STACY – Towards Safe Storage and Transportation of Cryogenic Hydrogen

Ernie Reinecke, Nabiha Chaumeix, Ahmed Bentaib, Hirohisa Tanaka

ELVHYS Workshop No. 1, Air Liquide, June 21, 2023

European Interest Group (EIG) CONCERT-Japan

European Interest Group (EIG) CONCERT-Japan

- 13 science, technology and innovation (STI) funding agencies from 11 European countries and Japan
- supporting Japanese-European research collaboration in a variety of fields
- supporting sustainable and multilateral research cooperation, especially promoting the transnational mobility between European and Japanese researchers

➔ **Focus on Networking**

European Interest Group (EIG) CONCERT-Japan

Call 2021: „Sustainable Hydrogen Technology as Affordable and Clean Energy"

- Ammonia hydrogen combustion in micro gas turbines (ADONIS)
- Structure-based metabolic engineering of algal H_2 production (H2M)
- **Towards Safe Storage and Transportation of Cryogenic Hydrogen (STACY)**
- Japanese-European Research Collaboration of New Affordable and Durable Electrocatalysts for Fuel Cells (NADC-FC)
- Sustainability development and cost-reduction of hybrid renewable energies powered Hydrogen stations by risk-based multidisciplinary approaches (SUSHy)
- Enhancement of Hydrogen Storage Properties of AlTiVCr Light Weight High Entropy Alloys (HEA) by Ti_3C_2 MXene and Severe Plastic Deformation (EHSAL)

STACY – Towards Safe Storage and Transportation of Cryogenic Hydrogen

Background

- World-wide efforts to decarbonize the energy sector with increasing fraction of renewable energies
- Energy storage technologies required to store excess energy generated from fluctuating sources
- Large-scale storage and transportation of liquefied (cryogenic) hydrogen (LH2) expected to play a fundamental role in a potential future hydrogen economy

➔ **Safe implementation of LH2 storage and transportation technologies mandatory with regard to economic benefit and public acceptance**

LH2-related safety issues

HySafe Research Priority Workshop, Québec, October 2023

- LH2 spills on water → spontaneous ignition
- Impact of fire-loads on multi-layer insulation and tanks
- Maritime – High ranked hazards:
  - **Confined and unconfined explosions**
  - Cryogenic spills on steel
  - **Accumulation of flammable gas mixtures**
  - Dense gas dispersion from LH2 releases
  - Rapid Phase Transition

STACY – Main Objectives

Contribute to the safety assessment of LH2 storage and transportation on long-distance carriers

(1) determine **fundamental safety-related combustion parameters** not yet available in the open literature,

(2) study **mitigation by means of catalytic recombiners** to prevent the formation of flammable gas mixtures in case of leakages,

(3) simulate potential **hydrogen release scenarios** and **efficiency of mitigation measures**.

STACY – Main Objectives

Contribute to the safety assessment of LH2 storage and transportation on long-distance carriers

(1) dete **para** ustion ature,

(2) stud to p in ca **biners** xtures

(3) simulate potential **hydrogen release scenarios** and **efficiency of mitigation measures**.

&

Focus on Networking and Collaboration between European and Japanese Institutions

STACY – Research Team

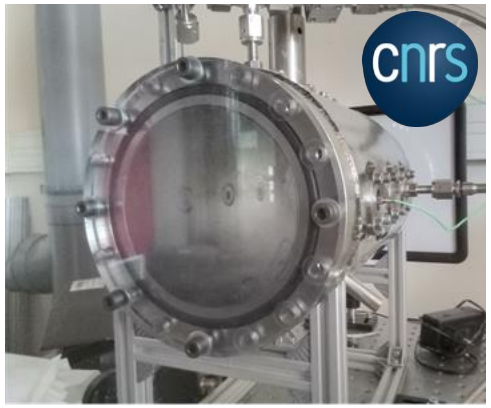
Expertise in the fields of combustion, recombination, catalysis, hydrogen safety assessment

- **CNRS-ICARE**: Flame and explosion dynamics, explosion safety, involved in industrial projects and research programs
- **IRSN**: Hydrogen safety assessment in nuclear power plants, involved in development of safety assessment methodologies and risk prevention procedures
- **KGU**: Catalyst development, involvement in “intelligent catalyst” development at Daihatsu Motor Co., Ltd.
- **FZJ**: Hydrogen recombiners, involvement in industrial recombiner development and recombiner qualification

