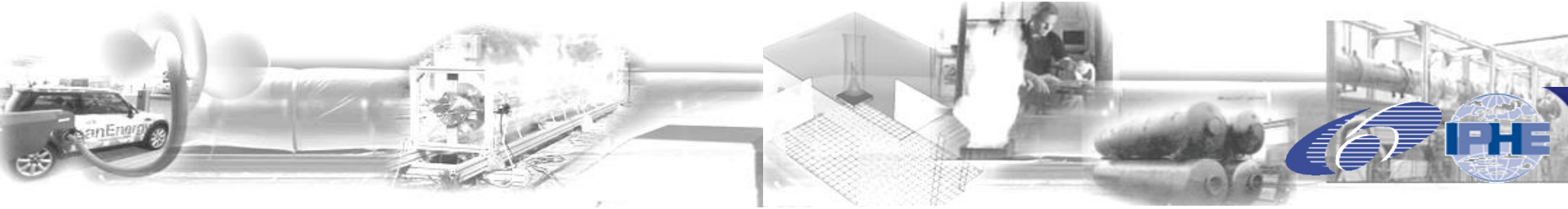




NoE "HySafe" Recent Results of Internal Research Projects

Dr.-Ing. Thomas JORDAN
coordinator@hysafe.net

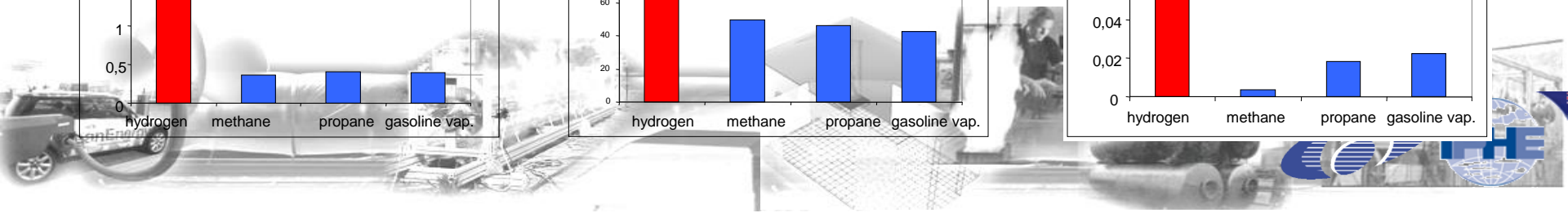
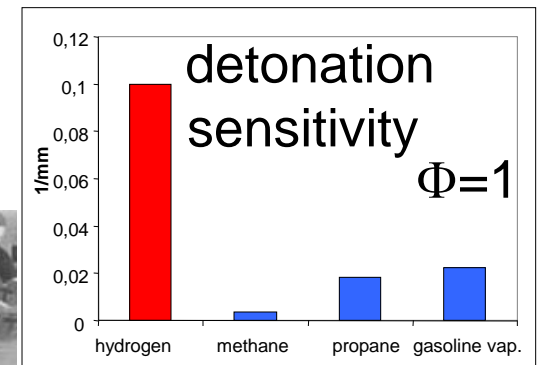
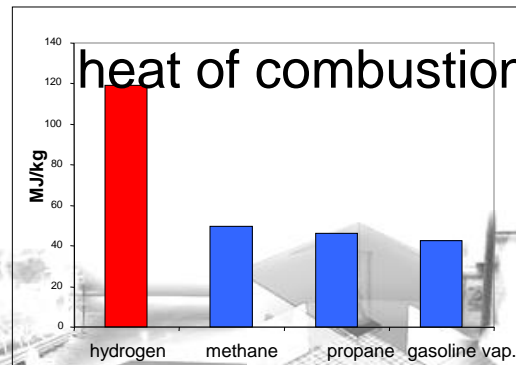
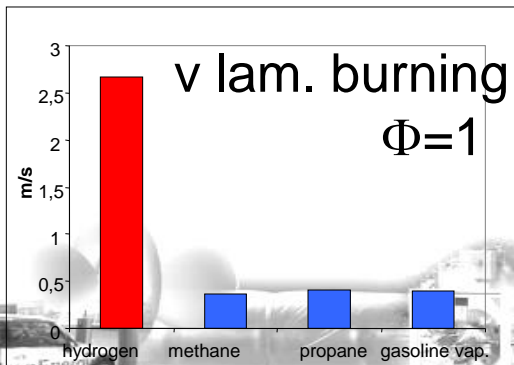
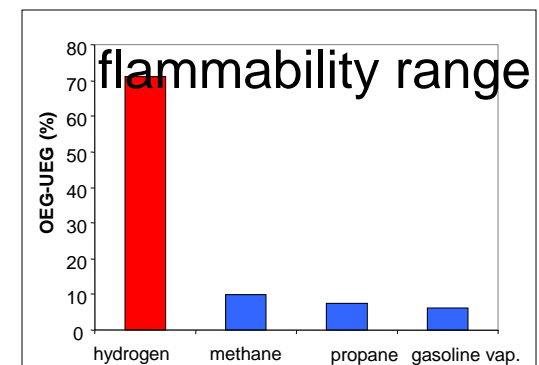
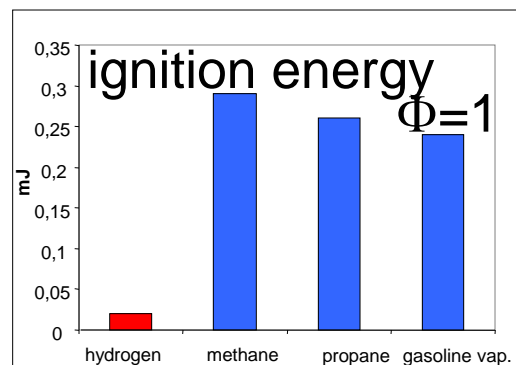
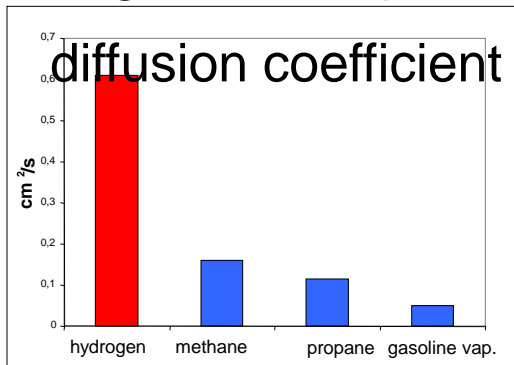
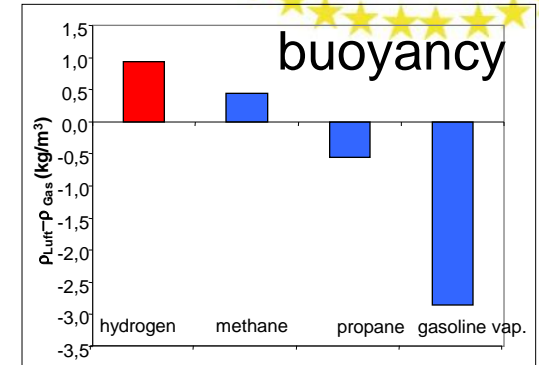
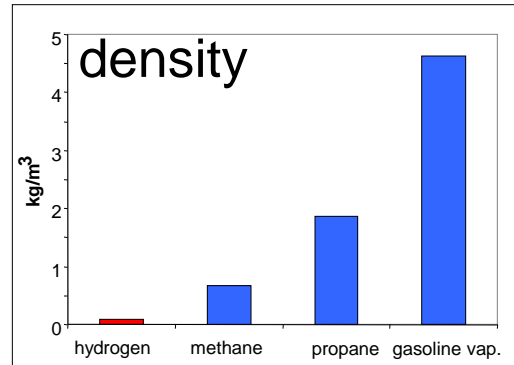
23 Oktober 2008, Standards and Safety Workshop, H2 Expo, Hamburg, Germany



Motivation

Safety relevant properties of - hydrogen

- methane
- propane
- gasoline vapour



NoE Objectives



NoE HySafe Objectives

- strengthen and focus, **integrate** fragmented **research** on hydrogen safety
→ competitive scientific and industrial community
- Promoting **public awareness and trust** in hydrogen technologies
- development of an excellent **safety culture**

dt =

General Goal

Contribute to a **safe transition** to a **sustainable development**

in Europe by facilitating the **safe introduction of hydrogen technologies / applications**



Some HySafe details



Consortium

- 24 partners from 12 European countries incl. Russia (Kurchatov Institute) and one Canadian partner (University of Calgary)
- 13 public research organisations, 7 industrial partners, 5 universities
- ~150 scientists involved

