Launch of the STACY Project – Towards Safe Storage and Transportation of Cryogenic Hydrogen

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International Conference on Hydrogen Safety, Québec City, Canada, September 19-21, 2023

European Interest Group (EIG) CONCERT-Japan

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- 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

➔ **Research-Network between Europe and Japan**

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 City, October 2022

- High ranked hazards, relevant for maritime transportation:
  - **Confined and unconfined explosions**
  - Cryogenic spills on steel
  - **Accumulation of flammable gas mixtures**
  - Dense gas dispersion from LH2 releases
  - …

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

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Focus on Networking and Collaboration between European and Japanese Institutions

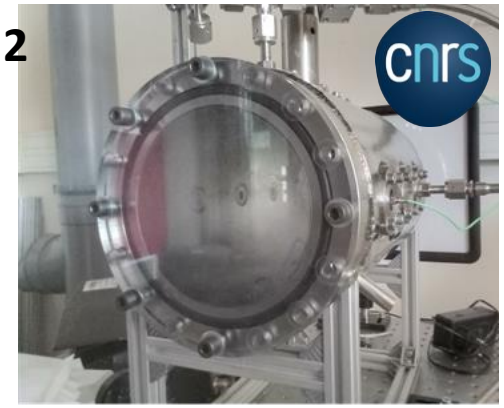
STACY – Research Team

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



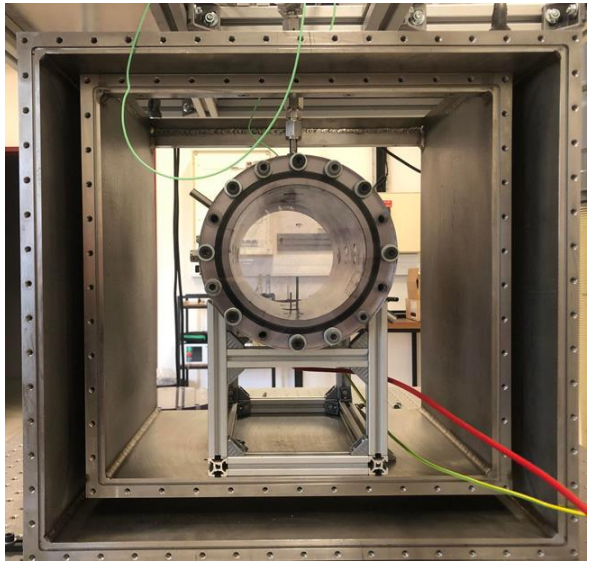
- Background: Knowledge gaps for low temperatures identified in the PRESLHY project
- Experiments at combustion laboratory at CNRS/ICARE
  - the flammability domain
  - the flame speed
  - the expansion ratio

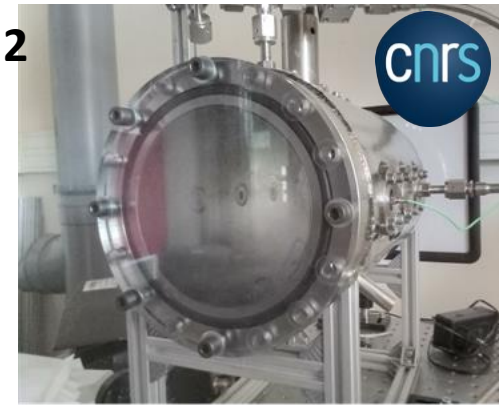
➔ **Criteria for e.g. flammability, laminar flame speed and flame acceleration under low temperatures**

STACY – Specific Objectives (1)

(1) Fundamental safety-related combustion properties of H_2

- Double-walled box for vacuum insulation
- Circulation of refrigerant fluid
  within double layer of cylindrical bomb
  → -20 °C with commercial cryostat
  → -180 °C with in-house cryostat





➔ **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

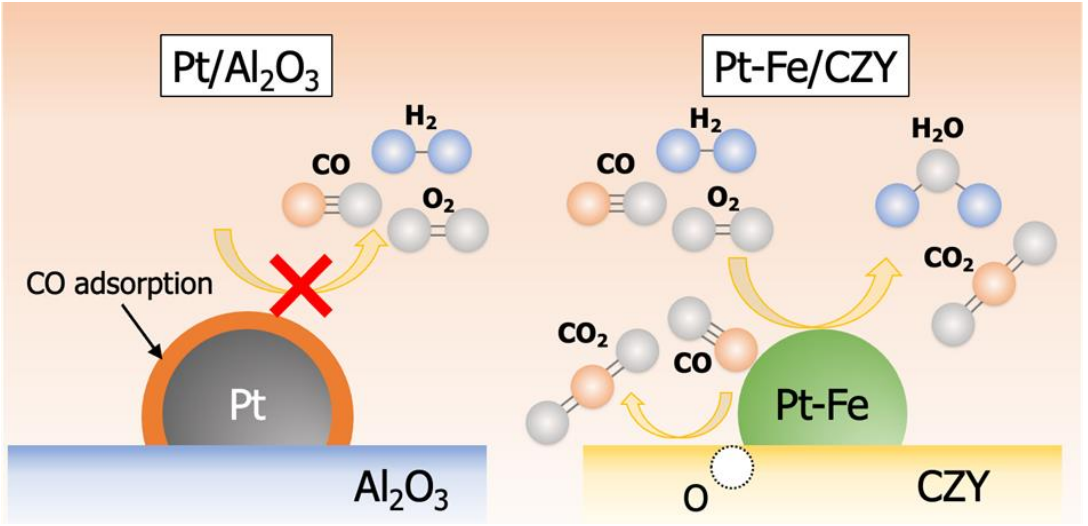
- Develop and qualify a specific catalyst to operate under the typical conditions of a LH2 carrier
- Catalyst development, manufacturing, and lab-scale testing at KGU (Japan)
- Recombiner qualification at FZJ (Germany)

➔ **Numerical model to describe recombiner operation**

STACY – Specific Objectives (2)

(2) Mitigation by means of catalytic recombiners

Issues	Solution
1) Cryogenics	Nano-particulation, Intelligent Catalyst
2) Ignition	Multi-stage design
3) High Flow	Nano-particulation
4) Poisoning	Utilizing technology accumulation through materials research Water / CO / Oxygen



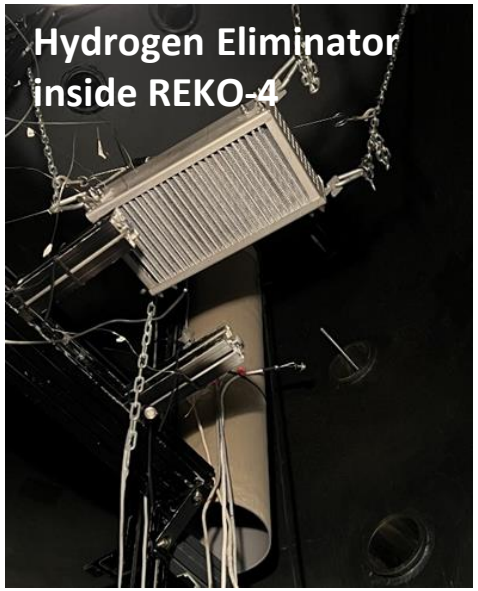
➔ **Numerical model to describe recombiner operation**

STACY – Specific Objectives (2)

(2) Mitigation by means of catalytic recombiners


EnerSys-Hawker – Hydrogen Eliminator

- Determination of operational characteristics at temperatures down to -80 °C


Hydrogen Eliminator inside REKO-4

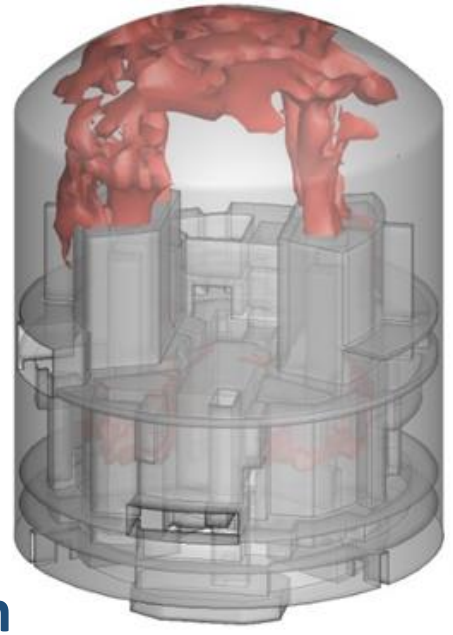
➔ **Numerical model to describe recombiner operation**

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

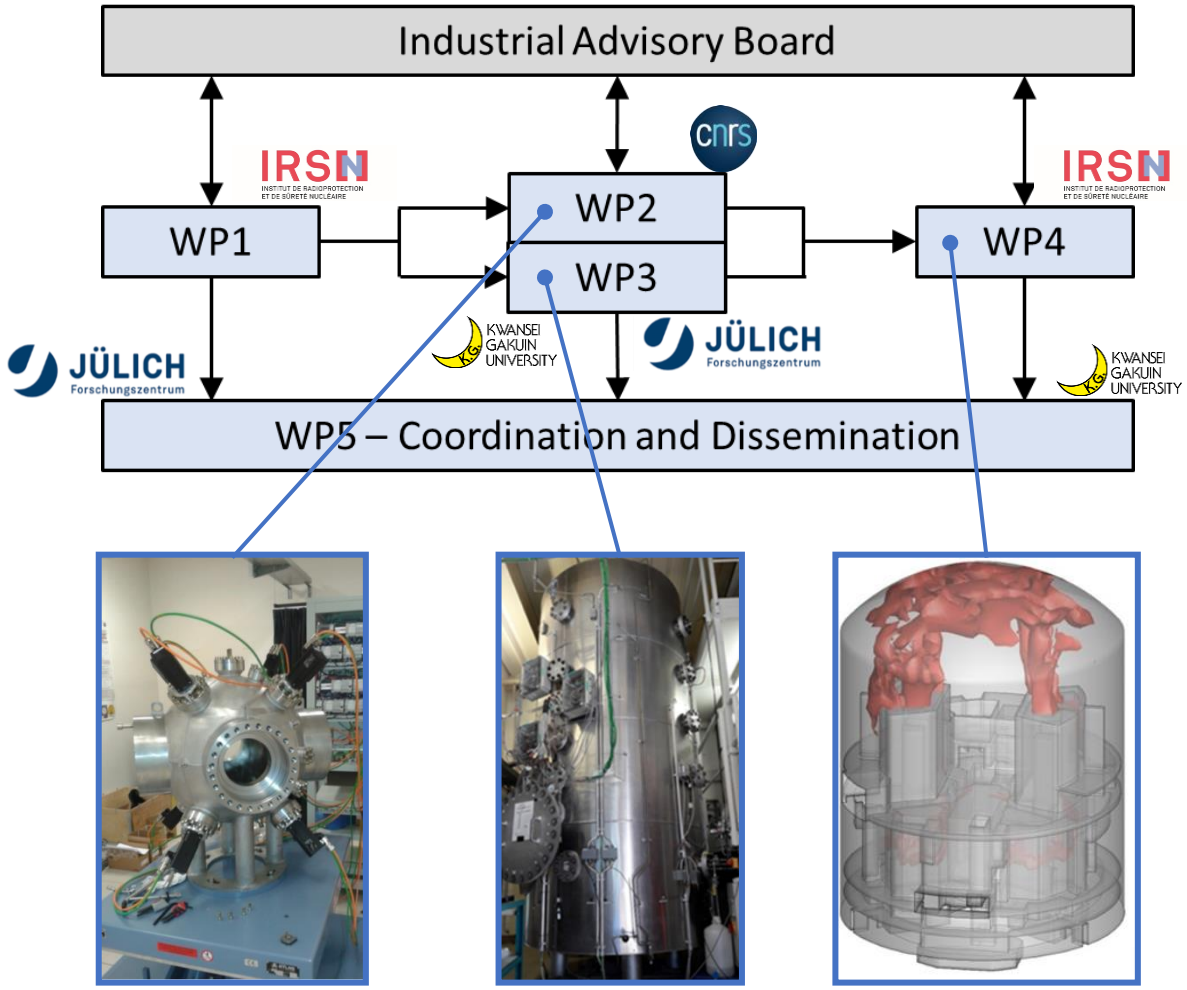
Ensuring the relevance of the scientific research

• 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

Duration: March 2022 – July 2025

- 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



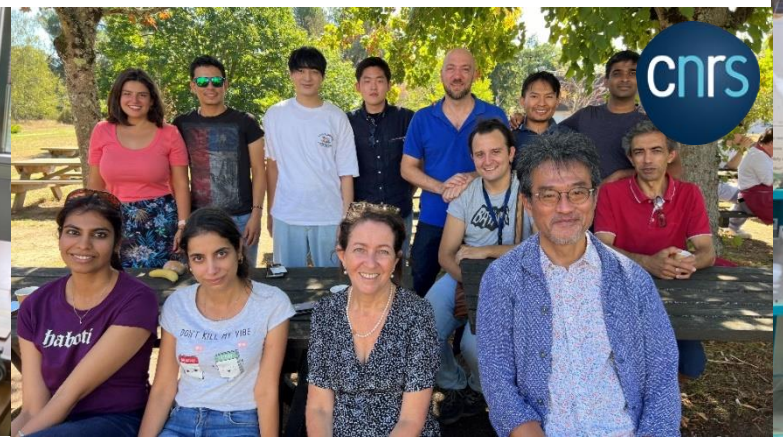
Intensifying International Collaboration

September 5-13, 2022

- Collaborative performance of experiments @FZJ
- Visit of CNRS/Orléans and IRSN/Paris

September 7-13, 2023

- Collaborative performance of experiments @FZJ



1st STACY Workshop

December 15/16, 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

2nd STACY Workshop

September 4/5, 2023, CNRS, Orléans, France

- Organized by ICARE
- Symposium
  - Lectures by STACY PIs, IAB and related projects
    - KHI, AirLiquide, Cataler Corp.
    - Didier Bouix, EOCONCEPT
    - French national project AIDHy
    - SUSHy, ELVHYS, ESKHYMO
- Young Generation Workshop
  - CORIA (Rouen University)
  - Pprime (Poitiers University)
- Lab Tour
  - Combustion research
  - Atmosphere research
  - Space propulsion

International Dissemination

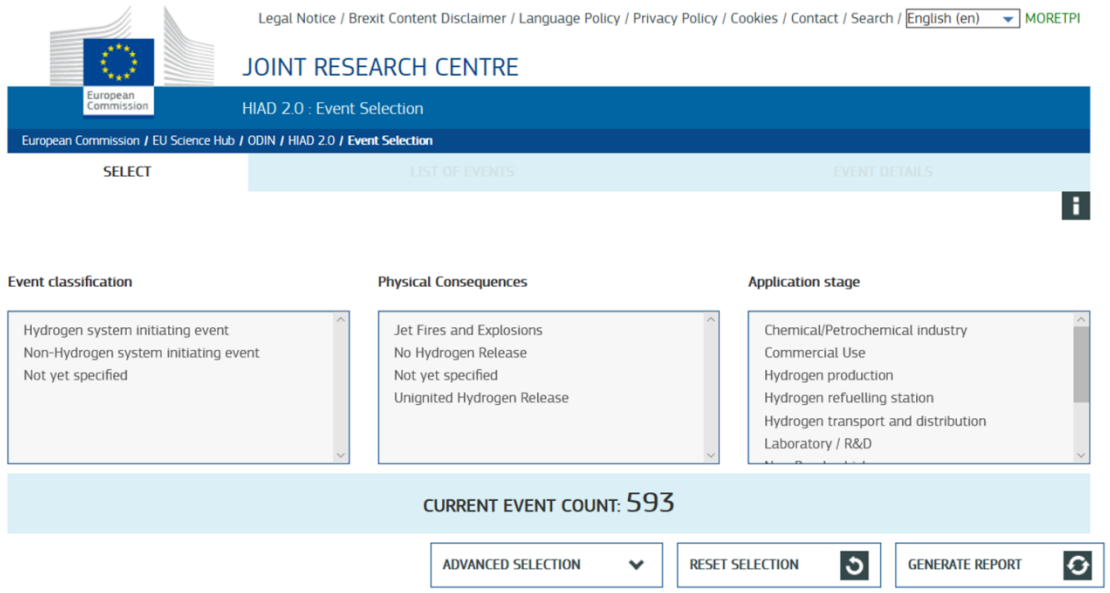
International Workshops and Seminars

- 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
- ELVHYS 1st Stakeholder's Workshop
  June 21, 2023, Paris, France (online)

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



HIAD 2.0 – Hydrogen Incident and Accident Database

International Knowledge Management

Potential Japanese Databases

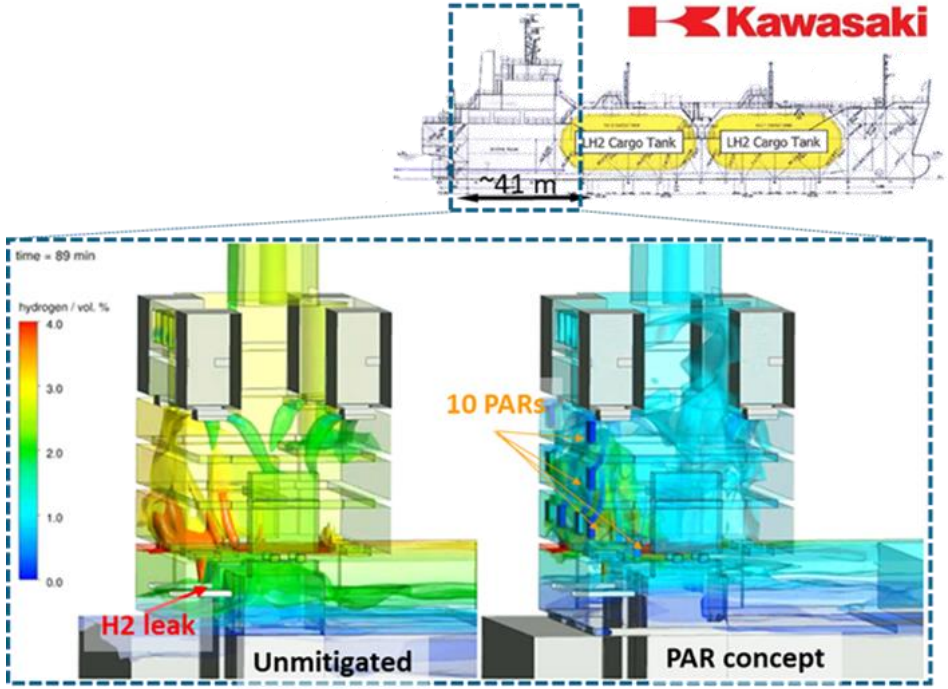
- The High Pressure Gas Safety Institute of Japan (KHK)

➔ On-line meeting with KHK on June 16, 2023

➔ Invitation of JRC/HIAD to Japanese Hydrogen Safety Workshop on September 25, 2023

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

- The authors thank the European Interest Group CONCERT-Japan for their support of the project in the framework of the 8th Joint Call "Sustainable Hydrogen Technology as affordable and clean energy".
- The German sub-project of the joint project STACY is funded by the German Federal Ministry of Education and Research under grant number 01DR22007.
- The French sub-project acknowledges the financial support of the French government within the program "EIG CONCERT-JAPAN" – STACY Grant agreement n° ANR-22-HTCE-0003-02.
- The joint project STACY is supported by Strategic International Collaborative Research Program of Japan Science and Technology Agency (JST SICORP), Grant Number JPMJSC21C3, Japan.

Thank you for your kind attention !

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GEFÖRDERT VOM