STACY – Specific Objectives (1)

(1) Fundamental safety-related combustion properties of H_2

- Background: Knowledge gaps for low temperatures identified in the PRESLHY project
- Experiments at combustion laboratory at CNRS/ICARE
  - the flammability domain
  - the flame speed
  - the expansion ratio



➔ **Criteria for e.g. flammability, laminar flame speed and flame acceleration under low temperatures**

STACY – Specific Objectives (2)

(2) Mitigation by means of catalytic recombiners

- Develop and qualify a specific catalyst to operate under the typical conditions of a LH2 carrier
- Catalyst development, manufacturing, and lab-scale testing at KGU (Japan)
- Recombiner qualification at FZJ (Germany)

➔ **Numerical model to describe recombiner operation**

STACY – Specific Objectives (2)

(2) Mitigation by means of catalytic recombiners

- Performance assessment of both commercial and generic recombiner

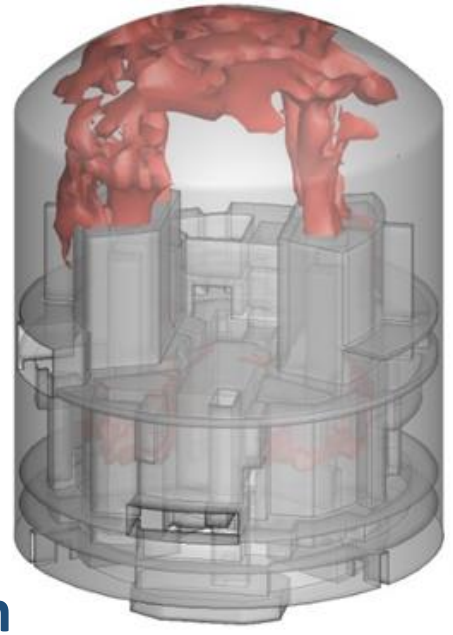
➔ **Numerical model to describe recombiner operation**

STACY – Specific Objectives (3)

(3) Simulation of potential hydrogen release scenarios and efficiency of mitigation measures

- Further develop numerical methods to describe hydrogen release and mixing under specific conditions of LH2 transportation
- Application of well-proved codes
  - to study potential accident scenarios, and
  - to provide information on potential boundary conditions and locations for additional mitigation measures

➔ **Information on hazardous areas and the efficiency of mitigation measures (active and passive venting, catalytic recombiners)**