Budget

Total > 13 M€ with a EC grant of max. 7 M€

Time schedule

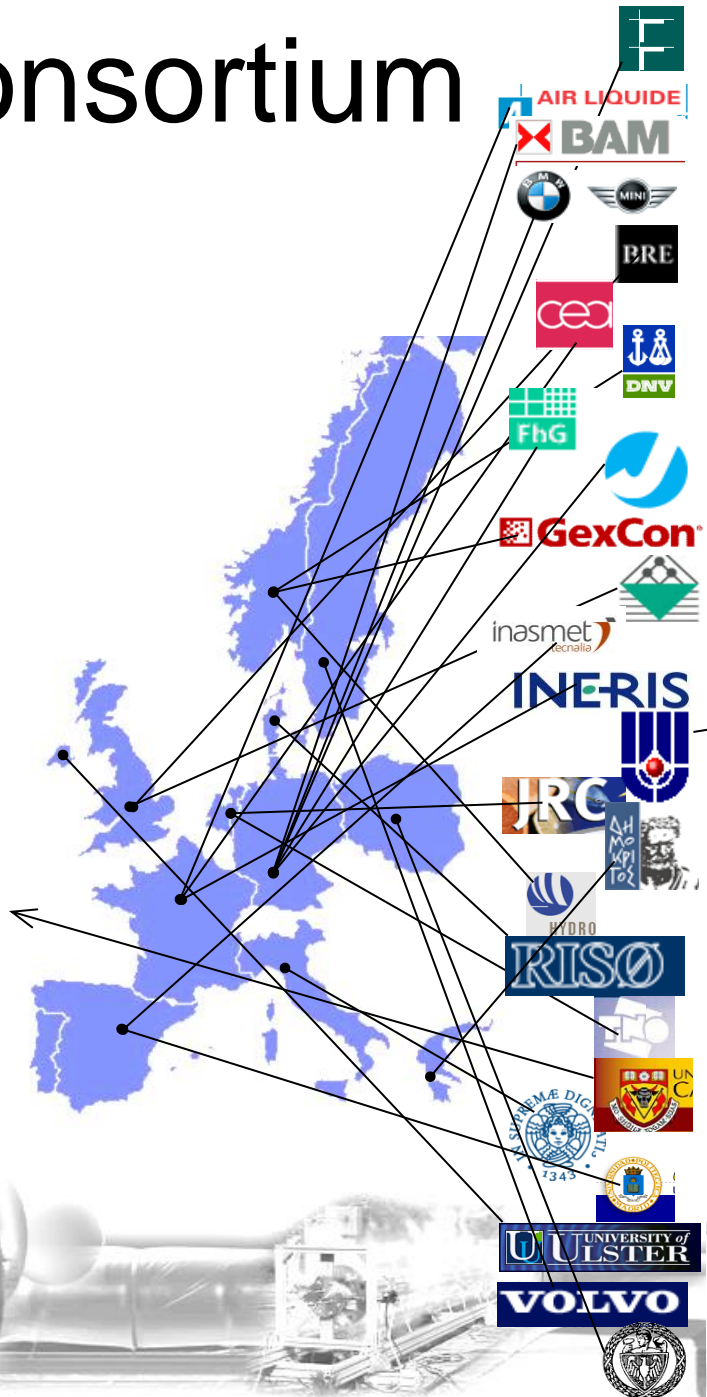
network/project start: 03/2004

subsidised max. duration: 5 years

→ 02/2009 activities transferred to the International Association “HySafe”



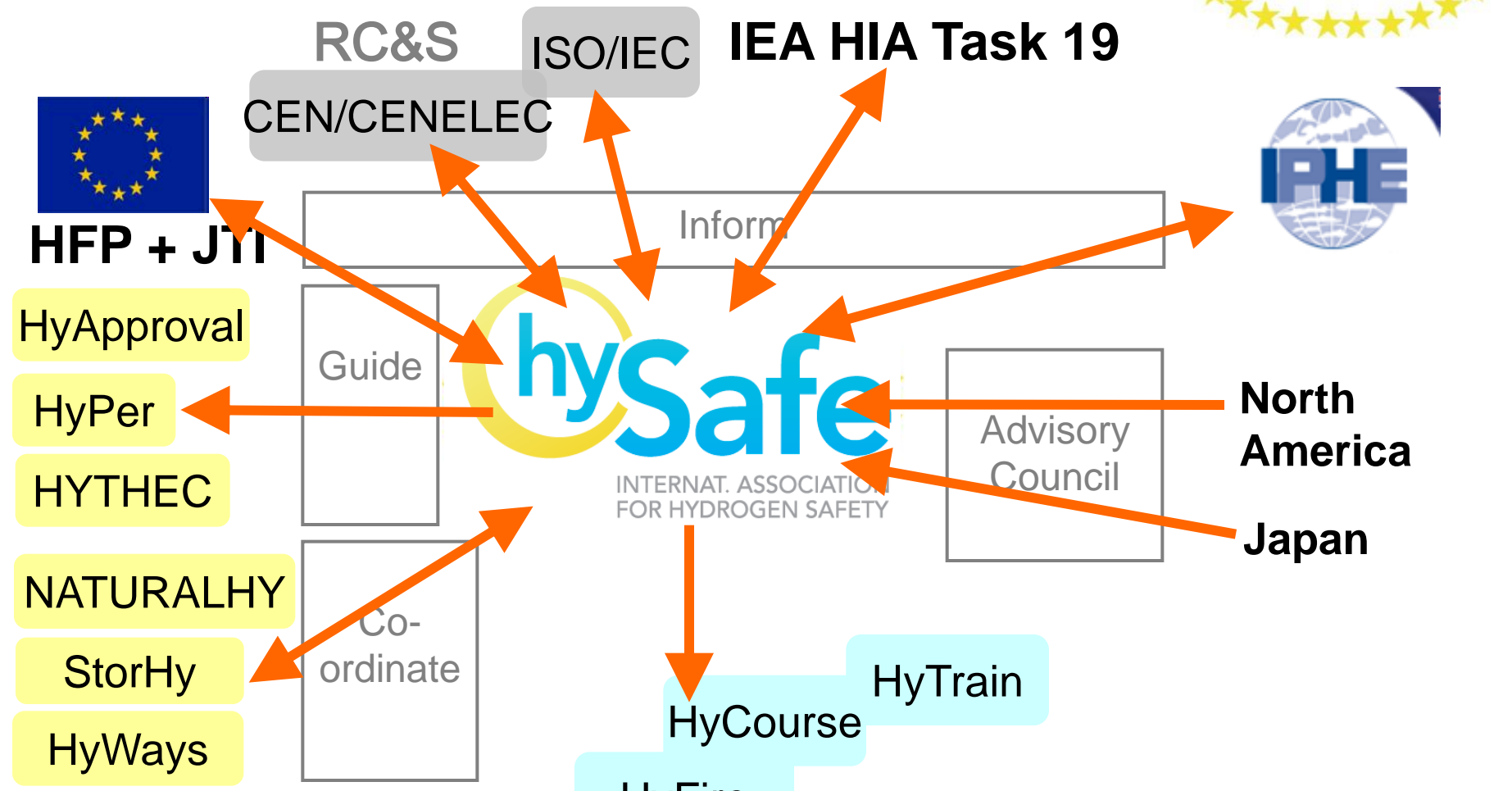
Consortium



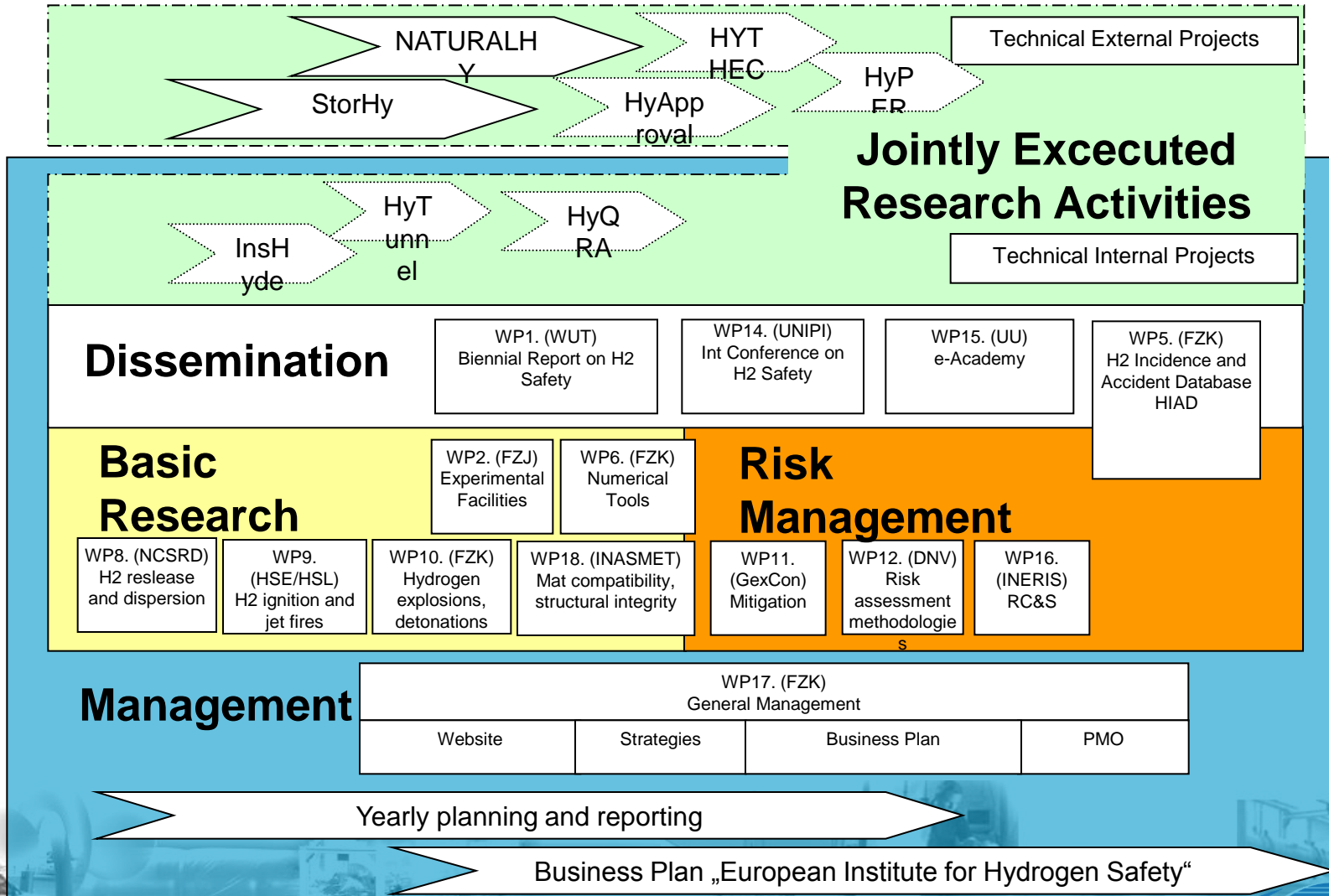
Forschungszentrum Karlsruhe GmbH	DE
L'Air Liquide	FR
Federal Inst for Materials Research and Testing	DE
BMW Forschung und Technik GmbH	DE
Building Research Establishment Ltd	UK
Commissariat à l'Energie Atomique	FR
Det Norske Veritas AS	NO
Fraunhofer-Gesellschaft ICT	DE
Forschungszentrum Jülich GmbH	DE
GexCon AS	NO
The UKs Health and Safety Laboratory	UK
Foundation INASMET	ES
Inst Nat de l'Environm industriel et des RISques	FR
European Commission - JRC - Inst for Energy	NL
National Center for Scientific Research Demokritos	EL
Norsk Hydro ASA	NO
Risø National Laboratory	DK
TNO	NL
University of Calgary	CA
University of Pisa	IT
Universidad Politécnica de Madrid	ES
University of Ulster	UK
VOLVO Technology Corporation	SE
Warsaw University of Technology	PL
Russian Research Centre Kurchatov Institute	RUS



