional life, thus leading to an accomplishment of the third andragogy principle. The addressing of the above mentioned points no. 2 and 4 are the essence of this paper in particular, and are the cornerstones in the development of high quality hydrogen safety training for first responders in general.

Hydrogen risk is a technological risk; hence it calls for a deep understanding of the main safety principles and features of FCH systems and infrastructure. Adult learners need to be convinced, and the technological elements should be explained in detail at the audience cognitive level.

As per Knowles, training objectives should be '**SMART'**:

- **S**pecific: clear and easy to understand
- **M**easurable: able to be quantified
- **A**chievable: able to be attained
- **R**ealistic: true to life
- **T**ask oriented

Within the scope of the HyResponse project these objective should consider:

- An evaluation of a first response agency's current state of emergency readiness to deal with hydrogen specific behaviors during incidents/accidents.
- Knowledge gaps, weaknesses, or areas of concern that might affect the agency's performance.
- A level of first responders' knowledge and understanding of hydrogen emergency preparedness roles and responsibilities.
- An applicability of current preparedness to emerging hydrogen safety problems.

With this in mind, the main objectives of the educational segment of the HyResponse programme are as follows:

- to provide first responders with the awareness and understanding of the specificities of hydrogen during its production, transportation, delivery and uses;
- to familiarise first responders with the operational principles and safety aspects of a range of FCH applications including FC vehicles, refuelling stations, back-up power generation and stationary FC systems for combined production of heat and power;
- to develop a critical evaluation of the safety issues associated with hydrogen physical and combustion properties;
- to achieve a systematic understanding of why the safety of hydrogen differs from that of conventional fuels;
- to provide first responders with the knowledge of potential hazards, relevant safety concepts and safety features for targeted FCH systems and infrastructure;
- to ensure that first responders are aware of typical risk scenarios for FCH systems and infrastructure;
- to instruct first responders on the correct intervention strategy and tactics on how to handle potential consequences of incidents/accidents at FCH systems and infrastructure;
- to develop in first responders an ability to deal in real life situations with hazardous phenomena involving accidental hydrogen release, hydrogen fires and explosions by applying the principles of hydrogen safety engineering;
- to provide first responders with the analysis of hydrogen safety approaches and requirements defined in RCS, related to FCH systems and relevant to the appropriate actions to be taken by first responders;
- to provide first responders with a clear picture of the safety requirements prescribed in RCS with respect to mitigation measures; assessment of the incident/accident scenes; safety strategies for the operation of first responders at the scene of an accident.

Although the lectures are very important to overcome biases and preconceptions, there is a need for adults to have a real, hands-on experience. This is achieved through a physical simulation platform available at ENSOSP premises. While the initial training sessions will definitely need this physical set-up, a widespread use of FCH technologies in the coming years will lead to the basic technical knowledge and acquired experience of the public.

The second andragogy principle implies that the training should be more *task-oriented* as opposed to simple memorization of facts, i.e. the learning/teaching activities should be in the context of the common tasks to be performed by first responders. To address this need, we will demonstrate in the following sections how the VR aligned to the lectures content can be used to achieve the task-

orientation, and how the VR will be used to provide experience acquisition through *problem-solving* approaches. Different types of problem-centred exercises will be described. Their purpose is to overcome inhibitions; to provide individual and shared experiences; and to take into account the wide range of learners' backgrounds, the diversity of institutions and cultures (nations), and allow for different levels/types of previous learning and professional experience. There are some challenges the tutors faced during the design and development of educational content of the EHSTP. In a short term (during face-to-face training sessions) the learners will represent the knowledgeable and motivated group of first responders (so-called 'elite), while in the long run the distant learning transmitted via online training course will target the general public. Therefore, it is very important to tailor the teaching materials as to meet the diverse demands and expectations of the HyResponse audience.

The VR technology gives an ample opportunity to address several expectations of the andragogy theory:

- explanation and explicitness: the production of real-life foreseen problematic of hydrogen wide use enables to picture and explicitly expose why specific protocols, functions, operations, etc. are needed;
- task-orientation and interaction: the VR is the perfect tool for this;
- relevance and real/personal life relation will have to be designed through the choice of environments, operational problem, and scenarios;
- the low cost of VR scenarios creation enables to provide a rich set of situations fitting first responders diverse experience as extensively as possible;
- the VR can accommodate the training schemes ranging from a single user to full size multi-agency set-ups providing many inhibition avoidance strategies, and gives a fresh approach to learning that may overcome existing beliefs or reluctance.

1.2 Training articulation

The HyResponse training utilises a blended learning approach. The trainees will attend a typical 'bricks-and-mortar' school-type structured sessions, where instructor-led lectures are combined with the VR exercises and supported with the hands-on operational training activities. The developed educational materials in their final versions will be made available to the public through the HyResponse website, thus allowing the trainees to control the time, place, route, or pace of their post-classroom studies. In addition, the interactive online training course will include videos of demonstrations and experiments, photos, links to other website and other sources of information, etc.

2 Virtual Reality Exercises

2.1 definitions

An exercise is the generic term for a range of activities that test emergency response readiness, evaluate an emergency response plan, and assess the success of training and development programmes. Typical purposes of the VR exercises are:

- to validate emergency plans as well as the curriculum effectiveness during and after pilot training sessions - **validation;**
- to develop first responders competencies and to give them practice in carrying out their roles, new doctrinal approaches, standard operating procedure (SOPs), and rules of engagement (ROEs) - **training;**
- to develop an understanding of organizational roles as well as hydrogen specific risks, inter-relationships and inter-dependencies - **learning;**
- to test the established procedures – **testing.**

There are five basic categories of VR exercises:

- orientation exercises,
- tabletop exercises (TTXs),
- drills,
- functional exercises (FEs),
- full-scale exercises (FSEs).

The first two categories of exercises are primarily discussion-based, whereas the other three are action-oriented. It should be noted that these categories and purposes of exercises are overlapping and inter-related, depending on the type of the audience to be trained. Thus, it is also necessary to define who will participate in the exercises. As for HyResponse project, first responders can be pictured as those who first arrive to a scene of an accident with a decision task: fire-fighters, police forces, medics, industrial experts, etc. Another feature of the targeted audience is that in the coming years we are likely to train seasoned professionals, already in the field, with a strong operational background and risk mitigation experience. The number of participants, both as trainees or trainers, would also impact on the aim, objectives of the VR exercise.

2.2 Orientation Exercises

These types of exercises are to be carried out during the lectures, workshops, and seminars. The purposes of an orientation exercise are to:

- familiarize novices with risks, emergency ROEs, SOPs;
- familiarize experienced first responders with new or changing information/procedures.

An orientation exercise is organized under a variety of circumstances, including the initiation of a new plan, procedure, or mutual aid agreement, or in the event of new staffing, leadership, facilities, or risk(s).The focus here is usually on a single function with the roles and responsibilities of participants clearly identified.

For the orientation exercises, a constructive and explicit problem exposure is usually coordinated by a single instructor in a face-to-face mode as an individual task or as a homogeneous participants group situation. The orientation exercises are designed to guide a learner towards a problem. This should involve a clear explanation why it is necessary to teach hydrogen safety, and should direct towards the different contents of the proposed training. Ultimately, we wish the public to be self-directing to the HyResponse lectures, so we need to provide the proper orientation. Both the physical and virtual simulators will be used to expose, illustrate, anchor and enforce the lectures contents. It should be noted that the virtual simulation tool will make it easier for trainees to catch up with new technologies, products, information and procedure changes, as well as to discuss a potential impact of FCH technology or regulations evolution.

The examples of orientation exercises will include:

- dissemination materials on the website (pictures and VR presentations);
- workshops or seminars presentation material gathering;
- an animation of constructive and explicit problem exposure and solving (usually performed by a single instructor in a face-to-face mode to a homogeneous participants group (e.g. films, VR presentations, etc.)

2.3 Tabletop Exercises

A tabletop exercise (TTX) is a low-stress event aimed to trigger a discussion of a simulated situation. TTX participants are encouraged to discuss issues in detail and to make decisions using slow-paced problem-solving methods driven by the instructor as opposed to the spontaneous, fast-paced ones typical for the actual or simulated emergency conditions. TTXs are introduced at early stages, in parallel to functional and full-scale exercises. A constructive problem-solving is the goal of such exercises. A copy of the appropriate emergency plan and other pertinent materials are available for the reference during a TTX. A person is assigned to act as a recorder documenting actions taken by participant during a TTX; these notations serve as a reference tool for evaluating the exercises. TTXs are designed to involve the participants in understanding the problem and the protocols/functions/operations he/she has to deal with. It enables to explicitly understand how these protocols are fitting in their everyday life and organisation. A TTX may involve multi-agencies as it enables to understand each other's limitations, expectations, needs and capabilities, forces and weaknesses.

A TTX begins with a briefing by the facilitator as to orient both the participants and simulators to the TTX objectives, ground rules, and communication and simulation procedures. The scenario narrative is then presented in an intelligence briefing. The scenario is generally invented and describes an event or emergency incident bringing participants up to a simulated 'present moment' in time. From there, a virtual simulator is used to provide realistic materials and visions suitable to describe the subsequent interactive pacing of events decisions and effects. A TTX should not be perceived as 'real time': some events may be accelerated if not conveying an interest for the discussion, others may be slowed down in order to expose inner mechanisms, or to simply provide enough time for discussion. The constructive and interactive problem-solving is usually performed by a single instructor, who teaches a group of heterogeneous participants.
In the frame of the first HyResponse workshop that took place at ENSOSP on the 3-4 September 2014, a simple presentation set-up has been provided as a TTX where the workshop participants played roles of hydrogen 'experts'. The set-up was designed around three virtual access points:

- The first responders team, which had access to the VR from their own point of view, performing proactive information gathering, making sense of the events and mitigating risk under tactical control.
- Tactical control was performed collaboratively and explicitly by the assembly of workshop attendees (TTX set-up) in a different room. They were provided with a projected view issued from a virtual camera (CCTV) located nearby the incident.
- Finally, a virtual helicopter was available for the attendees, ready to fly, with a real pilot at disposal.

Two scenarios were considered during the workshop: 1. A multiple car crash on a motorway involving a FC vehicle (Symbian equipped Kangoo) and 2. An overturned trailer currying liquefied

hydrogen positioned near the shopping mall. The conditions and environments of both scenarios are shown on Figures 2 and 3.

Figure 1 A screenshot of the VR exercise involving multiple cars crash on a motorway

Figure 2 A screenshot of the VR exercise involving the overturned trailer with liquefied hydrogen

More detailed report of the VR exercises can be found on the workshop web-page: http://www.hyresponse.eu/workshop.php

2.4 Drills

The main purpose of a drill is to use a repetition to instruct first responders thoroughly. Drills can be used to test and optimise personnel training, response time, inter-agency cooperation and resources, workforce and equipment capabilities. Another purpose of the drills is to put trainees in very different operational environments implying a danger area assessment in a wide variety of situations. For each FCH application (automotive, storage, distribution, production, etc.), the drills allow to test and improve a threat evaluation through a number of slightly different exercises (for example, automotive FCH systems: on the road, in open/underground car parks, in private garages, in a tunnel, in a city centre, etc). This enables to avoid 'task fixation blindness' by practicing situational awareness of an incident scene including personnel, teams, environments, resources and broad picture. Drills ought to induce the importance of situational awareness, personal safety, and personal accountability at the incident scene.

The drills optimally take place after the orientation exercises. First responders should have an understanding of an agency functions that will be tested during the drills and should be given an opportunity to ask questions. Operational procedures and safety precautions are reviewed before the drill begins. Drill categories include but are not limited to reaction, notification, communication, command post, and evacuation. In most cases, a general briefing by the drill designer sets the scene and reviews the drill's purpose and objectives. A drill is usually focused on a segmented functional part of a protocol such as 'immediate response' or 'operative answer'. The VR is used to provide shared operational exposure and understanding; to expose interactive pacing of decisions, actions and effects; and to sustain the drill action with spontaneous or planned events. Physical platform will be used to perform several drills, but the VR will offer a much broader variety of incidents scenes and rehearsal capabilities.

2.5 Functional Exercises

The purpose of a functional exercise (FE) is to test and evaluate the capabilities of an emergency response system or its parts, inter-agency cooperation and resources. The events and situations that would actually occur over an extended period of time are depicted or described. These events and situations are exposed explicitly using the VR or described orally or in writing. Unlike the drills, an FE encompasses more complete system by mixing functional and commandment levels of first responders.

In the context of the HyResponse, the inter-agency level will have to be tested and evaluated as well as coordination and cooperation at the first responders: police forces, medics, fire fighters, industry experts, etc. The VR is used in much the same way as in drills but the scenarios are different and longer enabling to encompass a function and, commandment-wide, systemic response. An example of FE set-up is given on Figure 4. In this set-up, many trainees are concurrently managing an emergency response. Those trainees may include fire-fighters, medics, or other kind of first responders (e.g. multi-agency), or a full hierarchical deployment of first responders up to an incident commander including media and other institutions. ENSOSP provides a virtual training facility that may encompass very complex set-ups such as multi-agency, joined forces operations involving multiple commandment levels, from field operators up to high level commandment.

2.6 Full-Scale Exercises

The purpose of a full-scale exercise (FSE) is to test and evaluate a major portion of the emergency operation plan in an interactive manner over an extended time period. The FSEs typically involve more than one agency. Similar to an FE, the objectives of an FSE must be specified, and the actual exercise begins with a simulated event that prompts the initiation of the plan. The FSE includes all of the activities taking place at the emergency operations centre (EOC) as well as on-scene use of simulated victims, equipment, and workforce. The activities at the scene serve as an input and require coordination with the EOC. An FSE combines planned and spontaneous messages characteristic for FEs with actions from the field. The goal here is to validate inter-agency cooperation and coordination. The use of the VR is much the same here as in FE exercises. The difference is that other agencies participants' experience, cognitive representation of the events, organisation and response are to be taken into account to build a shared representation of the operational context. The diversity of incident scenarios proposed by the VR framework will enable to run multiple FSEs at a low cost.

2.7 Distant learning capabalities

The developed VR assets can be re-used to compose any scene and to create any scenario. The VR tool is also used to provide technical, operational and illustrative materials, e.g. in the lectures to depict different types of storages, fuel cell buses, fuel cell vehicles, a refuelling station, an area with a fuel cell forklift, a small house with a fuel cell vehicle in garage, etc. The designed VR environment and assets will be used not only for the exercises. They will be integrated as a demonstration for the online course which is at the moment composed of:

- a short introduction illustrated with a picture gallery from the environment;
- a quiz on reflective actions in front of small scenes presented as screenshots;
- a dynamic 3D representation of a leak from a trailer and fire-fighters in action, exported from the VR training tool as 'pure HTML' not necessitating any software download or install on the client machine;
- a short film exported from the VR training tool exposing for example an attack lead on a trailer leak.

The online training course is the work-in-progress and its piloted version has been compiled as a demonstration (http://share.vr-vrisis.com/HyResponse/PresentationMilanoHTML/index.html), as a stand-alone epub e-book, readable on any computer or e-book reader (such as Kindle).

3 Choice of VR exercise categories for the pilot sessions

3.1 session program

VR training will be used in variable ways during the pilot training sessions . In the following program, sequences using VR are used in :

- Pre Session Online phase
- “Strategies and intervention” VR sequences
- Virtual Reality Training sequences
- Physical simulator for hands on exercising

	Monday		Tuesday	
08h00-08h30	**Welcome**		**CyberLaboratory** STM	
8h30 9h15	**Educational training.** **Lecture1.** Introduction to hydrogen and FC applications. Lecturers: STM, AZ, FV, SB		**Educational training.** **Lecture 3.** Safety of compressed hydrogen storage. Lecturers: STM, VM	
9h15 10h00	**Educational training.** **Lecture 2.** Hydrogen properties relevant to safety. Lecturers: STM, VM		**Strategies and intervention** Methodology and response guide Instructors: SB	
	Break 30 min		Break 30 min	
10h30 11h15	**Educational training.** **Lecture 4.** Hydrogen fires. Lecturers: STM,VM		**Strategies and intervention - class exercises.** **FC vehicles accident s(car, bus, forklift)** - application description - Safety features and related RCS -Typical scenarii - Intervention Strategy and tactics Instructors: AZ, FV, STM, SB	
11h15 12h00	**Educational training.**			
	Break 2 h		Break 2 h	
14h00 14h45	**VR Platform Presentation** Using virtual reality safety procedure, etc. Animator: EM Instructors: FV, FL, SB		**Operational Training** Exercise: Single FC car accident - FC car in fire - no extrication - small road (FC_Car_D_F2) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: FC bus in a fire on a small road (FC_Bus_D_F1) Animator: EM Instructors: 2 officers advisors
	Outfit change (fire suits)		Break 15 min	Break 15 min
15h00 15h45	**Operational Platform demonstration** Instructors: SB, FV, AZ Jet fires, delayed ignition, Gazous sensors efficiency for H2,CNG,LPG		**Operational Training** Exercise: Multi vehicle accident - FC car in a fire - no extrication - motorway (FC_Car_A_F 2) 3Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: Forklift in a fire inside a warehouse. (FC_Forklift_A_F1) Animator: EM Instructors: 2 officers 2 advisors
	Operational Platform exercices H2 jet fires 3Instructors ENSOSP: exercise director safety officier field officer +advisors	**Explosion demonstrations** 2 Instructors ENSOSP: safety officier field officer +advisors (CNG and H2 explosions at various concentrations)	Break 30 min	Break 30 min
16h15 17h00			**Virtual Reality Training** Exercise: FC bus in a fire on a small road (FC_Bus_D_F1) Animator: EM Instructors: 2 officers advisors	**Operational Training** Exercise: Single FC car accident - FC car in fire - no extrication - small road (FC_Car_D_F2) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors
17h00 17h45	**Explosion demonstrations** 3Instructors ENSOSP: safety officier field officer +advisors (CNG and H2 explosions at various concentrations)	**Operational Platform exercices** H2 jet fires 2 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: Forklift in a fire inside a warehouse. (FC_Forklift_A_F1) Animator: EM Instructors: 2 officers 2 advisors	**Operational Training** Exercise: Multi vehicle accident - FC car in a fire - no extrication - motorway (FC_Car_A_F2) 3Instructors ENSOSP: exercise director safety officier field officer +advisors
17h45 18h15	**Debriefing in classroom**	**Debriefing in classroom**	**Debriefing in classroom**	**Debriefing in classroom**

Figure 3 Pilot session program (Monday-tuesday)

	Wednesday		Thursday		Friday
08h00-08h30	**CyberLaboratory** STM		**CyberLaboratory** STM		**CyberLaboratory** STM
8h30 9h15	**Educational training. Lecture 5.** Harm criteria for people and environment, damage criteria for structures. Lecturers: STM,VM		**Educational training. Lecture 7.** Hazard of hydrogen use indoors. Lecturers: STM,VM		**Educational training. Lecture 9.** Ignition sources and prevention of ignition. Lecturers: STM,VM
9h15 10h00	**Educational training. Lecture 6.** Unignited hydrogen releases and their mitigation. Lecturers: STM,VM		**Educational training. Lecture 8.** Dealing with hydrogen explosions. Lecturers: STM,VM		**Virtual Reality Training** Exercise: Multi vehicle accident - dismantled storage - H2 jet fire from H2 trailer - extrication r conventional car - hazmat trailer involved- motorway. Animator: EM Instructors: 2 officers advisors
Break 30 min					
10h30 11h15	**Strategies and intervention - class exercises.** **Refuelling stations, storage and FC system accidents.** - application description - Safety features and related RCS -Typical scenarii - Intervention Strategy and tactics Instructors: AZ, FV, STM, SB, FH		**Strategies and intervention - Class exercises.** **Stationary and mobility applications** - application description - Safety features and related RCS -Typical scenarii - Intervention Strategy and tactics Instructors: AZ, FV, STM, SB, FH		
11h15 12h00					**Synthesis of training** **all Partners**
Break 2 h					
	Advanced level	**Advanced level**	**Expert level**	**Expert level**	**Expert level**
14h00 14h45	**Operational Training** Exercise: H2 leak in a refuelling station (H2_Refuelling_A_L1) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: FC car in fire at the refuelling station (H2_Refuelling_E_E1) Animator: EM Instructors: 2 officers advisors	**Operational Training** Exercise: Multi vehicle accident - dismantled storage - H2 jet fire from H2 trailer - extrication conventional car - motorway (H2_Trailer_E_F4) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: Multi vehicle accident - FC bus in a fire - extrication conventional car - urban environment (FC_Bus_E_F2) Animator: EM Instructors: 2 officers advisors	
	Break 15 min	Break 15 min	Break 15 min	Break 15 min	
15h00 15h45	**Operational Training** Exercise: FC system default - H2 leak - urban environment (FC_System_A_L1) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: H2 storage - H2 jet fire - industrial environment (H2_Storage_E_F1) Animator: EM Instructors: 2 officers advisors	**Operational Training** Exercise: H2 storage default - H2 leak - Refuelling station - urban environment (H2_storage_E_L1) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: Fire in an industrial environment - FC system in the environment (FCSY_E_E1) Animator: EM Instructors: 2 officers advisors	
	Break 30 min	Break 30 min	Break 30 min	Break 30 min	
16h15 17h00	**Virtual Reality Training** Exercise: FC car in fire at the refuelling station (H2_Refuelling_E_E1) Animator: EM Instructors: 2 officers advisors	**Operational Training** Exercise: H2 leak in a refuelling station (H2_Refuelling_A_L1) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: Multi vehicle accident - FC bus in a fire - extrication conventional car - urban environment (FC_Bus_E_F2) Animator: EM Instructors: 2 officers advisors	**Operational Training** Exercise: Multi vehicle accident - dismantled storage - H2 jet fire from H2 trailer - extrication conventional car - motorway (H2_Trailer_E_F4) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	
17h00 17h45	**Virtual Reality Training** Exercise: H2 storage - H2 jet fire - industrial environment (H2_Storage_E_F1) Animator: EM Instructors: 2 officers advisors	**Operational Training** Exercise: FC system default - H2 leak - urban environment (FC_System_A_L1) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	**Virtual Reality Training** Exercise: Fire in an industrial environment - FC system in the environment (FC_System_E_E1) Animator: EM Instructors: 2 officers advisors	**Operational Training** Exercise: H2 storage default - H2 leak - Refuelling station - urban environment (H2_storage_E_L1) 3 Instructors ENSOSP: exercise director safety officier field officer +advisors	
17h45 18h15	**Debriefing in classroom**	**Debriefing in classroom**	**Debriefing in classroom**	**Debriefing in classroom**	

Figure 4 Pilot session program (Wednesday-Friday)

Lecture

Strategies and intervention

Operational platform

Virtual reality training

3.2 Pre Session Online phase

Before they attend the pilot sessions, the trainees must have consulted the online training. In the online training, the Illustration VR mode is used for description of simple incident situations. Then the trainees are asked to answer multiple choice questions to assess the had understood the basic knowledge to enter the session.

3.3 "Strategies and interventions" VR sequences

During these sequences students face a variety of problematic situations. They are required to understand the situation by drawing on their own past experiences. Then, swapping and discussing together, they try to choose courses of action to resolve the situation.

Instructors guide the students by injecting timely informations in the exercise course.

So, during these face to face classroom learning phases, performed in the mornings of Tuesday, Wednesday and Thursday **Illustration**, **Orientation and Tabletop** categories are used.

3.4 Virtual Reality Training sequences

During these sequences trainees face in pairs or alone to equities has lead to a specific function. Twelve of the group is divided into binomials. binomials each occupies one of the functions of the Operational situation. **Tabletop** , **Functional** exercises are used on Tuesday, Wednesday and Thursday successively at discovery, advanced level.

On Friday, a Ful scale exercise allow them them to implement the lessons learned during the week. This last course is taught in **Full Scale Mode**.

3.5 Physical simulator for hands on exercising

The VR is not disconnected from the physical simulator. **Illustration**, eventually **Orientation** and **Drill** are perfectly adapted to the initial briefing and After Action Review (discussion, assessment)

4 Multilevel training exercises

4.1 Scenarii

A scenario is mainly defined by :

- the application involved (type, size…)
- the area around the application (access, buildings, stakes…)
- the weather conditions (wind)
- the incident occurring on the application (nature, duration…)
- the presence of victim (location, number…)

So, the number of possible scenario is infinitely variable. Virtual reality can provide implementation for all imaginable scenarii. Nevertheless, 109 scenarii have been imagined to cover a wide range of situations .Those scenarii cover the whole range of listed applications and are divided in 3 levels :

- Discovery level
- Advanced level
- Expert level

For the 3 pilot sessions 6 of them have been selected (colored in red in table 1).

Table 1 Available scenarii

	FCH application	Potential danger	LEVEL	Description	related tactic
1	**FC CAR**	**NO LEAK**	**DISCOVERY**	Single FC car **accident** - **no H2 leak** - **extrictation** - simple environment	**1**
2	**FC CAR**	**LEAK**	**DISCOVERY**	FC car default - **H2 leak** - simple environment (small road)	**2**
3	**FC CAR**	**LEAK**	**DISCOVERY**	Single FC car **accident** - **H2 leak** - no **extrictation** - simple environment (small road)	**2**
4	**FC CAR**	**H2 FIRE**	**DISCOVERY**	FC car default - **FC car in a fire** - simple environment (small road)	**3**
5	**FC CAR**	**H2 FIRE**	**DISCOVERY**	Single FC car **accident** - **FC car in fire** - no **extrication** - simple environment (small road)	**3**
6	**FC BUS**	**NO LEAK**	**DISCOVERY**	Single FC bus **accident** - no leak - **extrictation** - simple environment	**1**
7	**FC BUS**	**LEAK**	**DISCOVERY**	FC bus default - **H2 leak** - simple environment (small road)	**2**
8	**FC BUS**	**LEAK**	**DISCOVERY**	Single FC bus **accident** - **H2 leak** - no **extrictation** - simple environment	**2**
9	**FC BUS**	**H2 FIRE**	**DISCOVERY**	FC bus default - FC bus in a **fire** - simple environment (small road)	**3**
10	**FC BUS**	**H2 FIRE**	**DISCOVERY**	Single FC bus **accident** - FC bus in **fire** - simple environment (small road)	**3**
11	**H2 TRAILER (bundles cylinders or long cigars)**	**NO LEAK**	**DISCOVERY**	Single hydrogen trailer **accident** - no leak from the H2 trailer - **extrictation** - simple environment	**5**
12	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**DISCOVERY**	H2 trailer default - **H2 leak** - simple environment (small road)	**6**
13	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**DISCOVERY**	Single H2 trailer **accident - storage on the trailer** - **H2 leak** - **extrictation** - simple environment	**6**
14	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**DISCOVERY**	Single H2 trailer **accident - dismantled storage (MIKADO)** - **H2 leak** - **extrictation** - simple environment	**6**
15	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**DISCOVERY**	H2 trailer default - H2 trailer in **fire** - simple environment (small road)	**7**
16	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**DISCOVERY**	H2 trailer **accident -** H2 trailer in **fire** - storage on the trailer - simple environment (small road)	**7**
17	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**DISCOVERY**	Single H2 trailer accident - dismantled storage (MIKADO) - H2 jet fire - extrictation - simple environment	**7**

	FCH application	Potential danger	LEVEL	Description	related tactic
18	**FC FORKLIFT AND INSIDE REFUELLING**	**NO LEAK**	**DISCOVERY**	Single forklift **accident** - **no H2 leak** - **extrictation** - simple environment (outside warehouse)	**1**
19	**FC FORKLIFT AND INSIDE REFUELLING**	**LEAK**	**DISCOVERY**	Forklift default/accident - **H2 leak** - simple environment (outside warehouse)	**2**
20	**FC FORKLIFT AND INSIDE REFUELLING**	**H2 FIRE**	**DISCOVERY**	Forklift default - f**orklift in a fire** - simple environment (outside warehouse)	**3**
21	**H2 STORAGE**	**NO LEAK**	**DISCOVERY**	H2 storage false alarm - simple environment (remote environment)	**13**
22	**H2 STORAGE**	**LEAK**	**DISCOVERY**	H2 storage default - **H2 leak** - simple environment (remote environment)	**14**
23	**H2 STORAGE**	**H2 FIRE**	**DISCOVERY**	H2 storage default - H2 jet fire - simple environment (remote environment)	**15**
24	**H2 STORAGE**	**EXTERNAL THREAT**	**DISCOVERY**	**Fire in a simple environment (remote environment)** - Storage in the environment	**16**
25	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**NO LEAK**	**DISCOVERY**	FC system false alarm - simple environment (remote environment)	**13**
26	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**LEAK**	**DISCOVERY**	FC system default - **H2 leak** - simple environment (remote environment)	**14**
27	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**H2 FIRE**	**DISCOVERY**	FC system default - **H2 jet fire** - simple environment (remote environment)	**15**
28	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**EXTERNAL THREAT**	**DISCOVERY**	**Fire in a simple environment (remote environment)** - FC system in the environment	**16**
29	**H2 REFUELLING STATION (without storage)**	**NO LEAK**	**DISCOVERY**	Dispenser/FC car false alarm - Refuelling station in a remote environment	**9**
30	**H2 REFUELLING STATION (without storage)**	**LEAK**	**DISCOVERY**	Dispenser/FC car default - **H2 leak** - simple environment (remote environment)	**10**
31	**H2 REFUELLING STATION (without storage)**	**H2 FIRE**	**DISCOVERY**	Dispenser default - **H2 jet fire** - simple environment (remote environment)	**11**
32	**H2 REFUELLING STATION (without storage)**	**EXTERNAL THREAT**	**DISCOVERY**	**Fire in a refuelling station (remote environment)**	**12**

	FCH application	Potential danger	LEVEL	Description	related tactic
33	**FC CAR**	**NO LEAK**	**ADVANCED**	Multi vehicle accident - no H2 leak from the FC car - **extrictation** - complex environment (motorway, urban environment, tunnel)	**1**
34	**FC CAR**	**LEAK**	**ADVANCED**	FC car default - H2 leak from the FC car - medium complex environment (car mecanics, domestic house, open space parking)	**2**
35	**FC CAR**	**LEAK**	**ADVANCED**	Single FC vehicle **accident** - **H2 leak** from the FC car - **extrictation** - simple environment	**2**
36	**FC CAR**	**LEAK**	**ADVANCED**	Multi vehicle **accident** - **H2 leak** from the FC car - **no extrication** - complex environment (motorway, urban environment, tunnel)	**2**
37	**FC CAR**	**H2 FIRE**	**ADVANCED**	FC car default - FC car in a **fire** - medium complex environment (car mecanics, domestic house, open space parking)	**3**
38	**FC CAR**	**H2 FIRE**	**ADVANCED**	Multi vehicle accident - FC car in fire - no extrication - complex environment (motorway, urban environment, tunnel)	**3**
39	**FC CAR**	**EXTERNAL THREAT**	**ADVANCED**	**Fire in a medium complex environment** (car mecanics, domestic house, open space parking) - FC car in the environment	**4**
40	**FC BUS**	**NO LEAK**	**ADVANCED**	Multi vehicle accident - no H2 leak from the FC bus -**extrictation** - complex environment (motorway, urban environment, tunnel)	**1**
41	**FC BUS**	**LEAK**	**ADVANCED**	FC bus default - H2 leak from the FC bus - medium complex environment (car mecanique, bus warehouse, open space parking)	**2**
42	**FC BUS**	**LEAK**	**ADVANCED**	Single FC bus accident - H2 leak from the FC bus - extrictation - simple environment	**2**
43	**FC BUS**	**LEAK**	**ADVANCED**	Multi vehicle accident - H2 leak from the FC bus - no extrication - complexe environment (motorway, urban environment, tunnel)	**2**
44	**FC BUS**	**H2 FIRE**	**ADVANCED**	FC bus default - FC bus in fire - medium complex environment (car mecanique, bus warehouse, open space parking)	**3**
45	**FC BUS**	**EXTERNAL THREAT**	**ADVANCED**	Multi vehicle accident - FC bus in fire - no extrication - complex environment (motorway, urban environment, tunnel)	**4**
46	**FC BUS**	**EXTERNAL THREAT**	**ADVANCED**	Fire in a medium complex environment (car mecanique, bus warehouse, open space parking) - FC bus in the environment	**4**
47	**H2 TRAILER (bundles cylinders or long cigars)**	**NO LEAK**	**ADVANCED**	Multi vehicle **accident** - no H2 leak from the H2 trailer - **extrictation** - complex environment (motorway, urban environment, tunnel)	**5**
48	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**ADVANCED**	H2 trailer default - **H2 leak** from the H2 trailer - medium complex environment (trailer warehouse, parking, etc.)	**6**

	FCH application	Potential danger	LEVEL	Description	related tactic
49	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**ADVANCED**	Multi vehicle **accident - storage on the trailer** - **H2 leak** from the H2 trailer - **extrication** - complex environment (motorway, urban environment, tunnel, industrial environment)	**6**
50	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**ADVANCED**	Multi vehicle **accident** - dismantled storage (MIKADO) - **H2 leak** from the H2 trailer - **extrication** - complex environment (motorway, urban environment, tunnel, industrial environment, etc.)	**6**
51	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**ADVANCED**	H2 trailer default - H2 trailer in a **fire** - medium complex environment (trailer warehouse, parking, ?)	**7**
52	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**ADVANCED**	Multi vehicle **accident - H2 trailer in fire -** medium complex environment (trailer warehouse, parking, etc.)	**7**
53	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**ADVANCED**	Multi vehicle accident - dismantled storage (MIKADO) - H2 jet fire from the H2 trailer - extrication - complex environment (motorway, urban environment, tunnel, industrial environment)	**7**
54	**H2 TRAILER (bundles cylinders or long cigars)**	**EXTERNAL THREAT**	**ADVANCED**	Fire in a medium complex environment (trailer warehouse, parking, ?) - H2 trailer in the environment	**8**
55	**FC FORKLIFT AND INSIDE REFUELLING**	**NO LEAK**	**ADVANCED**	Single forklift **accident** - **no H2 leak** - **extrictation** - medium complex environment (inside warehouse)	**1**
56	**FC FORKLIFT AND INSIDE REFUELLING**	**LEAK**	**ADVANCED**	Forklift default/accident - H2 leak - medium complex environment (inside warehouse)	**2**
57	**FC FORKLIFT AND INSIDE REFUELLING**	**H2 FIRE**	**ADVANCED**	Forklift **accident** - **forklift in a fire** - medium complex environment (inside warehouse)	**3**
58	**H2 STORAGE**	**NO LEAK**	**ADVANCED**	H2 storage false alarm - medium complex environment (outside urban or industrial environment)	**13**
59	**H2 STORAGE**	**LEAK**	**ADVANCED**	H2 storage default - H2 leak - medium complex environment (outside urban or industrial environment)	**14**
60	**H2 STORAGE**	**H2 FIRE**	**ADVANCED**	H2 storage default - H2 jet fire - medium complex environment (outside urban or industrial environment)	**15**
61	**H2 STORAGE**	**EXTERNAL THREAT**	**ADVANCED**	**Fire in a medium complex environment (outside urban or industrial environment)** - Storage in the environment	**16**
62	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**NO LEAK**	**ADVANCED**	FC system false alarm - medium complex environment (outside urban or industrial environment)	**13**

	FCH application	Potential danger	LEVEL	Description	related tactic
63	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**LEAK**	**ADVANCED**	FC system default - H2 leak - medium complex environment (outside urban or industrial environment)	**14**
64	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**H2 FIRE**	**ADVANCED**	FC system default - H2 jet fire - medium complex environment (outside urban or industrial environment)	**15**
65	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**EXTERNAL THREAT**	**EXPERT**	**Fire in a medium complex environment (outside urban or industrial environment)** - FC system in the environment	**16**
66	**H2 REFUELLING STATION (without storage)**	**NO LEAK**	**EXPERT**	Dispenser/FC car false alarm - Refuelling station in a medium complex environment (outside urban or industrial environment)	**9**
67	**H2 REFUELLING STATION (without storage)**	**LEAK**	**EXPERT**	Dispenser/FC car default - H2 leak - medium complex environment (outside urban or industrial environment)	**10**
68	**H2 REFUELLING STATION (without storage)**	**H2 FIRE**	**EXPERT**	Dispenser default - H2 jet fire - medium complex environment (outside urban or industrial environment)	**11**
69	**H2 REFUELLING STATION (without storage)**	**EXTERNAL THREAT**	**EXPERT**	**Fire in a refuelling station (outside urban or industrial environment)** - FC car in the environment	**12**
70	**FC CAR**	**LEAK**	**EXPERT**	FC car default - H2 leak from the FC car - complex environment (motorway, urban environment, tunnel, underground parking)	**2**
71	**FC CAR**	**LEAK**	**EXPERT**	Multi vehicle **accident** - **H2 leak** from the FC car - **extrication** (FC car and/or conventional car) - complexe environment (motorway, urban environment, tunnel)	**2**
72	**FC CAR**	**H2 FIRE**	**EXPERT**	FC car default - FC car in a fire - complex environment (motorway, urban environment, tunnel, underground parking)	**3**
73	**FC CAR**	**EXTERNAL THREAT**	**EXPERT**	Multi vehicle accident - FC vehicle in fire - extrication (FC car and/or conventional car) - complex environment (motorway, urban environment, tunnel)	**4**
74	**FC CAR**	**EXTERNAL THREAT**	**EXPERT**	**Fire in a complex environment** (motorway, urban environment, tunnel, underground parking) - FC car in the environment	**4**
75	**FC CAR**	**EXTERNAL THREAT**	**EXPERT**	Multi vehicle accident - conventional car in fire - extrication from the FC vehicle - complex environment (motorway, urban environment, tunnel)	**4**
76	**FC CAR**	**EXTERNAL THREAT**	**EXPERT**	More complex situation with an Hazmat trailer involved	**4**

	FCH application	Potential danger	LEVEL	Description	related tactic
77	**FC BUS**	**LEAK**	**EXPERT**	FC bus default - H2 leak from the FC bus - complex environment (motorway, urban environment, tunnel, underground parking)	**2**
78	**FC BUS**	**LEAK**	**EXPERT**	Multi vehicle accident - H2 leak from FC bus - extrication (FC bus and/or conventional car) - complexe environment (motorway, urban environment, tunnel)	**2**
79	**FC BUS**	**H2 FIRE**	**EXPERT**	FC bus default - FC car in fire - complex environment (motorway, urban environment, tunnel, underground parking)	**3**
80	**FC BUS**	**H2 FIRE**	**EXPERT**	Multi vehicle accident - FC bus in fire - extrication (conventional car) - complex environment (motorway, urban environment, tunnel)	**3**
81	**FC BUS**	**EXTERNAL THREAT**	**EXPERT**	**Fire** in a complex environment (motorway, urban environment, tunnel, underground parking) - FC bus in the environment	**4**
82	**FC BUS**	**EXTERNAL THREAT**	**EXPERT**	Multi vehicle accident - conventional car in fire - extrication from the FC bus - complex environment (motorway, urban environment, tunnel)	**4**
83	**FC BUS**	**EXTERNAL THREAT**	**EXPERT**	More complex situation with an Hazmat trailer involved	**4**
84	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**EXPERT**	H2 trailer default - **H2 leak** from the H2 trailer - complex environment (motorway, urban environment, tunnel, industrial environment)	**6**
85	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**EXPERT**	Multi vehicle **accident** - storage on the trailer - **H2 leak** from H2 trailer - **extrication** (H2 trailer and/or conventional car) - complexe environment (motorway, urban environment, tunnel, industrial environment)	**6**
86	**H2 TRAILER (bundles cylinders or long cigars)**	**LEAK**	**EXPERT**	Multi vehicle **accident** - dismantled storage (MIKADO) - **H2 leak** from H2 trailer - **extrication** (H2 trailer and/or conventional car) - complexe environment (motorway, urban environment, tunnel, industrial environment)	**6**
87	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**EXPERT**	H2 trailer default - H2 trailer in a **fire** - complex environment (motorway, urban environment, tunnel, industrial environment)	**7**
88	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**EXPERT**	Multi vehicle accident - H2 trailer in a fire - storage on the trailer -- complex environment (motorway, urban environment, tunnel)	**7**
89	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**EXPERT**	More complex situation with an Hazmat trailer involved	**7**

	FCH application	Potential danger	LEVEL	Description	related tactic
90	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**EXPERT**	Multi vehicle accident - dismantled storage (MIKADO) - H2 jet fire from H2 trailer - extrication (H2 trailer and/or conventional car) - complexe environment (motorway, urban environment, tunnel?, industrial environment)	**7**
91	**H2 TRAILER (bundles cylinders or long cigars)**	**H2 FIRE**	**EXPERT**	More complex situation with an Hazmat trailer involved	**7**
92	**H2 TRAILER (bundles cylinders or long cigars)**	**EXTERNAL THREAT**	**EXPERT**	Fire in a complex environment (motorway, urban environment, tunnel, industrial environment) - H2 trailer in the environment	**8**
93	**H2 TRAILER (bundles cylinders or long cigars)**	**EXTERNAL THREAT**	**EXPERT**	Multi vehicle accident - fire close to the trailer - complex environment (motorway, urban environment, tunnel)	**8**
94	**FC FORKLIFT AND INSIDE REFUELLING**	**NO LEAK**	**EXPERT**	Single forklift **accident** - **no H2 leak** - **extrictation** - complex environment (inside warehouse close to the refuelling station)	**1**
95	**FC FORKLIFT AND INSIDE REFUELLING**	**LEAK**	**EXPERT**	Forklift default/accident - H2 leak - complex environment (inside warehouse close to the refuelling station)	**2**
96	**FC FORKLIFT AND INSIDE REFUELLING**	**EXTERNAL THREAT**	**EXPERT**	Multi vehicle **accident** - **Forklift in a fire** - complex environment (inside warehouse close to the refuelling station)	**4**
97	**FC FORKLIFT AND INSIDE REFUELLING**	**EXTERNAL THREAT**	**EXPERT**	**Fire in the warehouse** - Forklift in the environment	**4**
98	**H2 STORAGE**	**NO LEAK**	**EXPERT**	H2 storage false alarm - complex environment (inside urban or indsutrial environments)	**13**
99	**H2 STORAGE**	**LEAK**	**EXPERT**	H2 storage default - H2 leak - complex environment (inside urban or industrial environments)	**14**
100	**H2 STORAGE**	**H2 FIRE**	**EXPERT**	H2 storage - H2 jet fire - complex environment (inside urban or industrial environments)	**15**
101	**H2 STORAGE**	**EXTERNAL THREAT**	**EXPERT**	Fire in a complex environment (inside urban or industrial environments) - Storage in the environment	**16**
102	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**EXTERNAL THREAT**	**EXPERT**	FC system false alarm - complex environment (inside urban or indsutrial environments)	**16**
103	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**LEAK**	**EXPERT**	FC system default - H2 leak - complex environment (inside urban or industrial environments)	**14**
104	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**EXTERNAL THREAT**	**EXPERT**	FC system - H2 jet fire - complex environment (inside urban or industrial environments)	**16**

	FCH application	Potential danger	LEVEL	Description	related tactic
105	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**EXTERNAL THREAT**	**EXPERT**	Fire in a complex environment (inside urban or industrial environments) - FC system in the environment	**16**
106	**H2 REFUELLING STATION (without storage)**	**NO LEAK**	**EXPERT**	Dispenser/FC car alarm - Refuelling station complex environment (inside urban or indsutrial environments)	**9**
107	**H2 REFUELLING STATION (without storage)**	**LEAK**	**EXPERT**	Dispenser/FC car default - H2 leak - complex environment (inside urban or industrial environments)	**10**
108	**H2 REFUELLING STATION (without storage)**	**H2 FIRE**	**EXPERT**	Dispenser - H2 jet fire - complex environment (inside urban or industrial environments)	**11**
109	**H2 REFUELLING STATION (without storage)**	**EXTERNAL THREAT**	**EXPERT**	**Fire in a refuelling station** (inside urban or industrial environments) - FC car in the environment	**12**

4.2 Exercises an related tactics

4.2.1 Choice of releavant tactics

Strategies and tactics were previously developed in Deliverable 2.3.

For each exercise, the student is supposed to apply the related tactic. The following table shows the tactics expected for the 6 selected exercises experimented during the pilot sessions.

Table 2 Chosen scenario and related tactics

	FCH application	Potential danger	LEVEL	Description	related tactic
9	**FC BUS**	**H2 FIRE**	**DISCOVERY**	FC bus default - FC bus in a **fire** - simple environment (small road)	**3**
57	**FC FORKLIFT AND INSIDE REFUELLING**	**H2 FIRE**	**ADVANCED**	Forklift **accident** - **forklift in a fire** - medium complex environment (inside warehouse)	**3**
80	**FC BUS**	**H2 FIRE**	**EXPERT**	Multi vehicle accident - FC bus in fire - extrication (conventional car) - complex environment (motorway, urban environment, tunnel)	**3**
100	**H2 STORAGE**	**H2 FIRE**	**EXPERT**	H2 storage - H2 jet fire - complex environment (inside urban or industrial environments)	**15**
105	**FC SYSTEM, ELECTROLYSER, CHP SYSTEM, BACK UP POWER SYSTEM, HYDROGEN-BASED ENERGY STORAGE SYSTEM**	**EXTERNAL THREAT**	**EXPERT**	Fire in a complex environment (inside urban or industrial environments) - FC system in the environment	**16**
109	**H2 REFUELLING STATION (without storage)**	**EXTERNAL THREAT**	**EXPERT**	**Fire in a refuelling station** (inside urban or industrial environments) - FC car in the environment	**12**

4.2.2 Use of calculated separation distances

For assessing the incident situation, the separation distances are an important element. Here people will do excersise on calculating separation distances for different senarios

4.2.2.1 Exercises on calculating separation for different orifice diameters

In these exercises, it is expected to learn that the decrease of orifice diameter will dramatically reduce the separation distances.

The procedures for the exercise in this part are listed below.

- Step-1 Log on Cyber Lab http://h2fc.eu/sageserver

- Step-2 Choose the second model-flame length and separation distance for jet fires as shown in figure 5.

- Step-3 Input parameters and update the results as shown in figure 5.

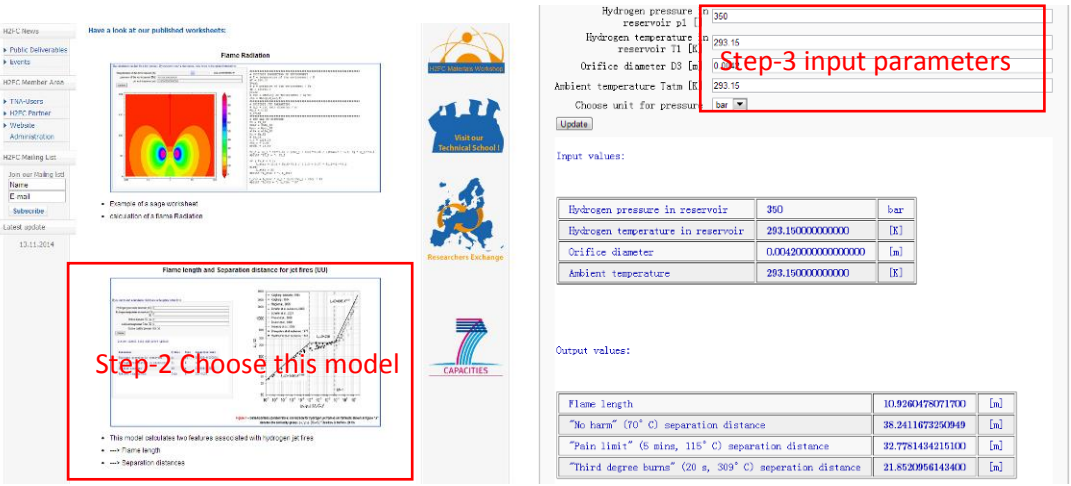

Figure 5 Procedure for calculating separation distances

4.2.2.2 exercise on the decrease of separation during a tank blowdown

In these exercises, it is expected to learn that the tank pressure is falling during a tank blow down and lead to the decrease of separation distances.

The procedures for the exercise in this part are listed below.

- Step-1 Log on Cyber Lab http://h2fc.eu/cyber-laboratory/44, choose "Isothermal blowdown of storage tank" or adiabatic blowdown.

- Step-2 Input the parameters in table 3 and click "run", as shown in figure 6 below.

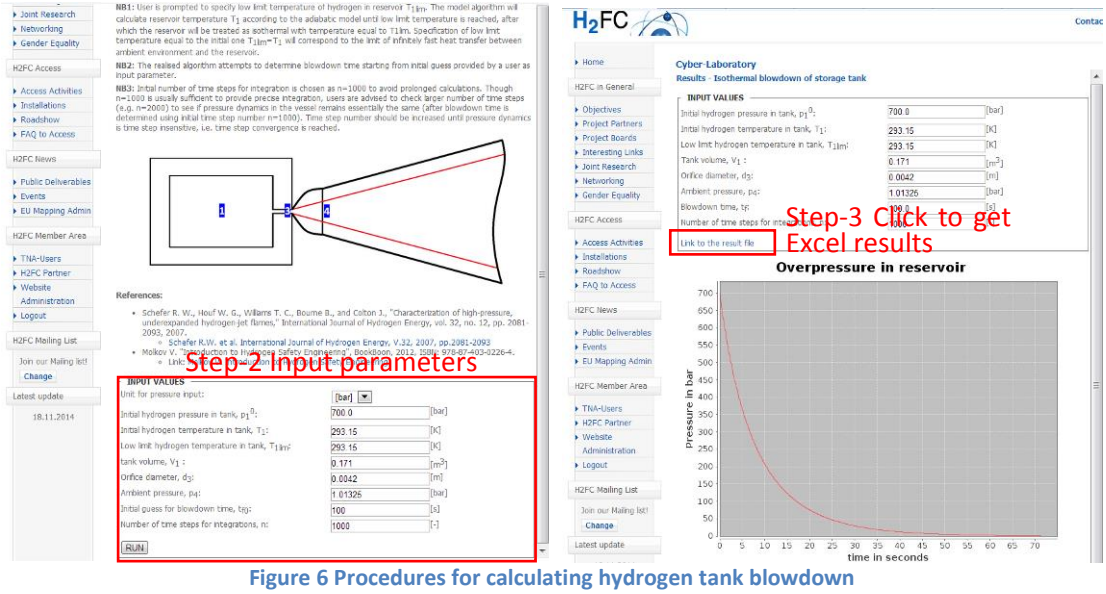

Figure 6 Procedures for calculating hydrogen tank blowdown

- Step-3 Click “Link to the results file” and get the excel data as shown in figure 6.
- Step-4 Repeat step 2 and step 3 in calculating separation distances.

4.3 Flowcharts

4.3.1 FCH bus in fire (simple environment):

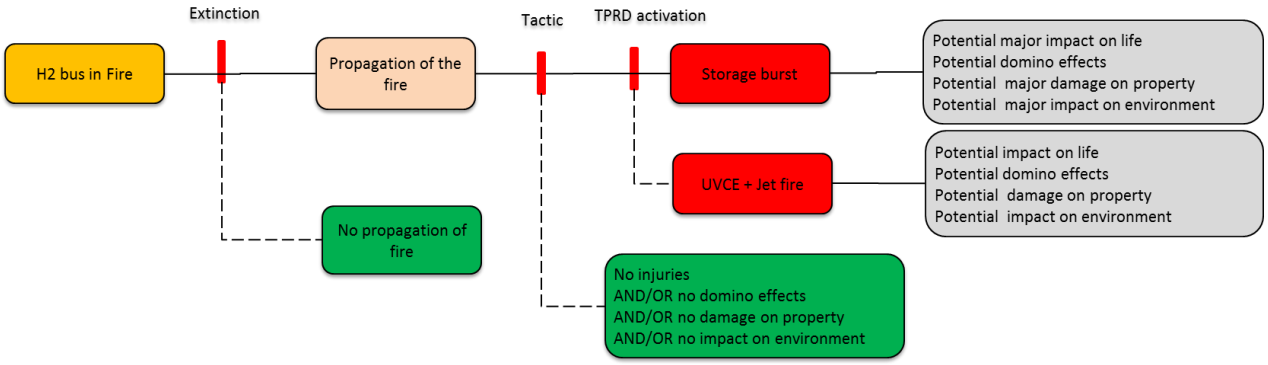

Figure 7 Bus in fire (Simple environment)

4.3.2 FCH Forklift in fire in a warehouse:

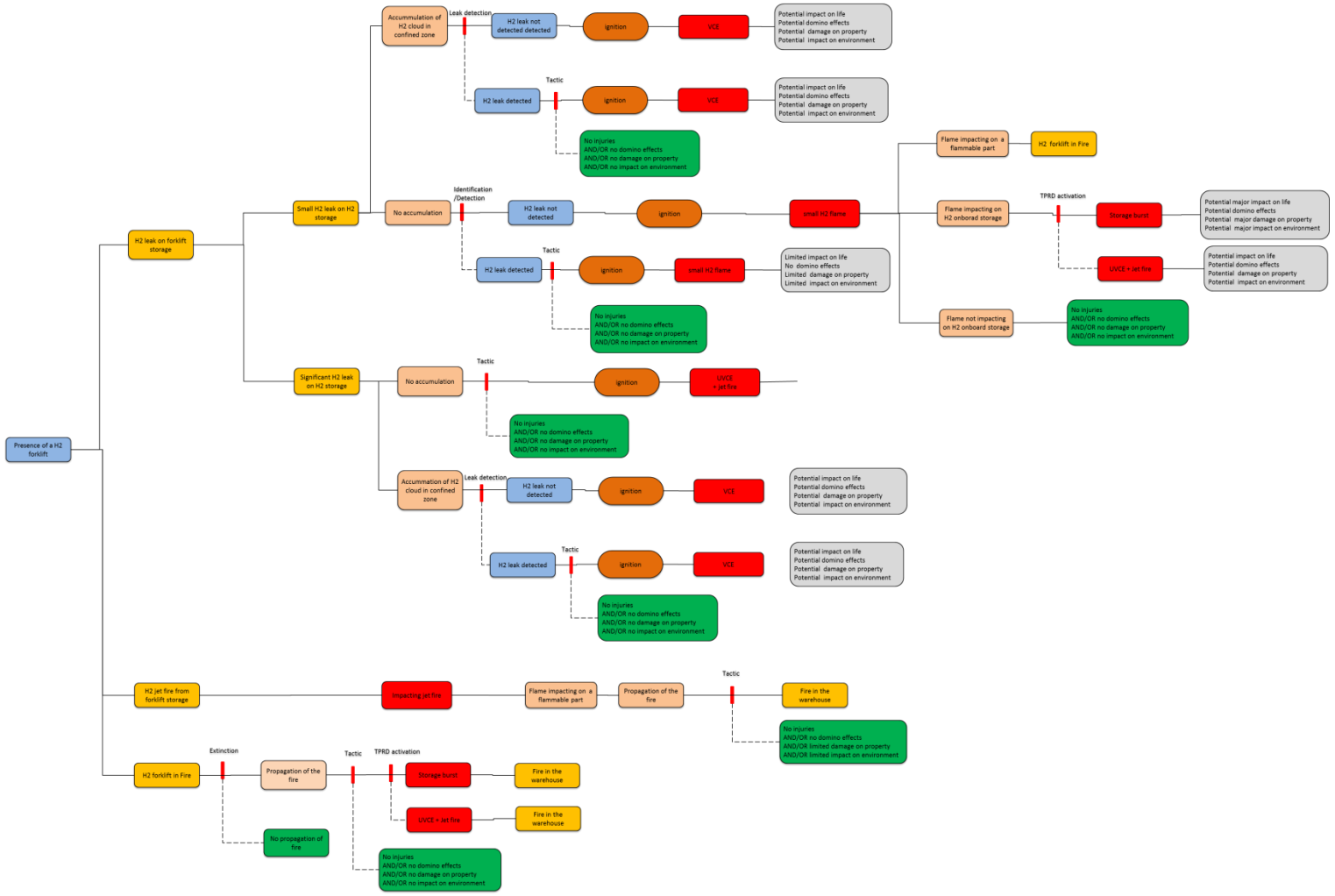

Figure 8 FCH Forklift in fire in a warehouse

Figure 9 Presence of Hazmat in the Warehouse

Figure 10 Presence of a dispenser in the warehouse

4.3.3 FCH Bus in fire (complex environment):

The increasing of complexity can be provided by

- the presence of numerous other involved vehicles, including Hazmat
- the presence of injured persons
- the presence of a builded area with a threatened population. Presence of a FCH BUS

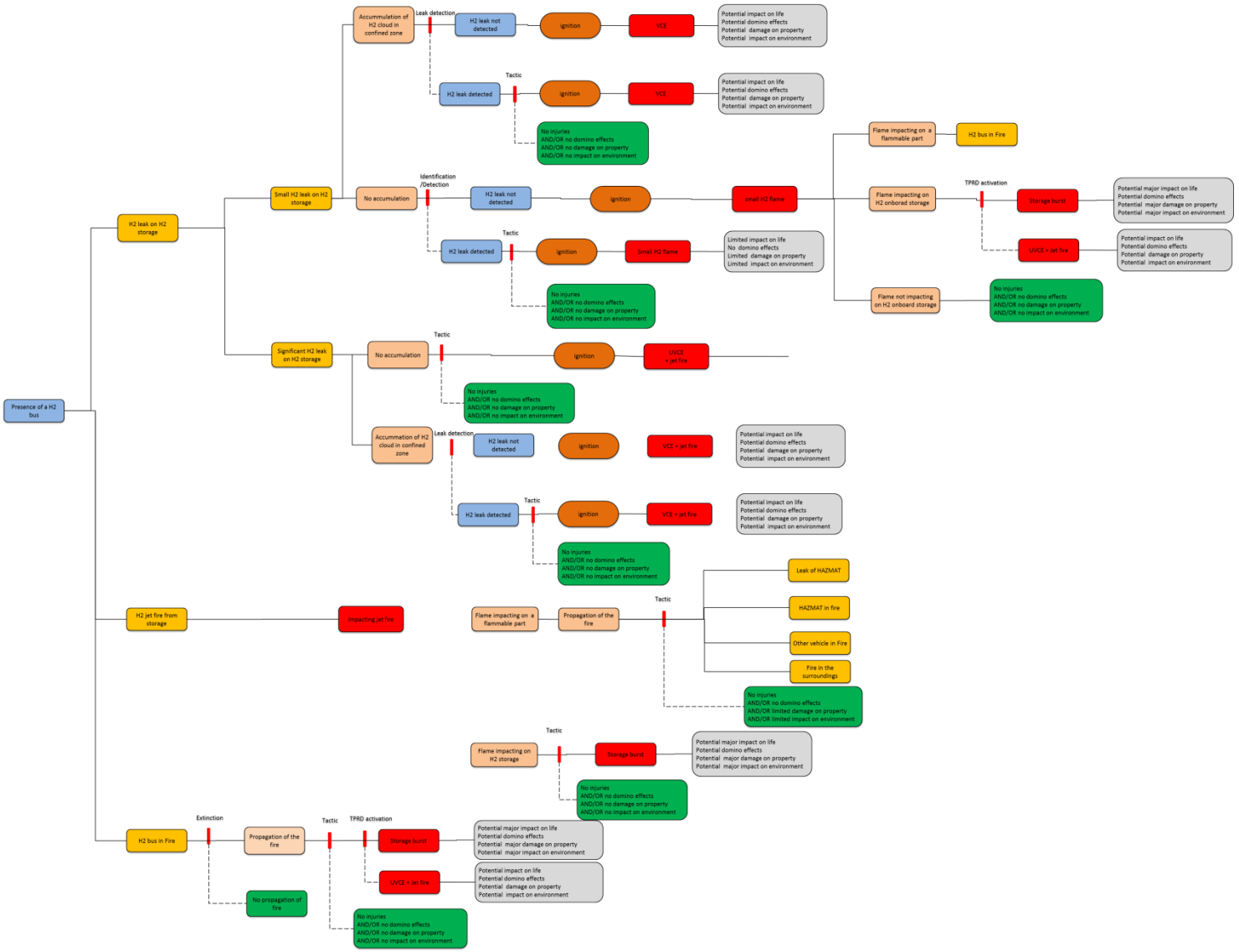

Figure 11 FCH bus in fire Complex environment

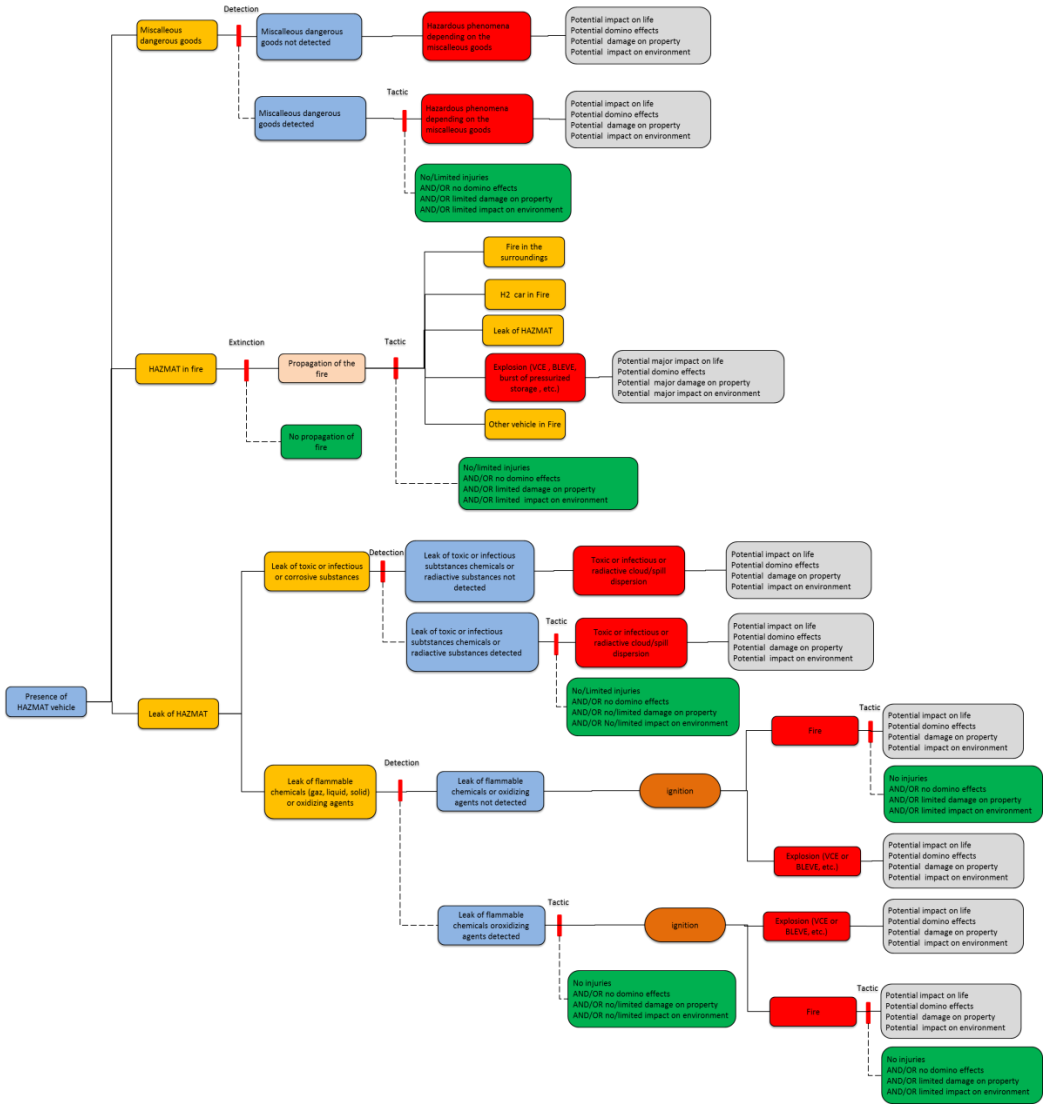

Figure 12 Presence of HAZMAT vehicles

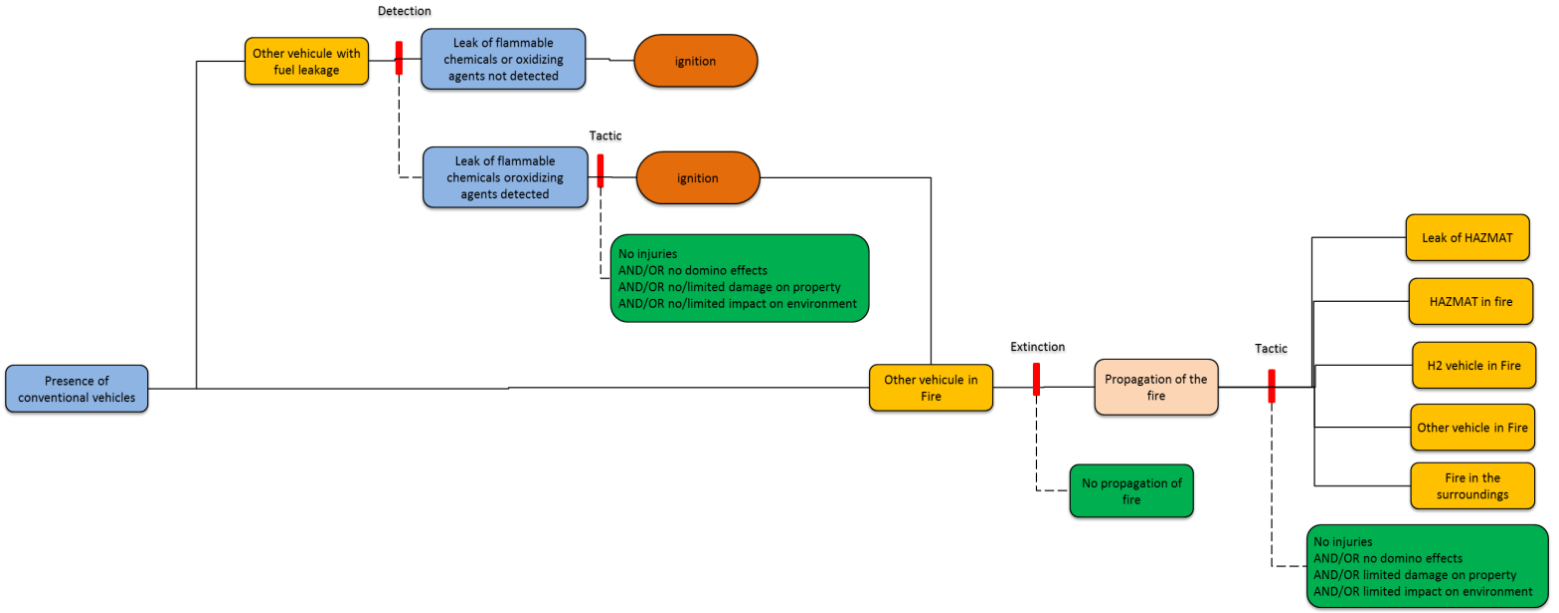

Figure 13 Presence of conventional vehicules

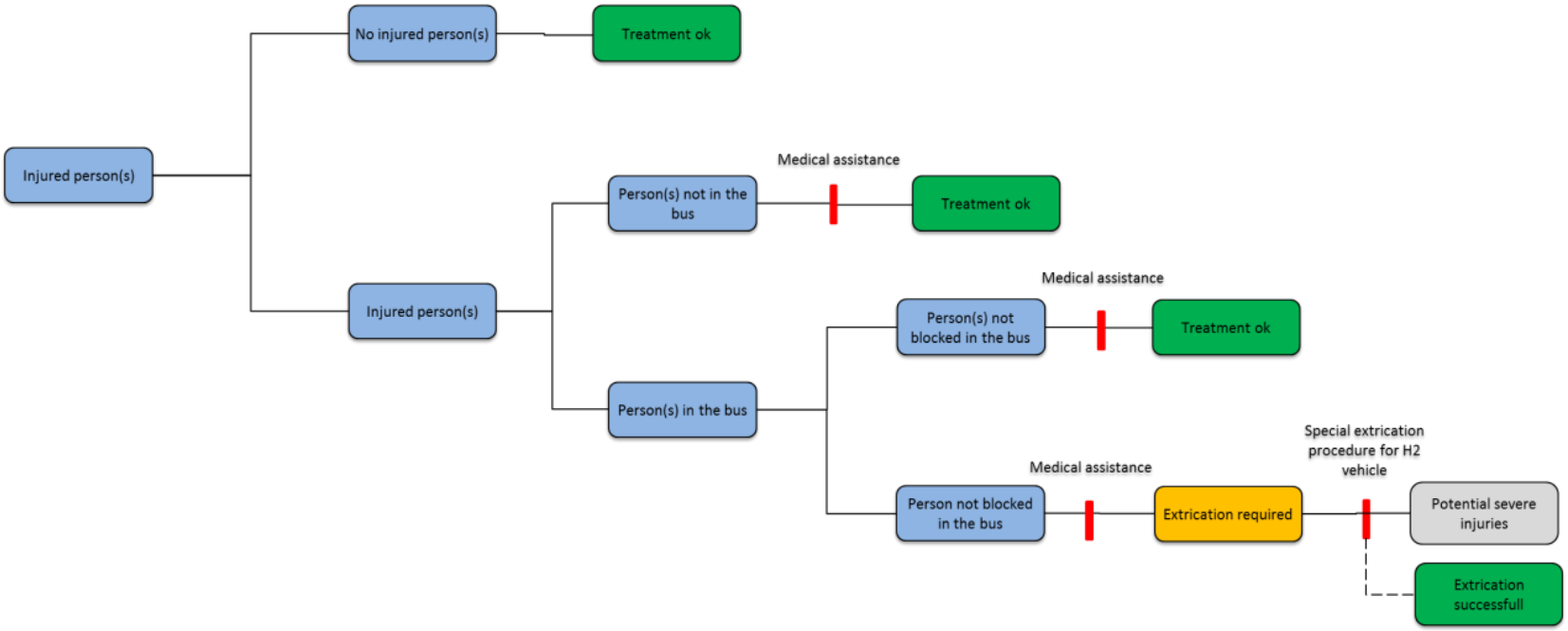

Figure 14 Presence of infured persons

4.3.4 H2 storage

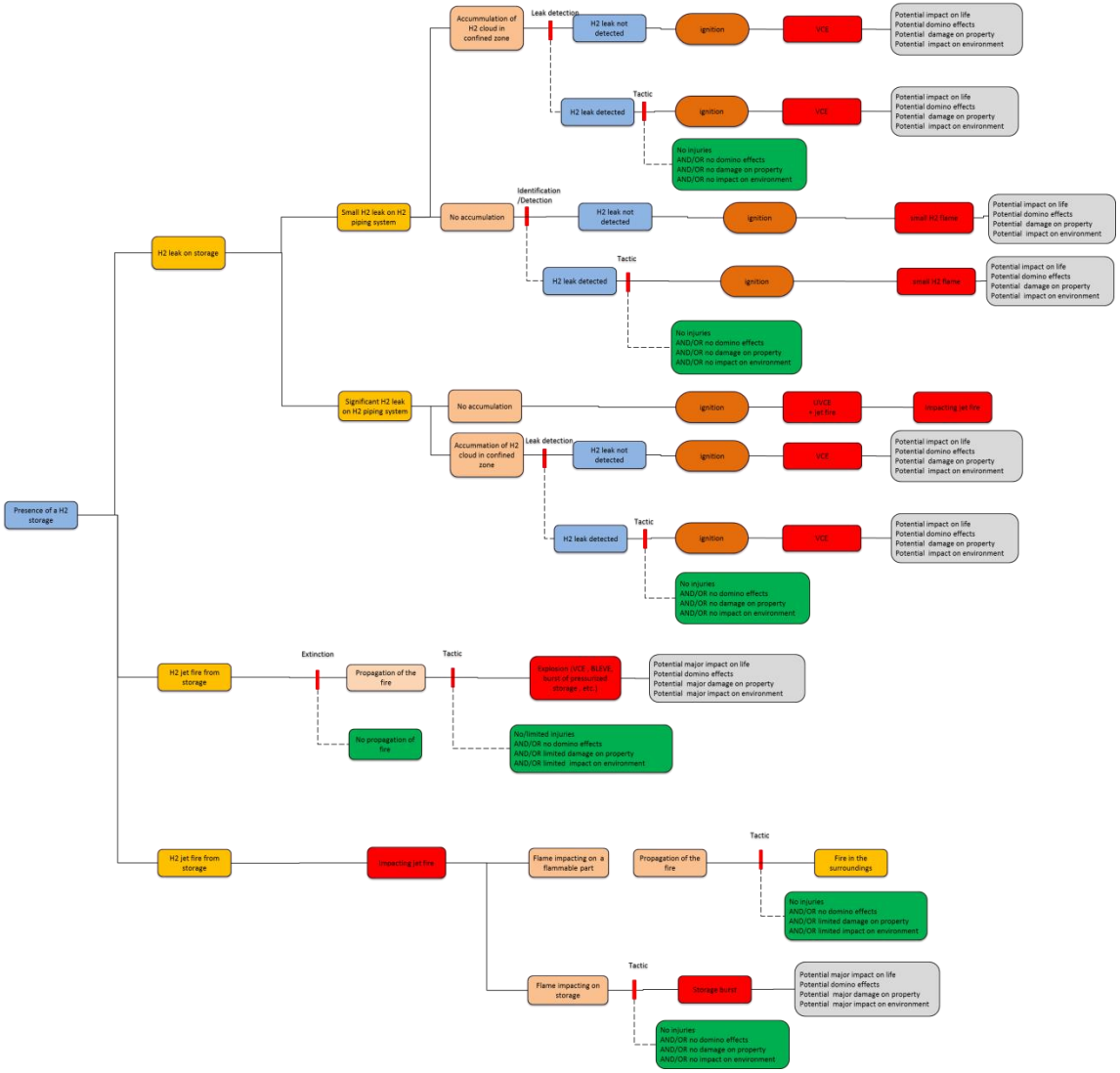

Figure 15 H2 storage

:

4.3.5 FC System, electrolyser, chp system, back up power system, hydrogen based energy storage system.

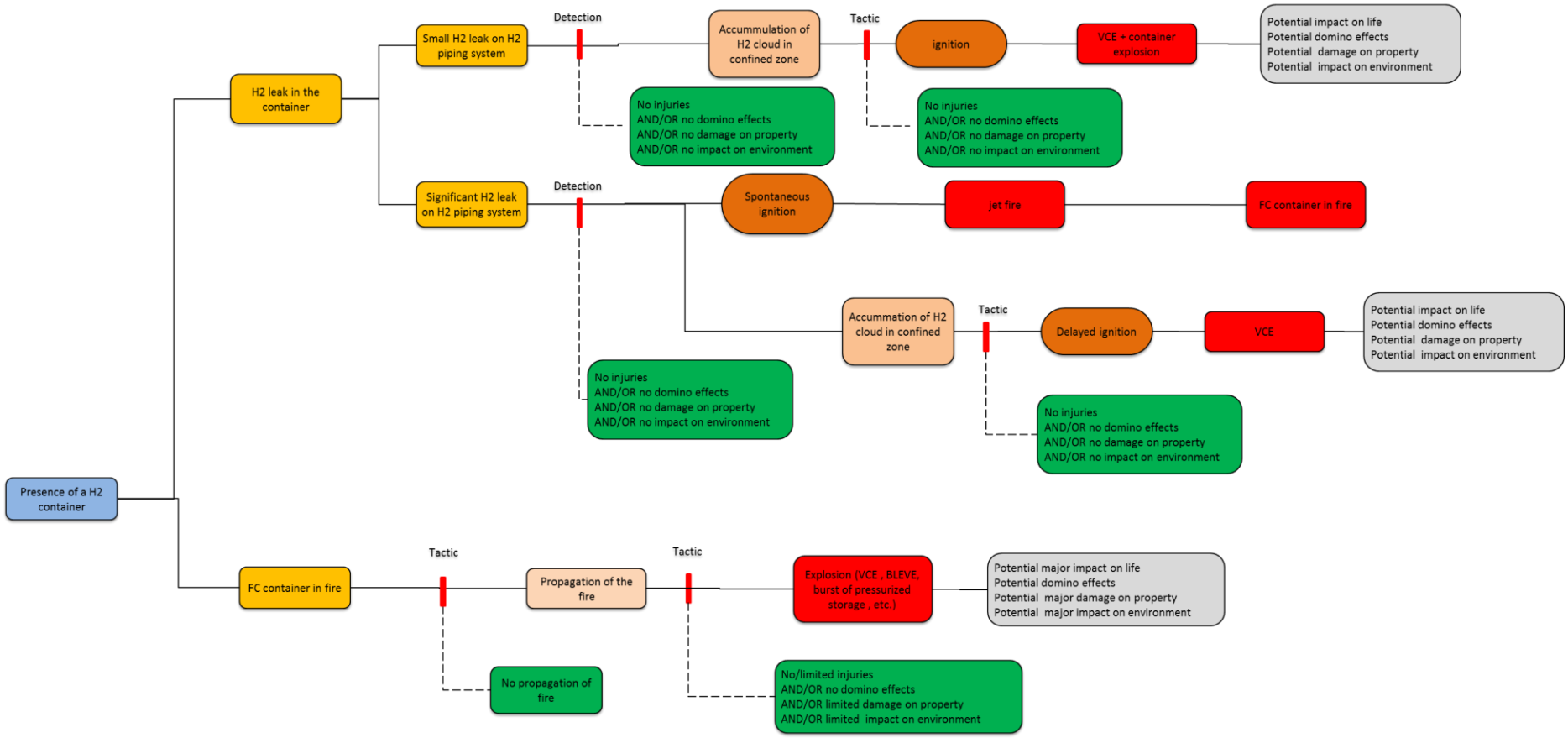

Figure 16 FCH system (container)

4.3.6 Refueling station

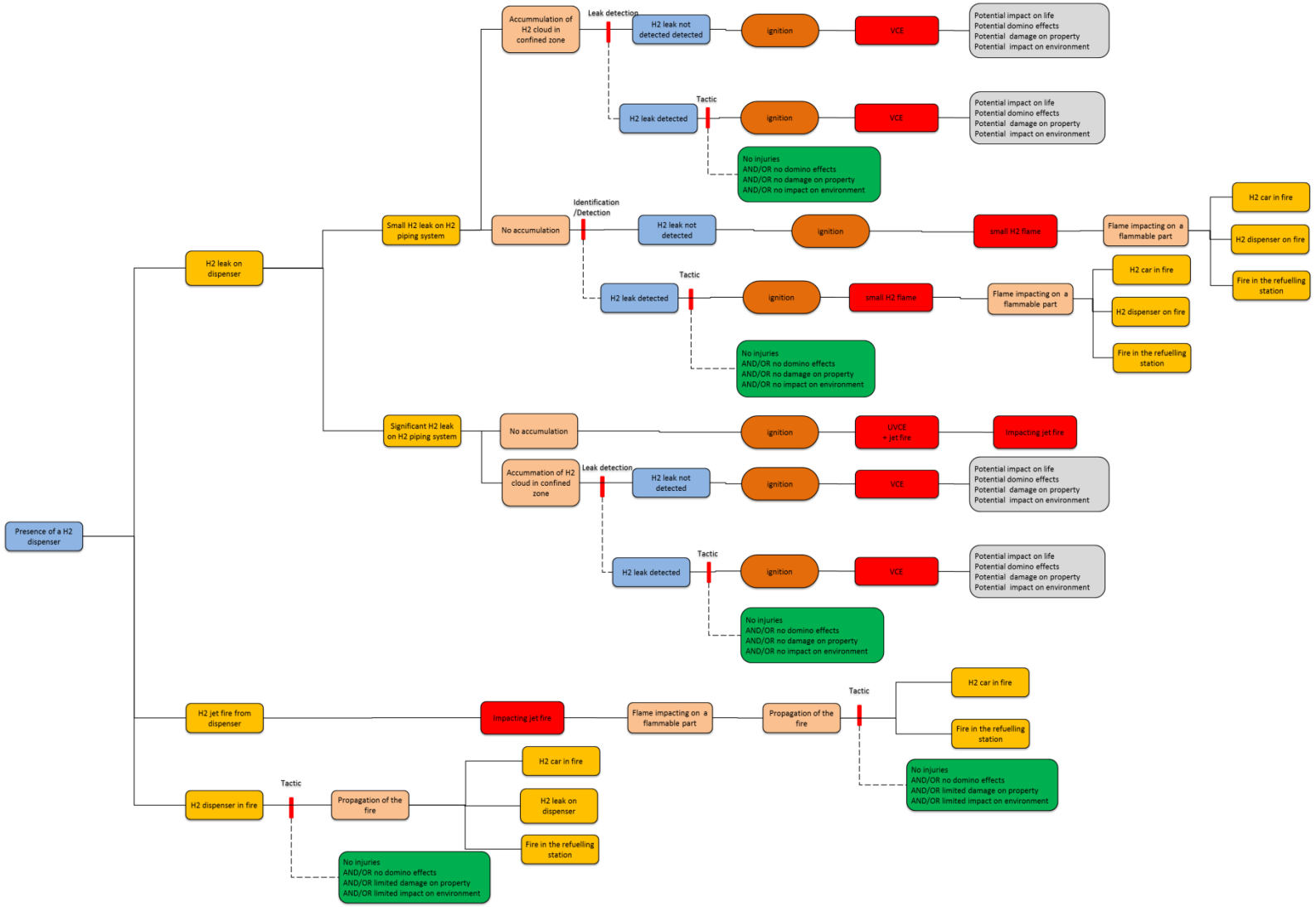

Figure 17 Refueling station

5 Assessment

5.1 Assessment sheet

The following table is the template of the assessment sheet that will be used for the pilot training sessions. This sheet must be filled by the instructor at the end of each exercise. The assessment is individual. The instructor checks the items required in the related tactic and provide comments and improvement orientations.

Table 3 Example of exercise individual assessment sheet

EXERCISE ASSESMENT SHEET		Date :		HyResponse
	Exercise identification :	Instructor name:		Student name : Team: - - - -
	Tactic expected :			
		CORRECT	FALSE	COMMENTS
AT THE FIRE STATION				
Check that the fire appliance is ready and operational				
Check every first reponder portection suit				
Take into account the informations about the incident (short brirefing for the team)				
Take weather conditions				
Choose a safe itinerary				
Take specific tools				
ARRIVAL ON SCENE				
Choose a safe way to get to the incident ground				
Stop the applicance a the required distance				
Set the required safety area				
Make the arrival radio call				
SIZE UP THE SCENE				
Collect informations about the situation				

Make a complete recognition of the incident scene			
Decide to engage immediate rescue if needed			
Complete the information collect			
Make the first report radio call (situation confirmation)			
RESCUE			
Engage rescue in the safest manner for first responders			
Make the paramedic requirement radio call (if needed)			
	CORRECT	FALSE	COMMENTS
EXPOSURE PROTECTION			
Prevent exposure of persons			
Prevent exposure of properties			
Prevent exposure of environment			
Use personnel in a reasonable manner			
INCIDENT TREATMENT			
Engage incident treatment as required in the related tactic			
Use personnel in a reasonable manner			
Make the second report radio call (situation treatment information to authority)			
Make a permanent scene assessment			
OVERHAUL			
Control that no risk remains			
Stay on scene as long as needed			
Make the paramedic requirement radio call (if needed)			

Global assessment				
validation	YES		NO	
Instructor signature :				

Conclusion

After a description of the pedagogic scope and concept of virtual reality trained, this deliverable describe the elaboration of the virtual training exercises completing the multi-level operational training exercises.
The whole scenarios are described in detailed flowcharts. The conduct of a training session is held by implementation of simple scenarios dedicated to basic actions and complex scenarios, dedicated to multi aspects situations that may involve several and combined actions.

Combined whith the operational training implemented on the EHSTP, the virtual training will enable trainees to make a meaningful assessment of incidents and situations to choose knowingly adapted tactics and strategies.

references

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MARANNE, E. (2015, october). MIXED E-LEARNING AND VIRTUAL REALITY PEDAGOGICAL APPROACH FOR INNOVATIVE HYDROGEN SAFETY TRAINING FOR FIRST RESPONDERS. *ICHS 2015*. Japan.

Verbecke et al., F. V.-N. (9-11 september 2013). European hydrogen safety training platform for first responders: HyResponse project, Proceedings of the Fifth International Conference on Hydrogen Safety.

Illustrations

Figures

Tables