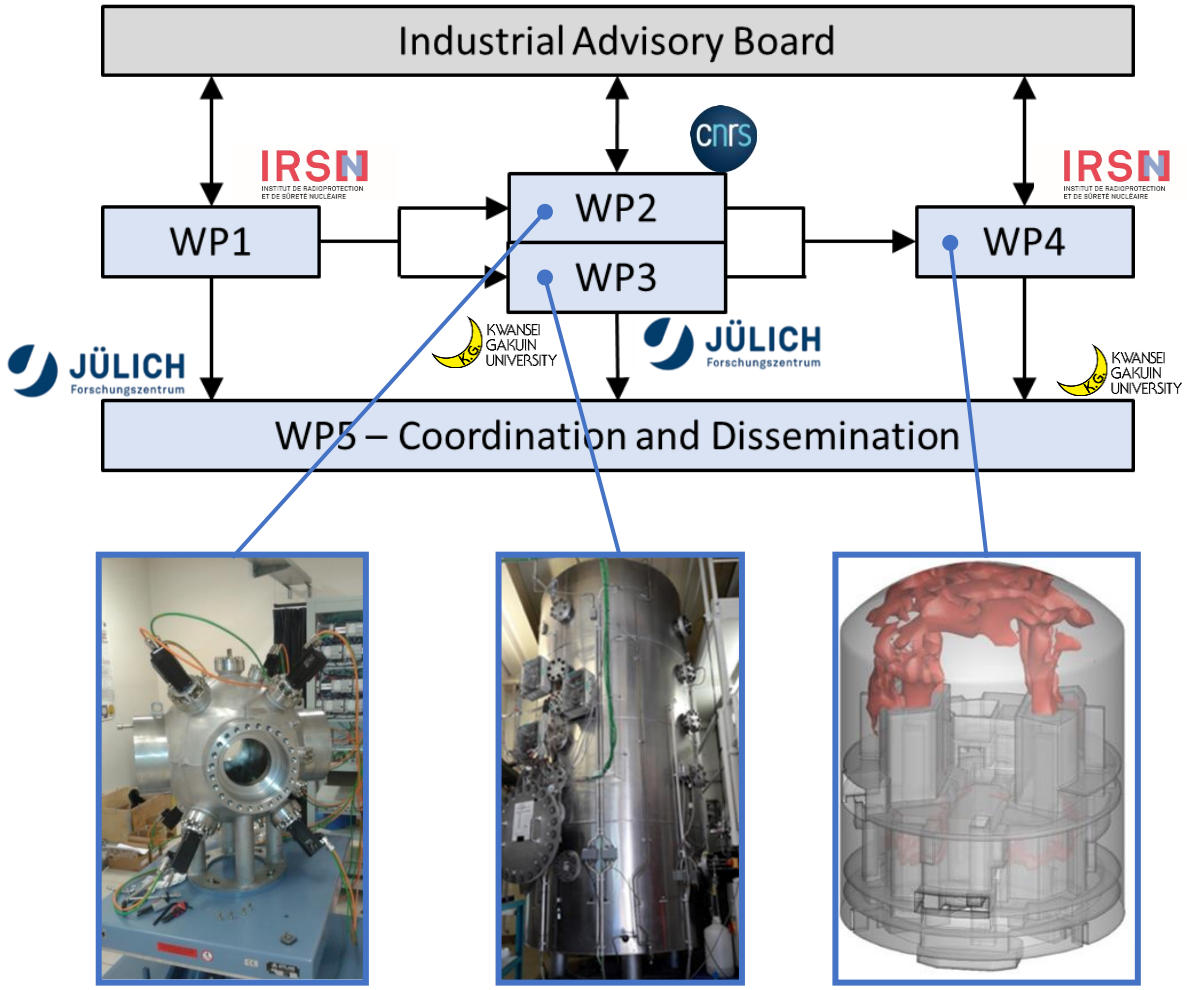
STACY – Industrial Advisory Board

Ensuring the relevance of the scientific research

• Kawasaki HI	LH2 carriers
• Daihatsu Motor Co.	LH2 storage, car catalyst
• JAEA	Hydrogen safety in nuclear power plants
• Air Liquide	Production, storage, and distribution of GH2/LH2
• CCD	Prototyping catalytic systems
• EnerSys-Hawker	Catalytic recombiners

STACY – Work Packages

- WP 1: Critical review
  and scenario identification
- WP 2: Combustion fundamentals
- WP 3: Catalytic recombination
- WP 4: Safety methodology assessment
- WP 5: Coordination and Dissemination



STACY – Schedule

Towards Safe Storage and Transportation of Cryogenic Hydrogen (STACY)	2022			2023				2024				2025		
	Q II	Q III	Q IV	Q I	Q II	Q III	Q IV	Q I	Q II	Q III	Q IV	Q I	Q II	Q III
	M1-3	M4-6	M7-9	M10-12	M13-15	M16-18	M19-21	M22-24	M25-27	M28-30	M31-33	M34-36		
		M1-3	M4-6	M7-9	M10-12	M13-15	M16-18	M19-21	M22-24	M25-27	M28-30	M31-33	M34-36	
		M1-2	M3-5	M6-8	M9-11	M12-14	M15-17	M18-20	M21-23	M24-26	M27-29	M30-32	M33-35	M36
AP 1 - Critical Review and Scenario Identification														
Task 1.1 - Critical review of methodologies/practices														
Task 1.2 - Identification of relevant scenarios				MS1										
AP 2 - Combustion Fundamentals														
Task 2.1 - Experiments on flammability limits														
Task 2.2 - Experiments on laminar flame speed											MS2			
AP 3 - Catalytic recombination														
Task 3.1 - Catalyst selection and preparation														
Task 3.2 - Catalyst/recombiner characteristics														
Task 3.3 - Development of correlation model												MS3		
AP 4 - Application of the Safety Methodology														
Task 4.1 - Implementation of results														
Task 4.2 - Assessment of safety measures														
AP 5 - Coordination and Dissemination														
Task 5.1 - Project coordination														
Task 5.2 - Dissemination							R1							R2