External Networking



Clusters and Packages



Research Headlines



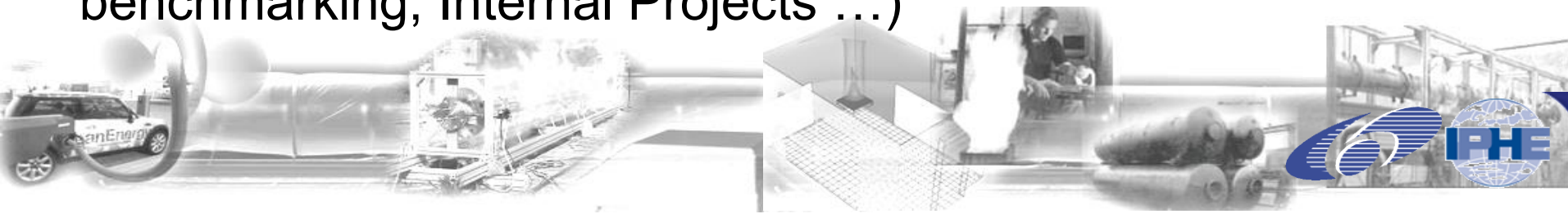
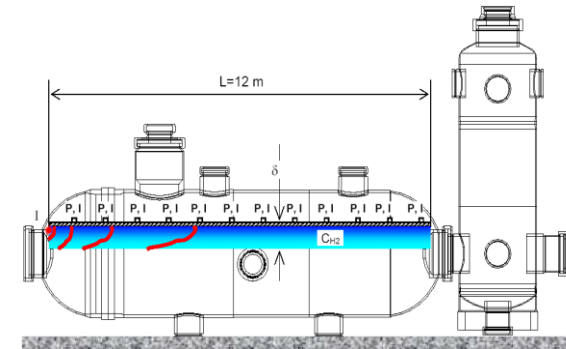
- **(Partially) Confined Releases**
- **Mitigation**

determined by

- initial PIRT study
- expert questionnaire
- state-of-the-art survey



communicate the network's working topics,
orientate the work on intermediate time scale (proposals for experiments, benchmarking, Internal Projects ...)



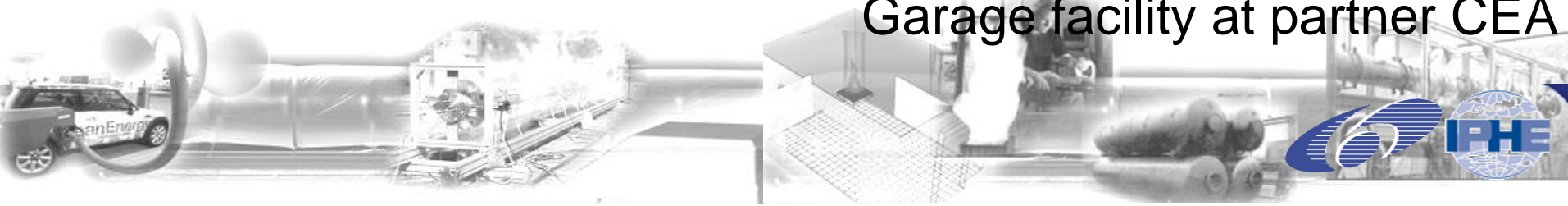
Internal Project “InsHyde”



- Investigation of realistic non-catastrophic releases in (partially) confined areas
- Determination of permeation and release limits
- Systematic assessment of mitigation (including detection) measures (sensors + venting + recombiner...)
- Simulations and experiments for critical releases
- Deriving „Recommendations“, → standards, ...
- Proposing a dedicated EC project “HyGarage” (lead NCSRD)



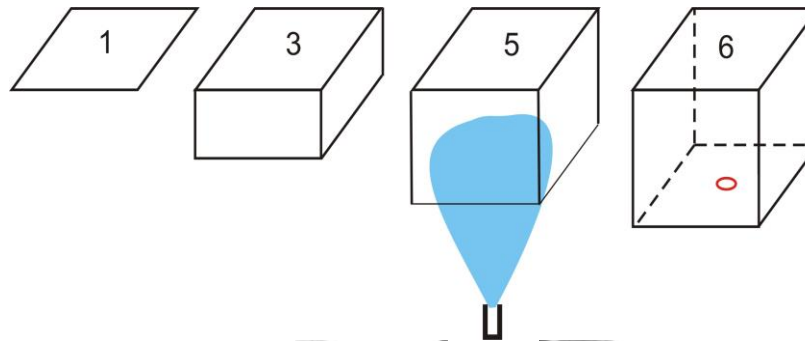
Garage facility at partner CEA



“InsHyde” Max. Inventory



- Released mass of Hydrogen: - 1-10 g (Standard variation)
- Release time: - 0.1-100 s (Jet → Plume)
- Ignition time: } - to be chosen in a way, that presumably
- Ignition location: } maximum H₂- combustion occurs
- Ignition energy: } - weak, strong
- Complexity of geometry
 - a) Obstacles: - different number of wire netting layers
→ turbulence and flame convolution
 - b) Enclosure: - different number of restrictive plates
(i.e. aluminum)



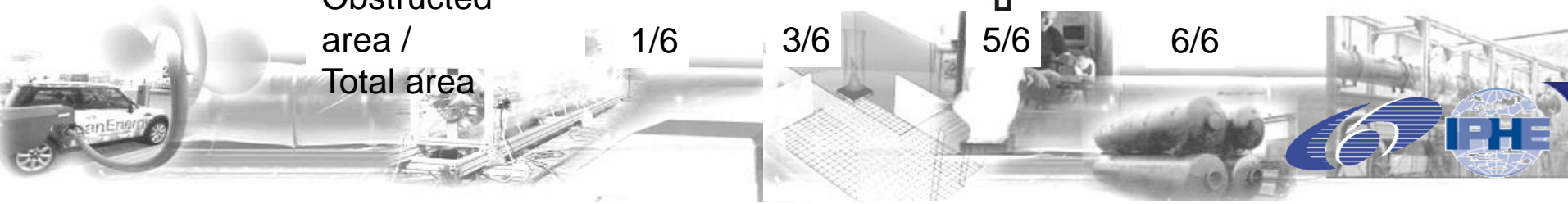
Obstructed
area /
Total area

1/6

3/6

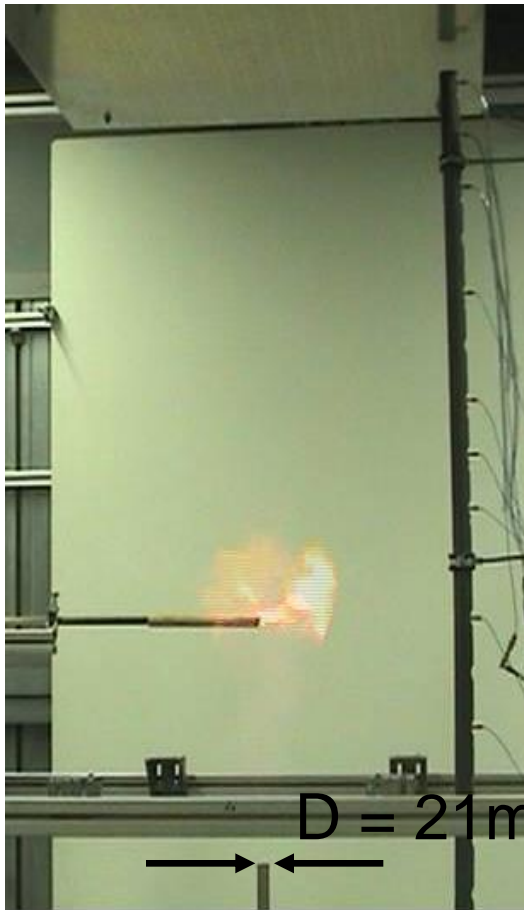
5/6

6/6



“InsHyde” – Integral tests

Inventory 10 g



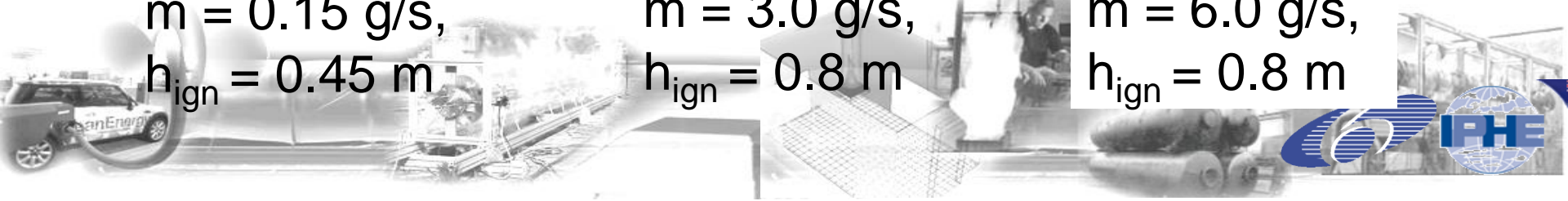
$D = 21\text{ mm}$



$\dot{m} = 0.15\text{ g/s},$
 $h_{\text{ign}} = 0.45\text{ m}$

$\dot{m} = 3.0\text{ g/s},$
 $h_{\text{ign}} = 0.8\text{ m}$

$\dot{m} = 6.0\text{ g/s},$
 $h_{\text{ign}} = 0.8\text{ m}$



“InsHyde” – Permeation Survey on Existing Allowable Rates



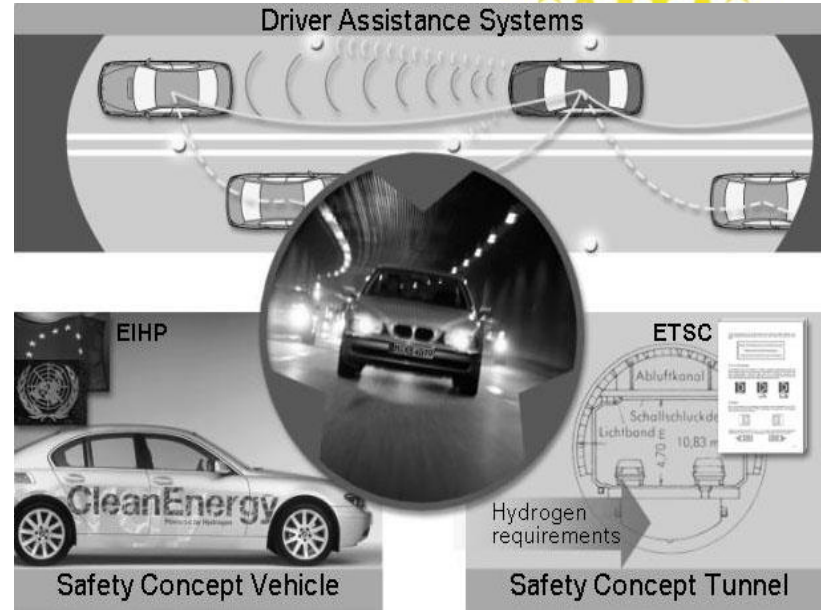
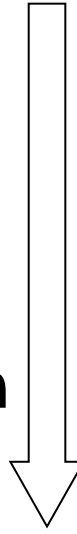
- Draft UN ECE regulation (EIHP draft & possibly the basis of the EU Regulation) and superseded versions of draft ISO/DIS15869:
 - For Type 4 containers, the steady state permeation rate $< 1.0 \text{ NmL/hr/L}$ internal vol.
 - The test is conducted at ambient temperature and nominal working pressure.
- ISO/DIS 15869.2 & .3:
 - For Type 4 containers, the steady state permeation rate $< 2.0 \text{ NmL/hr/L}$ water capacity at 35 MPa, and 2.8 NmL/hr/L water capacity at 70 MPa.
 - The test is conducted at ambient temperature and nominal working pressure.
- SAE J2579, Jan. 2008:
 - The steady state hydrogen discharge rate due to leakage and permeation from the hydrogen storage system shall not $> 75 \text{ NmL/min}$ at 85°C and nominal working pressure for a standard passenger vehicle.
 - The rate may be increased in proportion to the enclosure volume for large vehicles.



Internal Project “HyTunnel”

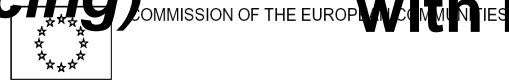


- Selection of broadly accepted szenarios.
- Review of available relevant numerical and experimental simulations
- Qualitative assessment on standard mitigation measures effectiveness (benchmark)



- i. Experimental part (depending on financing)*
- ii. Extension of the EC Tunnel „directives“*

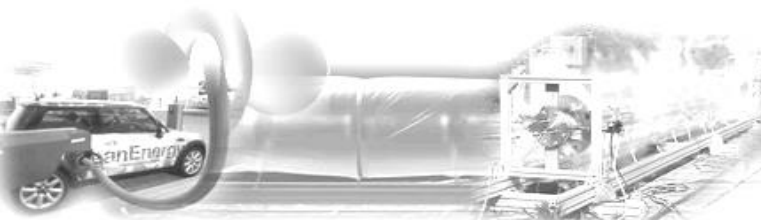
→ Improved Tunnel Safety with H₂ as the fuel of the future



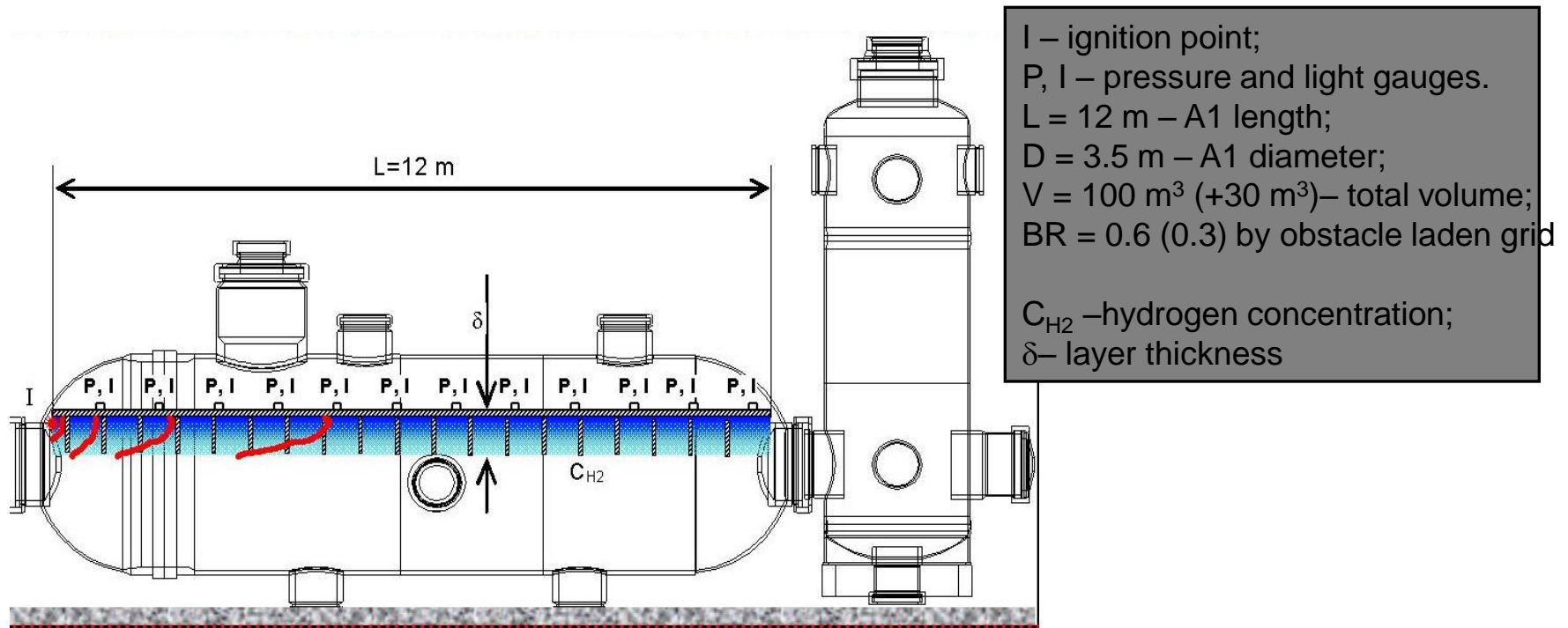
Brussels, 30.12.2002
COM(2002) 769 final
2002/0309 (COD)

Proposal for a
DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

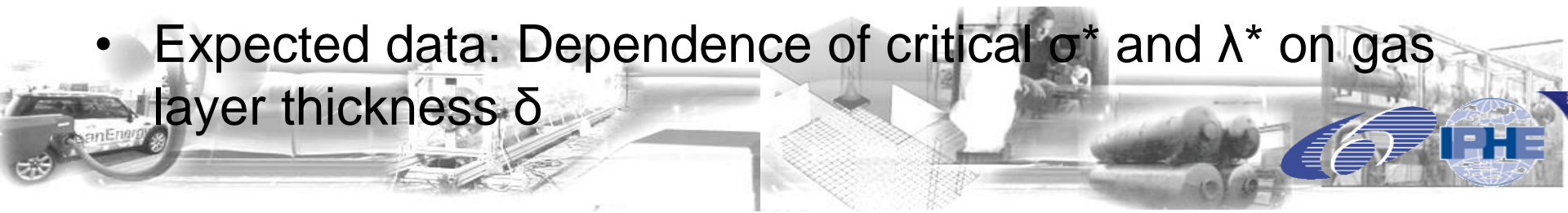
on minimum safety requirements for tunnels in the
Trans-European Road Network



“HyTunnel” - Experimental Layout



- Objective: Critical conditions for FA and DDT in semi-confined gas mixture layer
- Expected data: Dependence of critical σ^* and λ^* on gas layer thickness δ



“HyTunnel” – Main Experiments



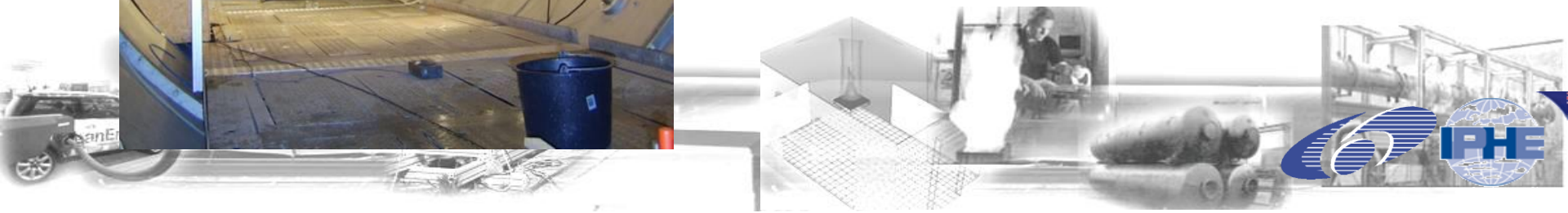
Large scale facility (5.7 x 1.6 x 0.6 m)

- effective venting ratio $\alpha = 0.46$ (layer thickness $\delta = 0.15$ m)

Diagonal view



Film opening



“HyTunnel” – FA/DDT

some results



- Large scale test completed
- Effective flame acceleration (FA) depends on mixture reactivity and gas layer thickness.

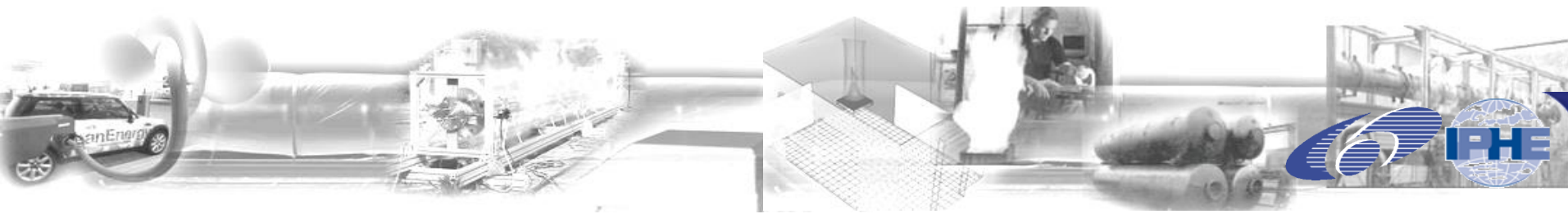
Flame accelerates to sonic velocity:

for **15% H₂** **$d \geq 0.6$ m**

for **20% H₂** **$d \geq 0.3$ m**

- **Detonation** in semi-confined geometry at **25% H₂** can occur if gas layer **$d \geq 0.3$ m**
- Critical layer thickness for **detonation propagation**:

$$15 > d/l > 7.5$$



WP18.3 Sub-task “HyFrac”



Objectives

Experience from space research/rocket engineering indicates that hydrogen 5.0 with less than 5ppm O₂ contamination (HPH₂, as required for PEM FC) can induce accelerated material damage processes.

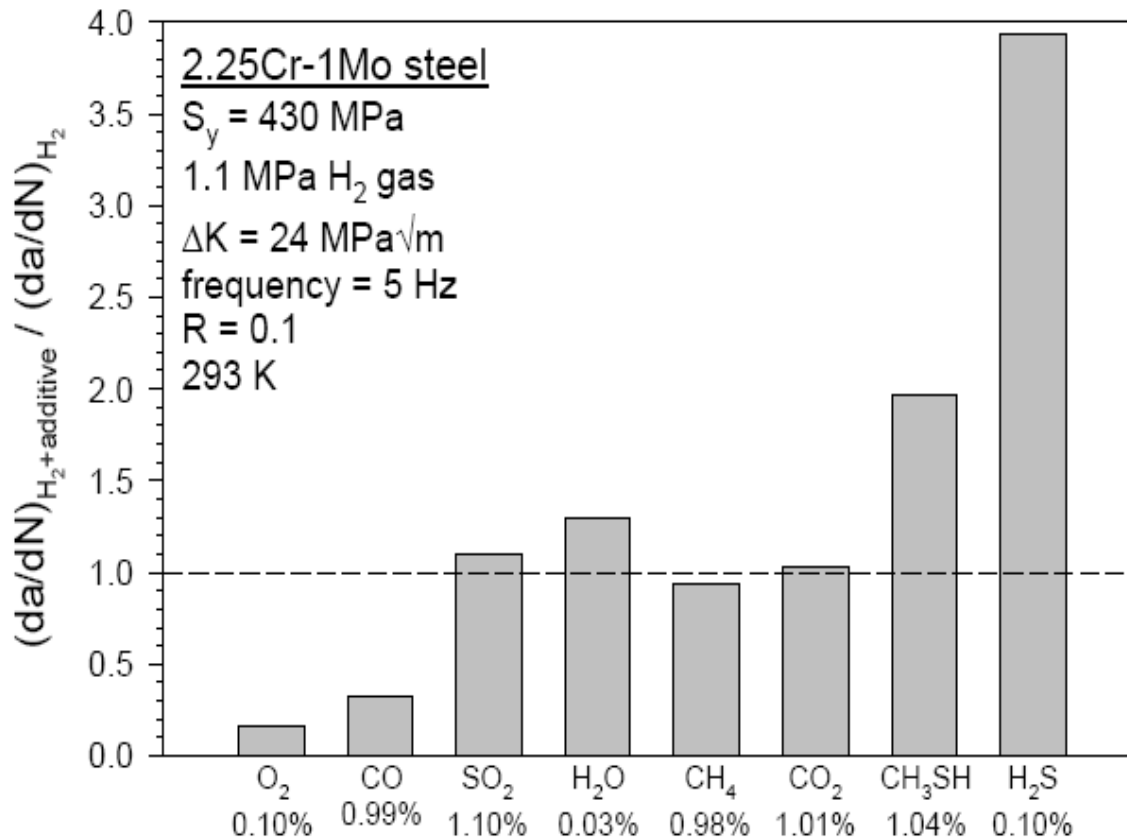
Objectives:

- Investigation of the effect of HPH₂ induced cracking
- Recommendations for the safety aspects of the use of HPH₂ in fuel cell cars

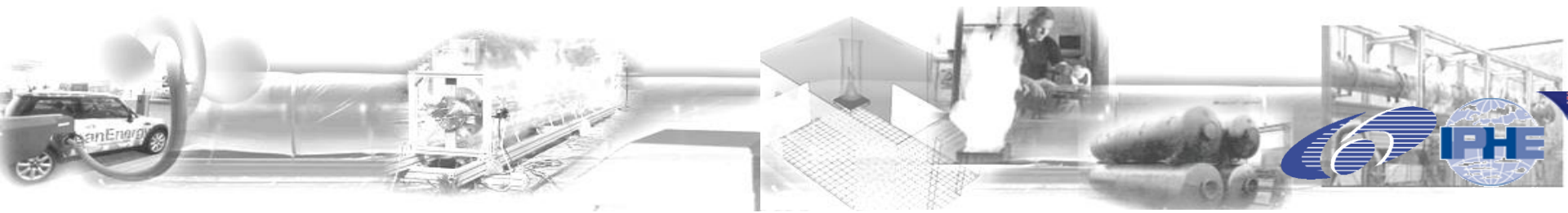
Lead: **AL** Partners: BAM, DNV, HSE/HSL, INASMET, Risø
and Active Supporters: ET, INTA.



Impurity effects on fatigue crack growth



Comparison between pure gas and H_2 with additives [4]

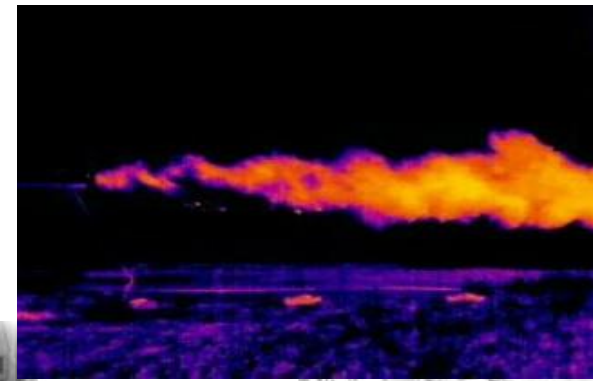


WP18.4 “HyNano” – Objectives



Fundamental understanding the safety issues regarding nano-scaled solid-state hydrogen storage materials/systems through:

- (i) development of standard testing techniques to quantitatively evaluate both materials and systems,**
- (ii) understand the fundamental science of environmental reactivity of hydrides and**
- (iii) develop methods and systems to mitigate the risks to acceptable levels.**



nano-structured alanate blown out of a heat exchanger tube at 10 bar and 120 °C (frames of a high speed video (left) and of a infrared video (right) at the same instant)

Progress status WP18.4



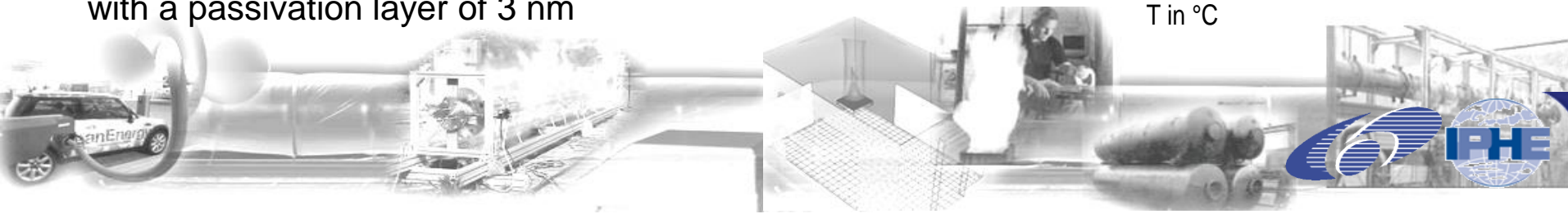
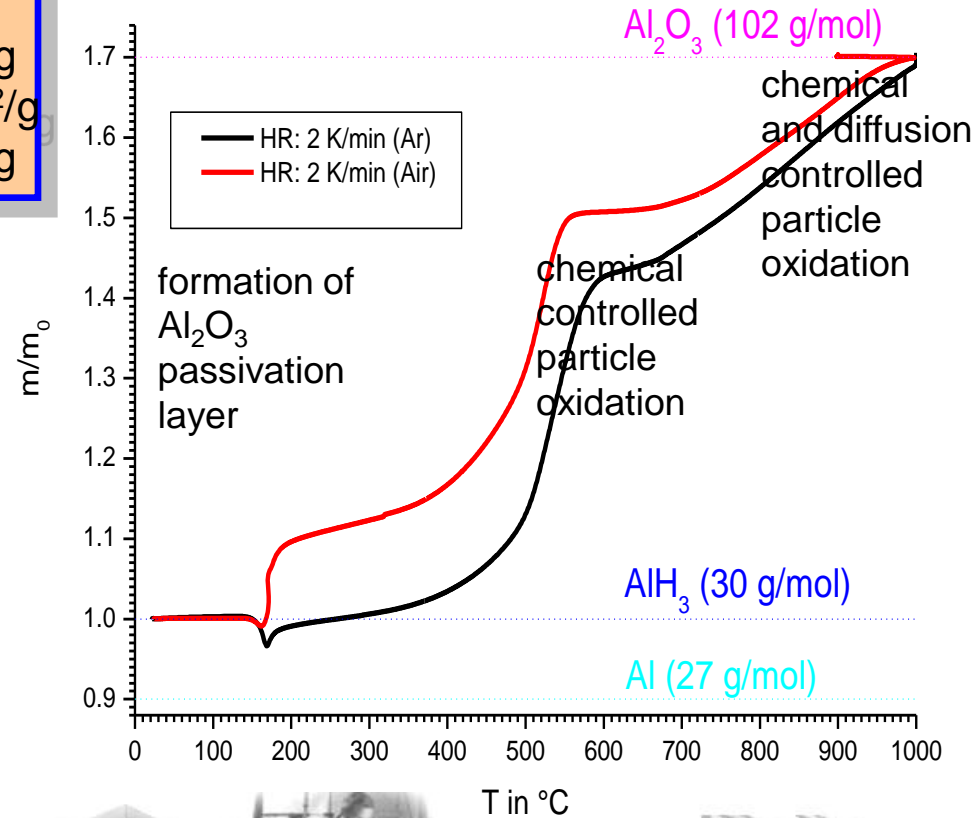
Methods of investigation: decomposition – oxidation

AlH ₃ from pyrolysis furnace	2.59 m ² /g
AlH ₃ in TGA*	15 to 20 m ² /g
AlH ₃ (original crystals)	0.69 m ² /g
ALEX (nano-Al)	12.28 m ² /g
5 μm Aluminum (ALCAN)	1,36 m ² /g

Methods of Thermal Analysis:
DSC, TG, X-Ray

**Specific Surface by BET-
Analysen and TGA analysis**

*estimated from mass increase by
oxidation
with a passivation layer of 3 nm

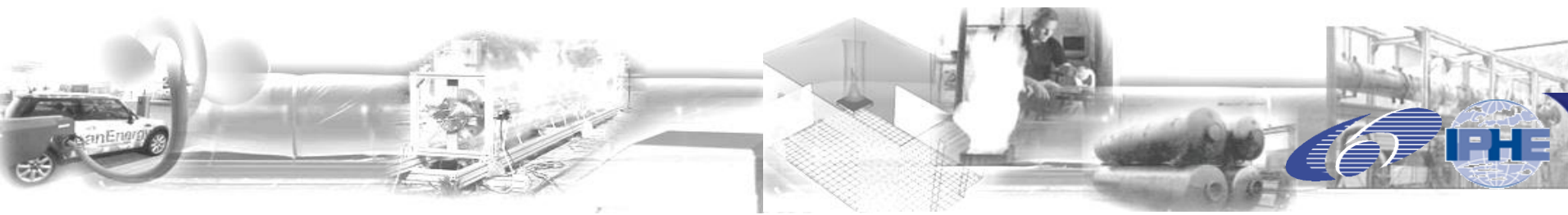


Internal Project HyQRA

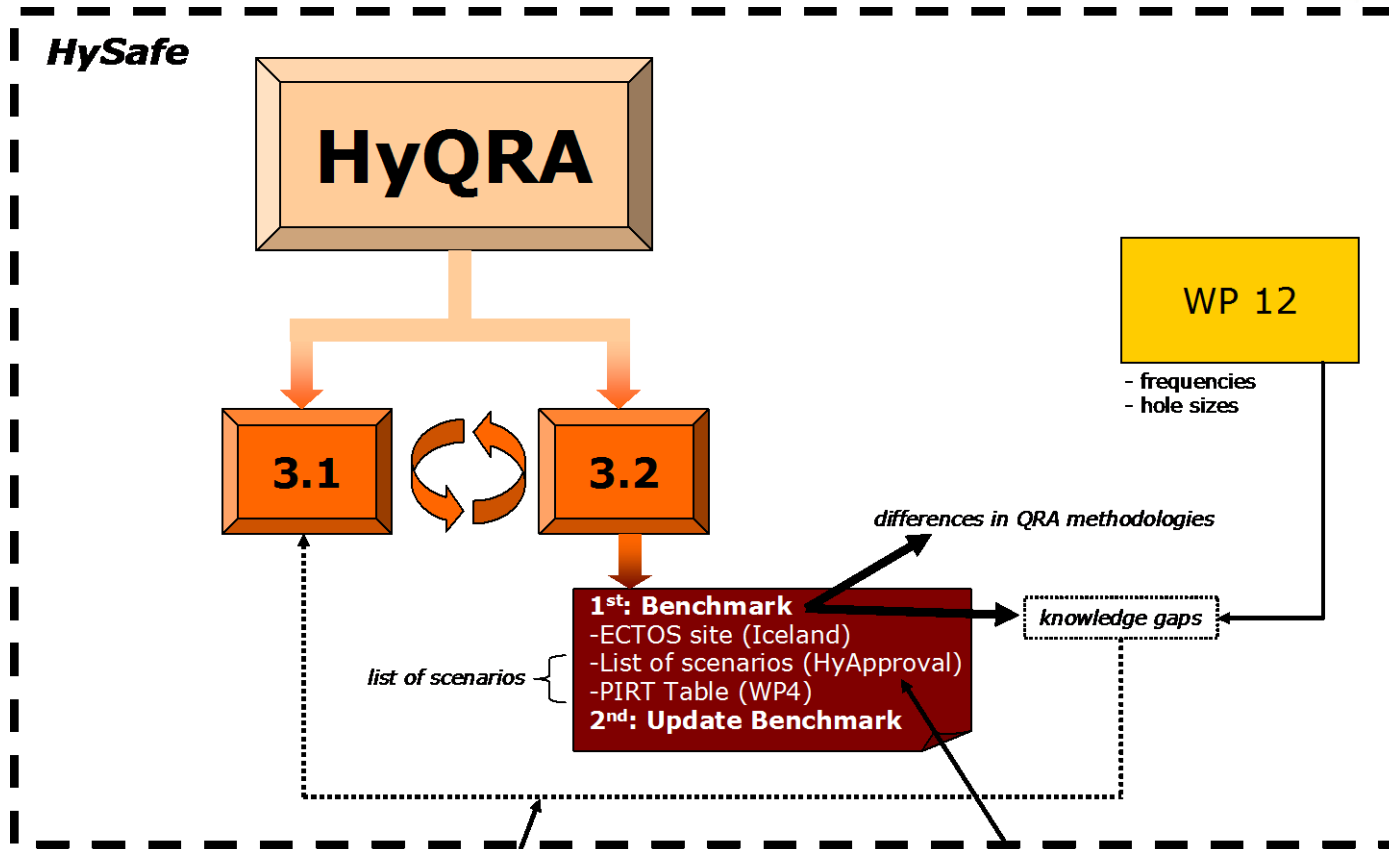


Benchmark exercise, expected outcomes

- Identification of differences in QRA methodologies and expressions of risk concepts
- Identification of knowledge gaps on data used in various QRA steps, specifically for hydrogen
- For this purpose, a not too detailed reference installation would provide sufficient insight in the various concepts, but with flexibility to demonstrate risk approaches both for on-site as well as for off-site risks.
- We defined the 'Benchmark Base Case' hydrogen refuelling station: BBC.