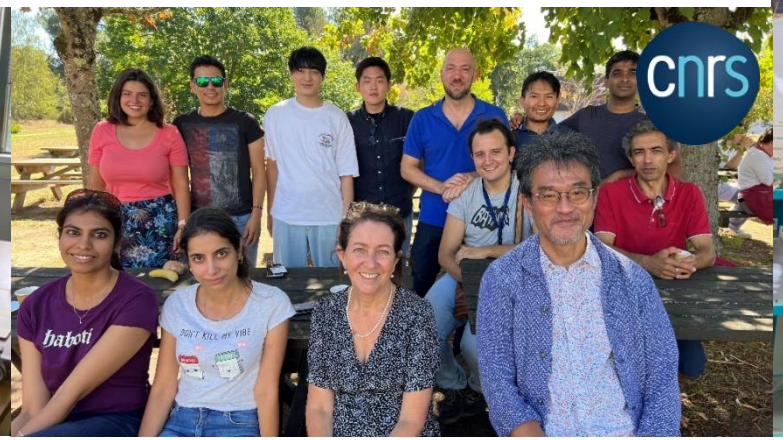
Intensifying International Collaboration

September 5-9, 2022: KGU@FZJ Jülich

- Collaborative use of experimental facilities

September 12-14, 2022

- Visit of KGU@CNRS Orléans
- Visit of KGU@IRSN Paris



1st STACY Workshop

December 15, 2022,
Kobe International Conference Center, Japan

- Organized by Tanaka Laboratory, Endorsed by Kwansei Gakuin University
- Symposium
  - Lectures by STACY PIs and IAB
- LH2 excursion through the courtesy of Kawasaki Heavy Industries
  - Hydrogen co-generation system
  - LH2 receiving terminal
- Young Generation Workshop
- Technical Tour to SPring-8 synchrotron radiation facility