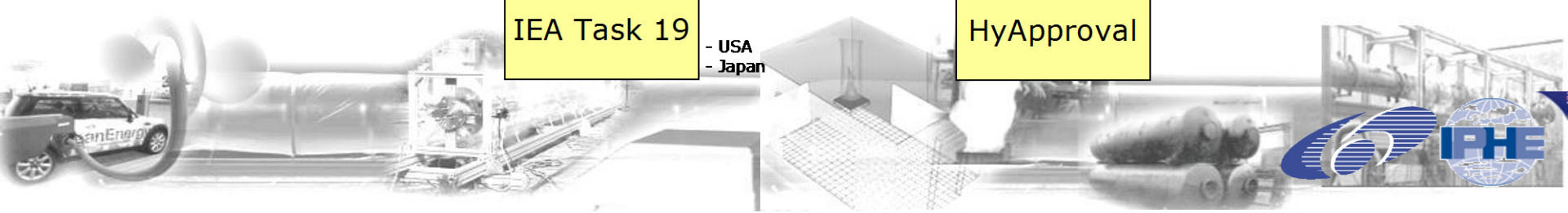


HyQRA Project Structure



IEA Task 19
- USA
- Japan

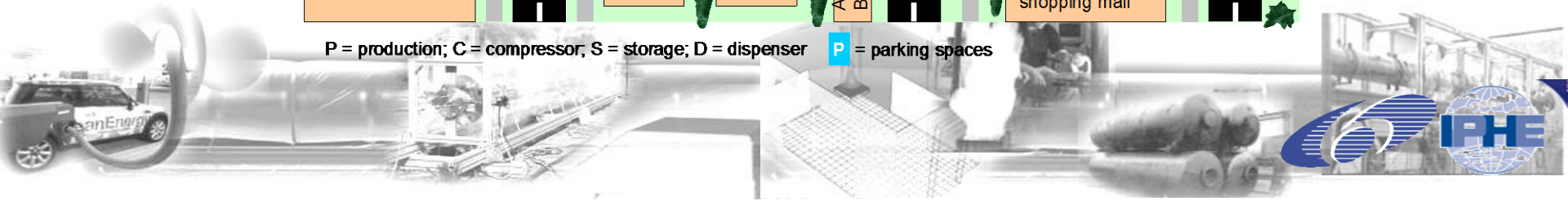
HyApproval



Surrounding geometry of the Benchmark Base Case - HRS



P = production; C = compressor, S = storage; D = dispenser P = parking spaces



Education and Training Offers



Home Page	Potential Students	Current Students	Staff Resources	Campus Information
---------------------------	------------------------------------	----------------------------------	---------------------------------	------------------------------------

Potential Students

PGCert Hydrogen Safety Engineering

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Introduction

The Postgraduate Certificate programme in Hydrogen Safety Engineering offered at the University of Ulster is the only such programme in the UK and worldwide, giving graduates the opportunity to specialise in a new field. The programme comprises of two 30 CATS point modules, namely, one on "Principles of Hydrogen Safety" and one on "Applied Hydrogen Safety".

The topical content of the modules complies with the International Curriculum on Hydrogen Safety <http://www.hysafe.org/index.php?ID=68> There is a growing need for specialists in hydrogen safety engineering. Graduates with a PGCert in Hydrogen Safety Engineering will be suitably qualified for employment opportunities at various industrial corporations, governmental bodies, research organisations, and educational institutions.

Quick Facts

Course Name
PGCert Hydrogen Safety Engineering

Faculty
Engineering

Course Code(s)
PGCert: C514PJ

Duration
PGCert: One year (two semesters)

Progress in Hydrogen Safety
International short course series

Hydrogen and fuel cell technologies: Safety issues

29 September - 3 October 2008, Belfast, UK



Early booking recommended for all courses!

for details see www.hysafe.net/PGC

Further courses in 2008/2009 series

Hydrogen regulation, codes and standards
January 2009

Safety of hydrogen fuelled vehicles
April 2009

The hydrogen and fuel cell infrastructure
June 2009

Supported by

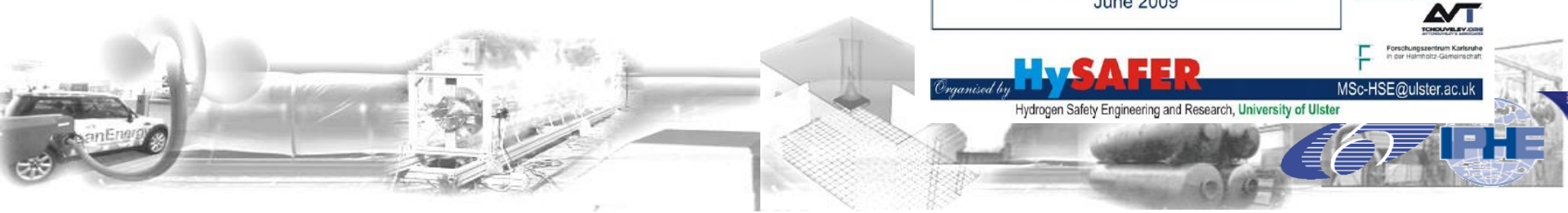
HySAFER

Organised by
Hydrogen Safety Engineering and Research, University of Ulster

F

Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

MSc-HSE@ulster.ac.uk



Invitation to the 3rd Int. Conf. on Hydrogen Safety

September 16-18th, 2009

Ajaccio, Corse, France



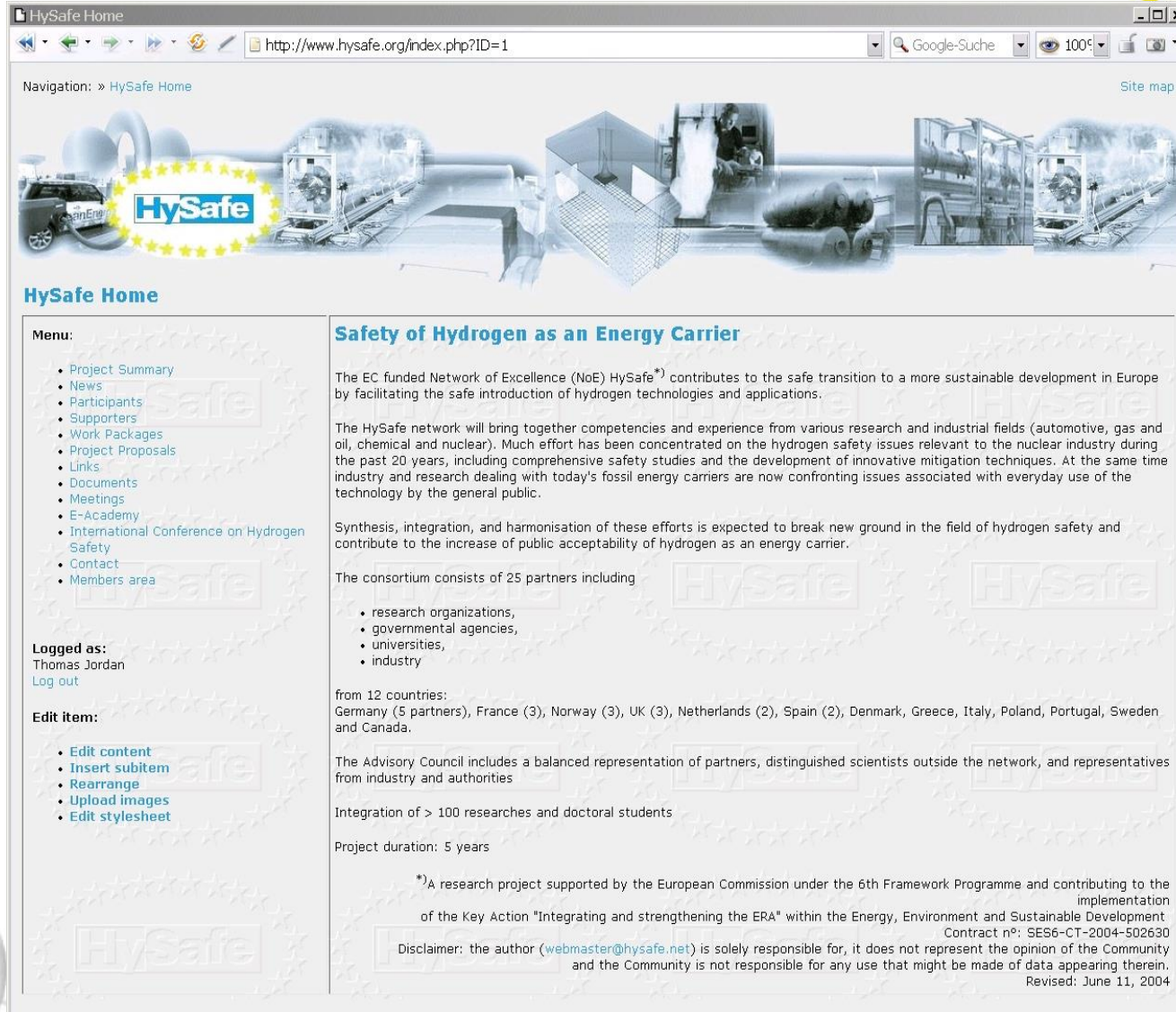
Contact: ICHS@hysafe.org

INTERNATIONAL CONFERENCE ON HYDROGEN SAFETY

All Information → www.hysafe.net



HySafe



The screenshot shows a web browser window with the URL <http://www.hysafe.org/index.php?ID=1>. The page features a navigation bar, a site map, and a main content area. The main content area is titled "HySafe Home" and includes a menu, a section on "Safety of Hydrogen as an Energy Carrier", and a disclaimer.

Navigation: » HySafe Home Site map

HySafe Home

Menu:

- Project Summary
- News
- Participants
- Supporters
- Work Packages
- Project Proposals
- Links
- Documents
- Meetings
- E-Academy
- International Conference on Hydrogen Safety
- Contact
- Members area

Logged as:
Thomas Jordan
[Log out](#)

Edit item:

- [Edit content](#)
- [Insert subitem](#)
- [Rearrange](#)
- [Upload images](#)
- [Edit stylesheet](#)

Safety of Hydrogen as an Energy Carrier

The EC funded Network of Excellence (NoE) HySafe^{*)} contributes to the safe transition to a more sustainable development in Europe by facilitating the safe introduction of hydrogen technologies and applications.

The HySafe network will bring together competencies and experience from various research and industrial fields (automotive, gas and oil, chemical and nuclear). Much effort has been concentrated on the hydrogen safety issues relevant to the nuclear industry during the past 20 years, including comprehensive safety studies and the development of innovative mitigation techniques. At the same time industry and research dealing with today's fossil energy carriers are now confronting issues associated with everyday use of the technology by the general public.

Synthesis, integration, and harmonisation of these efforts is expected to break new ground in the field of hydrogen safety and contribute to the increase of public acceptability of hydrogen as an energy carrier.

The consortium consists of 25 partners including

- research organizations,
- governmental agencies,
- universities,
- industry

from 12 countries:
Germany (5 partners), France (3), Norway (3), UK (3), Netherlands (2), Spain (2), Denmark, Greece, Italy, Poland, Portugal, Sweden, and Canada.

The Advisory Council includes a balanced representation of partners, distinguished scientists outside the network, and representatives from industry and authorities

Integration of > 100 researches and doctoral students

Project duration: 5 years

*)A research project supported by the European Commission under the 6th Framework Programme and contributing to the implementation of the Key Action "Integrating and strengthening the ERA" within the Energy, Environment and Sustainable Development
Contract n°: SES6-CT-2004-502630

Disclaimer: the author (webmaster@hysafe.net) is solely responsible for, it does not represent the opinion of the Community and the Community is not responsible for any use that might be made of data appearing therein.
Revised: June 11, 2004



Support

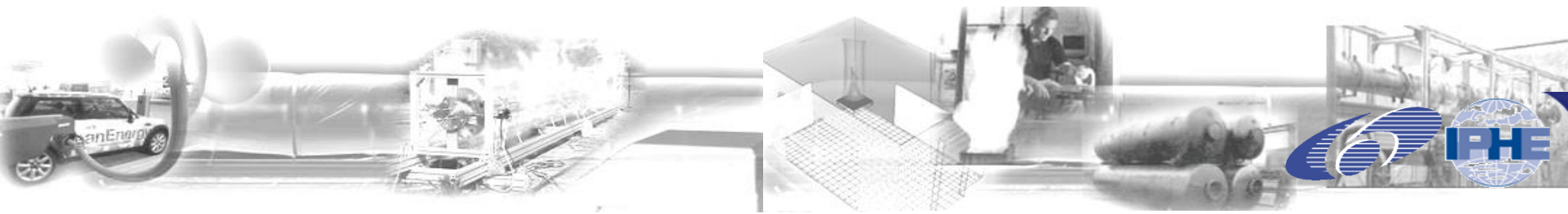


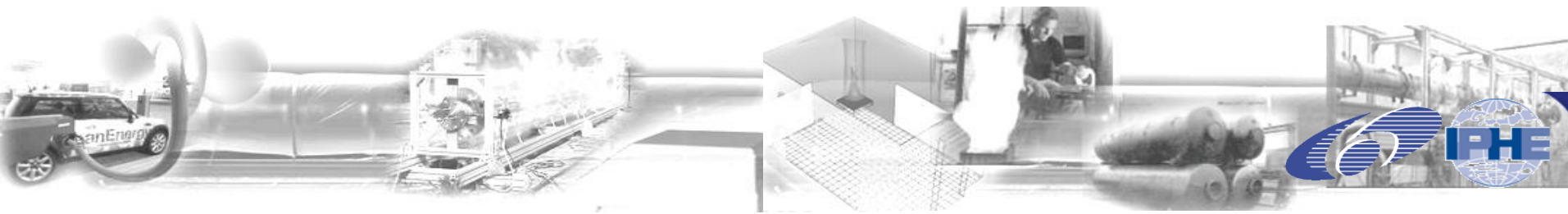
NoE HySafe is co-funded by the European Commission within the 6th Framework Programme (2002-2006); Contract n°: SES6-CT-2004-502630.

The network is contributing to the implementation of the Key Action "Integrating and strengthening the ERA" within the Energy, Environment and Sustainable Development.

Thanks to all HySafe colleagues...

... and thank you for your attention.





Post Graduate Certificate



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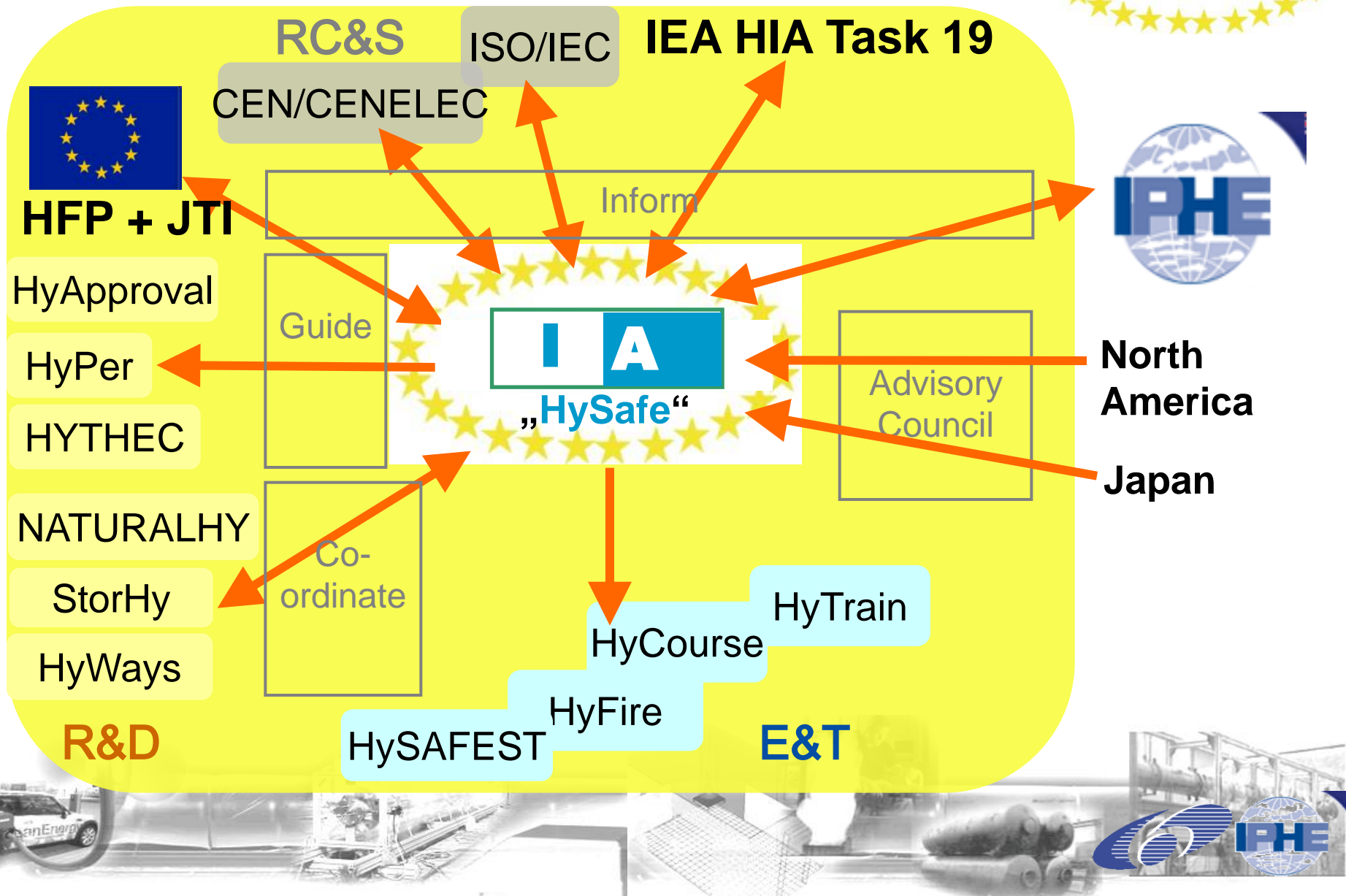
PGCert: C514PJ

Duration

PGCert: One year (two semesters)

for details see www.hysafe.net/eAcademy

External Networking



RC&S

ISO/IEC

IEA HIA Task 19

CEN/CENELEC



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Guide



Advisory Council

North America

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HYTHEC

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Co-ordinate

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HyWays

HyFire

R&D

HySAFEST

E&T