International Dissemination

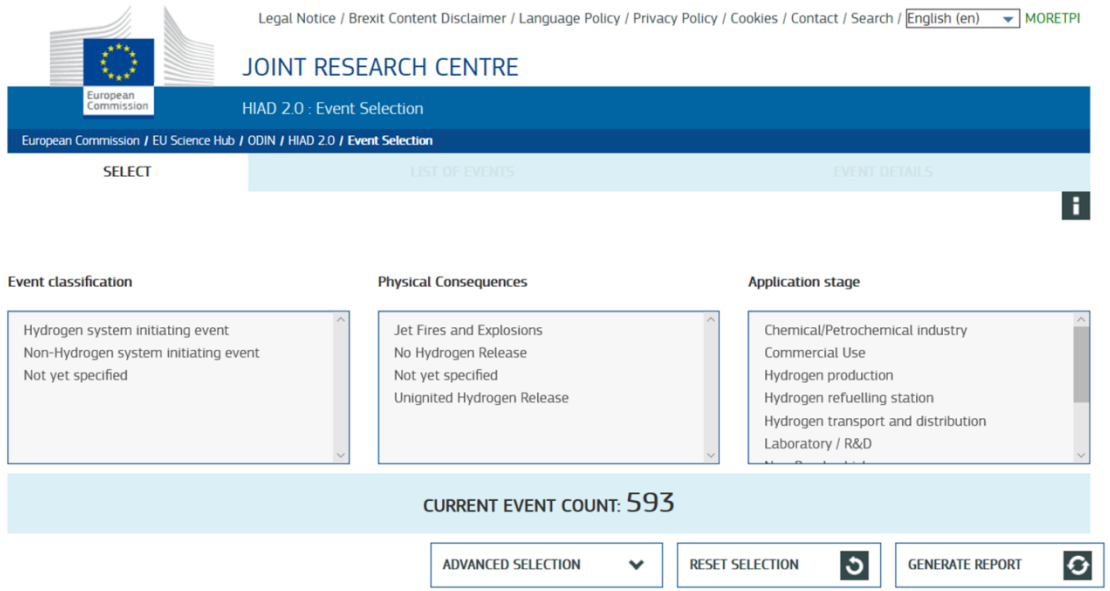
International Workshops and Seminars

- HySafe Research Priorities Workshop
  November 21-23, 2022, Quebec, Canada
- CNL Hydrogen Safety Workshop
  November 24-25, 2022, Ottawa, Canada
- Int. Workshop on Hydrogen Safety for NPPs
  January 19-20, 2023, Fontenay-aux-Roses, France
- 1st SUSHy Joint Workshop
  March 9-10, 2023, Bergen, Norway (online)
- ESKHYMO: LH2 - Technical Workshop
  March 29-30, 2023, Paris, France

International Knowledge Management

Collaboration on Accident Databases

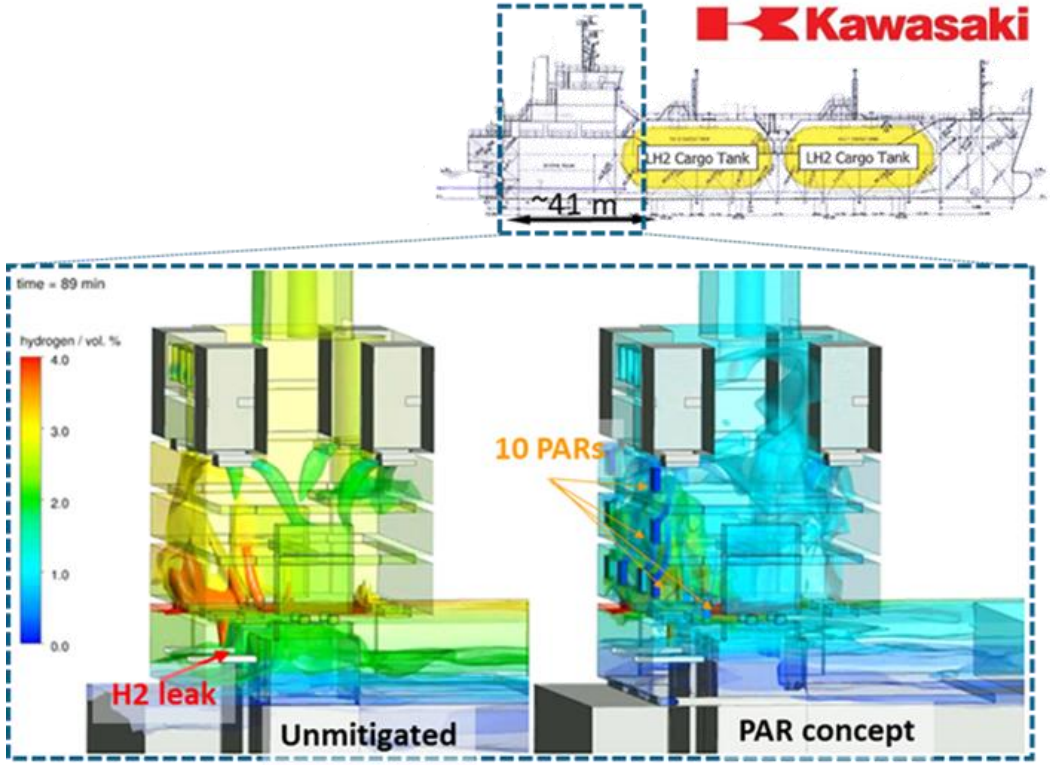
- Effort to stimulate collaboration between the European Hydrogen Safety Panel and Japanese experts
- Effort to exchange information, e.g. through databases on hydrogen incidents and accidents
- Meeting with High Pressure Gas Safety Institute of Japan (KHK) on June 16, 2023



HIAD 2.0 – Hydrogen Incident and Accident Database

Conclusions

- Contribution to LH2-related safety technologies, numerical models and methodologies for risk assessment
- Stimulate networking activities to promote hydrogen safety between European and Japanese institutions
- Exchange of hydrogen safety-relevant information through databases



Kelm et al., Simulation of H2 mixing and PAR operation during accidental release in an LH2 carrier engine room, ICHS, 2021

Thank You For Your Kind Attention !

https://stacy-project.eu

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

anr agence nationale de la recherche
AU SERVICE DE LA SCIENCE

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung