HYDROGEN IMPLEMENTING AGREEMENT

Natural Resources Canada

Ressources naturelles Canada

Sandia National Laboratories

Pacific Northwest NATIONAL LABORATORY

NREL

JRC EUROPEAN COMMISSION

International Energy Agency
Hydrogen Implementing Agreement
Task 31 - Collaboration on Hydrogen Safety

ENAA

AIR LIQUIDE

KIT Karlsruhe Institute of Technology

UQTR Université du Québec à Trois-Rivières Savoir. Surprendre.

cmr Gexcon

United Technologies

Høgskolen i Telemark

INERIS controlling risks for sustainable development

AVT

UNIVERSITÀ DI PISA

SRI International

University of ULSTER

HEALTH & SAFETY LABORATORY

TNO

cea

Toho University

William Hoagland
Element One, Inc.
May 15, 2012

Project ID: SCS013

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Project Start: Oct 1, 2010
- Project End: Oct 1, 2013
- % Complete: 50%

Budget

- Total Project Funding
  - DOE: $185K
  - NRCAN: $185K
- Funding FY11: $126 K
- Planned FY12: $104 K

Barriers

- Limited access and availability to safety data & information
- Lack of knowledge by AHJs
- Insufficient data to revise standards
- availability and affordability of insurance
- Lack of harmonization of RCS
- Lack of hydrogen training materials for emergency responders

Partners

- **Partners:** Natural Resources Canada
- **Collaborators:** Canada, European Commission/JRC, France, Germany, Greece, Italy, Japan, UK, Netherlands, Norway, Switzerland, U.S.
- Project Lead: W. Hoagland

Relevance to DOE Objectives

DOE MYPP 3.7 (2011 Draft): Safety, Codes and Standards

- R&D that provides experimentally validated fundamental understanding of the relevant physics, critical data, and safety information needed to define requirements for technically sound and defensible codes and standards.
- Collaborative efforts among governments, industry, SDOs, universities, and national laboratories to harmonize domestic and international regulations, codes and standards (RCS).

IEA HIA Mission

- To accelerate hydrogen implementation and widespread utilization of hydrogen energy systems.

Task 31 Hydrogen Safety – Project Objectives

- To conduct a collaborative R&D program to develop risk informed predictive methods, data and other information to facilitate the adoption of risk-informed codes and standards.

Relevance – Impact

RCS for the safe deployment of hydrogen and fuel cell technologies in the U.S. and major international markets that are

- Based on sound and traceable technical and scientific data and analysis;
- Harmonized with global technical regulations and codes and standards;
- Not unnecessarily restrictive or overly conservative;
- Allow informed choices of design (most economic mitigation measures, equipment and safety factors; and
- Facilitate approvals, permits and insurability.

Task Collaborative Approach

This task is a unique, international collaboration that brings together the foremost hydrogen safety experts from 11 countries to:

- Share and discuss and reach consensus on:
  - unpublished R&D data and results;
  - data interpretation and technical insights;
  - national perspectives
  - R&D priorities,
  - Safety related technical barriers and knowledge gaps
- Provide coordinated input to national programs to minimize duplication and allocation of funds;
- Share status of codes and standards development to harmonize technical inputs, and;
- Develop products for stakeholders to facilitate codes and standards development, public acceptance, insurability and project approvals.

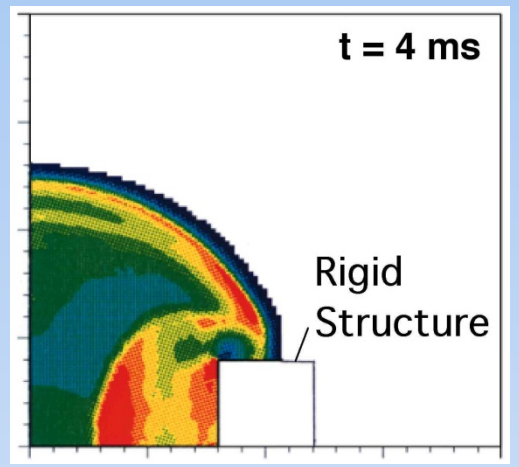
Estimated level of effort of R&D shared in the collaboration by each member country

	Person years
Canada	6
EC (JRC)	2
France	7
Greece	1
Germany	10
Italy	2.5
Japan	1
Norway	2
Netherlands	2
UK	2
USA	9
Total	44.5

Previous Task 19 Technical Approach: 2007–2010

Fundamental Data

Modeling



Component Testing

Mitigation Effects

Databases, Safety Events and Lessons Learned

Task 31 Technical Approach Work Scope 2010-2013

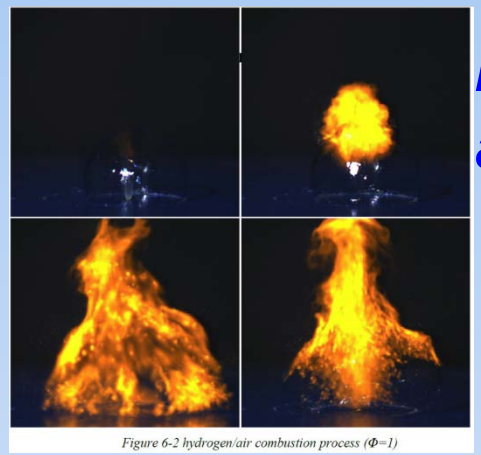
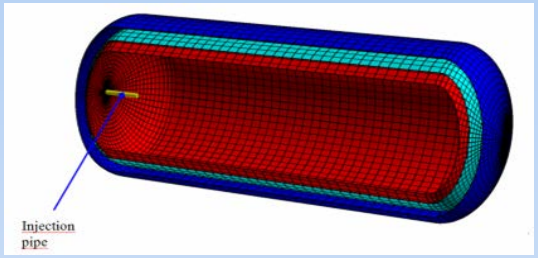


Figure 6-2 hydrogen/air combustion process (Φ=1)

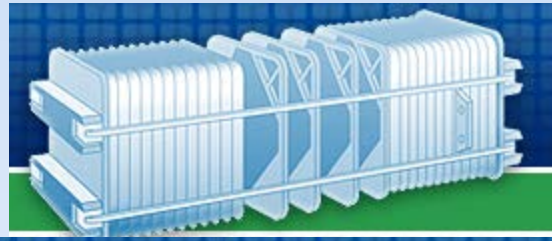
Physical phenomena and knowledge gaps

H2 Storage systems and materials compatibility



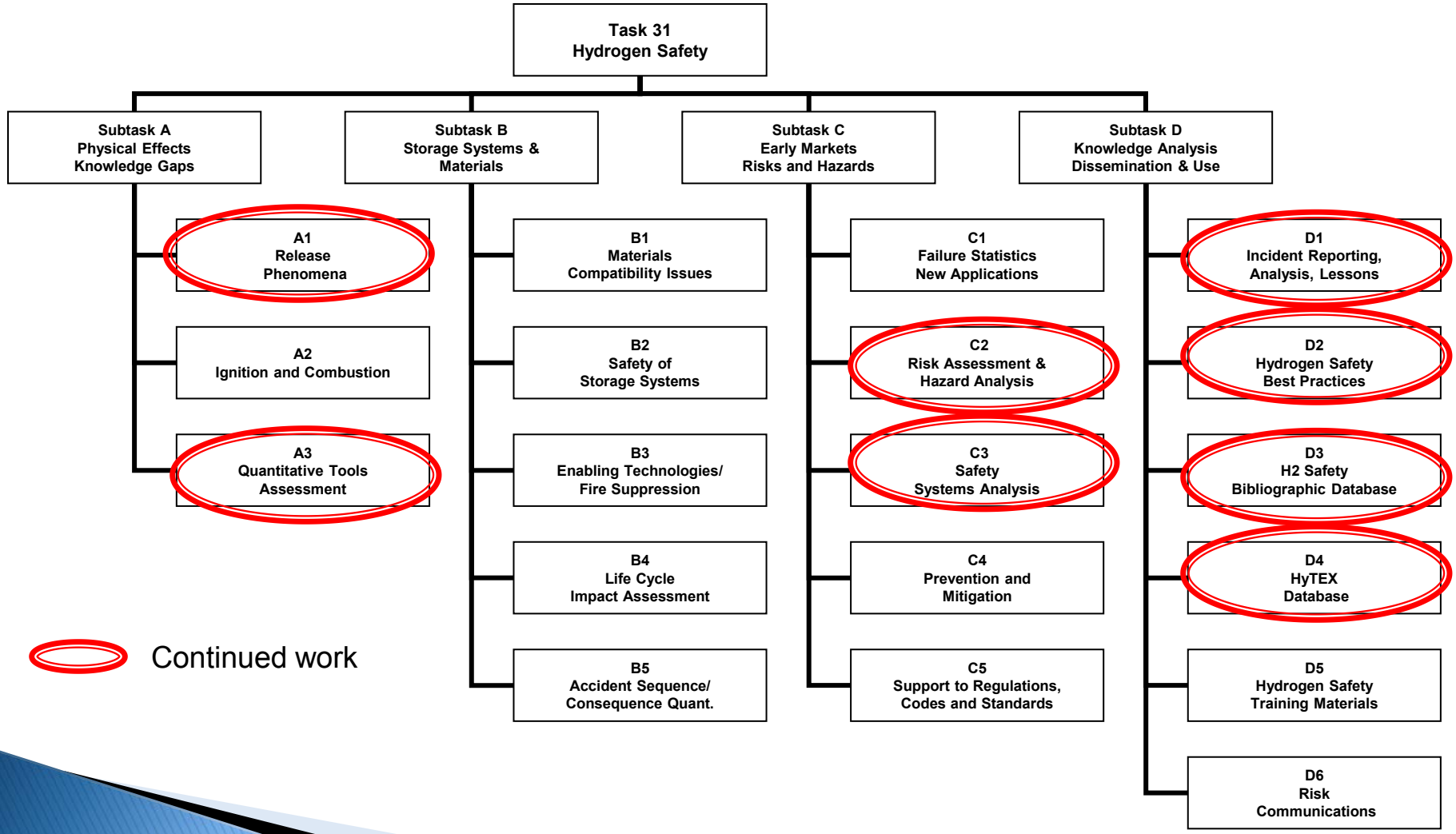
Early markets: risk characterization and hazards analysis

Knowledge analysis, dissemination and use



H_2 Incident Reporting and Lessons Learned

Task 31 Technical Approach
Work Breakdown Structure



Subtask A
Physical Effects – Knowledge Gaps

The task will tackle issues pertaining to sources, release phenomena, dispersion processes, ignition and combustion modes. Experimental, theoretical and numerical analyses are covered by this task.

This subtask addresses knowledge gaps on the physical and chemical properties of hydrogen as a gas or a liquid in support of the work performed in the other subtasks and to increase the knowledge base on hydrogen properties relevant to safety issues.

Subtask B
Hydrogen Storage Systems and Materials Compatibility

1. Safety, storage materials reactivity and risk mitigation of hydrogen storage in different forms;
2. Safety and risk mitigation measures of hydrogen storage systems and system interfaces for mobile and stationary applications;
3. On-board vehicular storage systems materials compatibility issues;
4. Enabling technologies for fire suppression systems and fire suppression agents compatible with different forms of hydrogen storage technologies; and
5. Safety categorization framework for hydrogen storage materials and associated life cycle impact assessment (LCIA).

Subtask C
Early Markets: Risk Identification and Hazard Analysis

This task will address the barriers to commercialization of hydrogen technologies for mobility, stationary and materials handling applications by tailoring safety assessment methods, data, and use of mitigation methods. The scope of this subtask will include the improvement in the data, models, and risk assessment methods to facilitate less restrictive RCS requirements through:

- Systematic data collection from new hydrogen-based operating facilities;
- Gathering failure/leak frequency data;
- Assessing specific risk mitigation technologies and methods such as sensors, barriers/walls and safety distances; and
- Analysis and communication of findings to stakeholders within international codes & standards development activities to ensure those requirements are risk-informed and evidence-based.

Subtask D
Knowledge Analysis, Dissemination and Use

Safety knowledge tools can take many forms and serve to help disseminate the wealth of information that already exists on the safe use and handling of hydrogen and to remove barriers to the successful commercialization of hydrogen and fuel cell technologies. This subtask seeks to

- Enhance databases and websites that have been integral work products and accomplishments of Task 19.
- Develop collaborations and tools to serve worldwide interest in expanded applications of hydrogen and hydrogen systems.
- Support work product development in the other subtasks in appropriate ways to ensure that knowledge dissemination for broad use becomes an integral goal of Task 31 as a whole.

Previous Technical Accomplishments and Progress – Highlights (2007–2010)

- ✓ Further developed dispersion models for H_2 releases (April 2008)
- ✓ Published white paper on Hydrogen Safety Knowledge Gaps (January 2009)
- ✓ The IEA Hydrogen Implementing Agreement co-organized the *Third International Conference on Hydrogen Safety* and Task 19 members presented more than 10 technical papers (September 2009)
- ✓ Established a list of existing engineering models (November 2009)
- ✓ Completed White Paper on
- ✓ Developed more detailed thermal radiation model that accounts for crosswinds (November 2009)
- ✓ Hydrogen Technical Experimental Database (HyTEX) launched (November 2009)
- ✓ Executed collaborative agreement with International Association for Hydrogen Safety (IAHySAFE, March 2011)

Technical Accomplishments (2010 – Present)

1. Since last AMR review (2010), conducted four technical experts meetings and one technical workshop (Jan 2012, Oslo, Norway), and reported results and progress to the IEA Hydrogen Executive Committee at four meetings.
2. Significant technical progress was made toward establishing a risk-informed methodology for CDO's to use as a template in evaluating risk prevention and mitigation measures.
3. Established a Task 31 SharePoint site to augment the existing web site as a means for increasing the effectiveness of collaborative activities.
4. Established and populated the HyTEX database that has been vetted by the technical community (refereed literature)
5. Numerous publications, technical papers and presentations:
   - 11 technical papers at the World Hydrogen Energy Conference in May 2010 in Essen, Germany
   - 33 conference papers at the Fourth International Conference on Hydrogen Safety in September 2011 in San Francisco, CA
   - 1 paper at Hypothesis IX, San José, Costa Rica, December 12-15, 2011
   - 2 journal articles in the International Journal of Hydrogen Energy, submitted March 2012
6. Established organizing committee and initiated planning for two stakeholder workshops.

Accomplishments and Progress – A Few Examples Knowledge Analysis, Dissemination and Use

- Collaboration with partners in Task 31 to add safety events records to *Hydrogen Incident Reporting and Lessons Learned* (H2incidents.org)
- Collaboration with Task 22 (Fundamental and Applied Hydrogen Storage Materials Development) to develop "Hydride Storage and Handling" for Hydrogen Safety Best Practices (http://h2bestpractices.org)
- Weiner, S.C. and Blake, C.W., "Safety Knowledge Tools Enhanced by International Collaboration," A White Paper of the International Energy Agency Hydrogen Implementing Agreement Task 19 – Hydrogen Safety, PNNL-19901, October 18, 2010.
- On-line demonstrations of "H2incidents.org" and the *Hydrogen Incident and Accident Database* (HIAD – http://www.hysafe.org/HIAD_DAM/HIAD.php) at the International Conference on Hydrogen Safety, San Francisco, CA, September 12-15, 2011.

Accomplishments – Task 19/31 Meetings

2004 – Washington, DC, USA
2005 – Paris, France
2005 – Pisa, Italy
2006 – Long Beach, CA, USA
2006 – Vancouver, Canada
2007 – Tsukuba, Japan
2007 – San Sebastian, Spain (ICHS 2)
2008 – Sacacomie, Canada
2008 – Oslo, Norway
2009 – San Francisco, CA, USA
2009 – Corsica, France (ICHS 3)
2010 – Fairfax, VA, USA
2010 – Rome, Italy
2011 – Karlsruhe, Germany
2011 – San Francisco, CA, USA (ICHS 4)
2012 – Oslo, Norway (Subtask A)
2012 – Paris, France
2012 – Golden, CO, USA (Tentative)

Collaborations

- IEA Task 31 is a 100% collaborative, task shared effort of more than 25 foremost experts from key organizations in 11 countries:

  - USA
  - Canada
  - European Commission
  - France
  - Germany
  - Greece
  - Italy
  - Japan
  - The Netherlands
  - Norway
  - United Kingdom

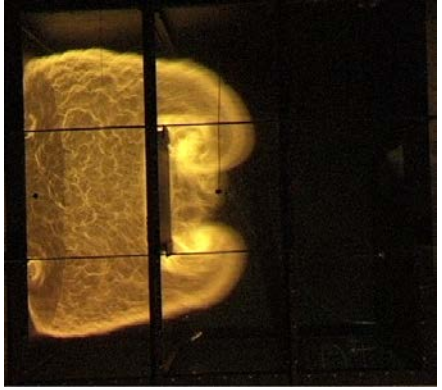
- In May 2010, The Hydrogen Implementing Agreement entered into a memorandum of understanding for joint collaboration with the International Association for Hydrogen Safety

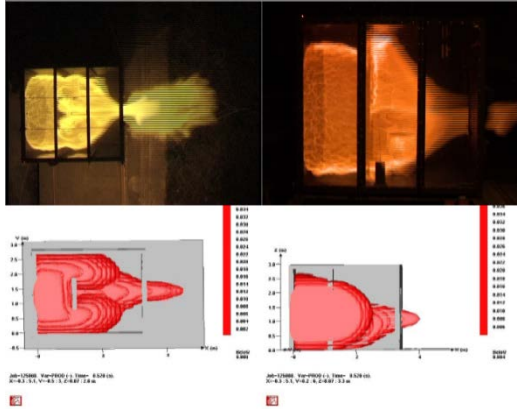
Future Work

- Continued technical, task shared collaborations (Semi-annual experts meetings) according to established work plan focusing on:
  - Continued refinement of QRA analysis methods, physical phenomena and addressing knowledge gaps
  - Separation distances, tiered risk criteria, mean time between failures, maintenance schedules, redesigns …
  - Analysis of hydrogen infrastructure
  - Barriers/mitigation measures
  - Ignition, flammability
  - Auto-ignition, turbulent flame stability, wall bounded, …
  - Unintended leaks in confined areas (garages, tunnels, …)
  - Liquid spills and leaks

- Position paper on Hydrogen Safety for HIA adoption (2013)
- Two white papers including one on how information exchange amongst technical experts is helping to advance the hydrogen safety knowledge base.
- Task Stakeholder Workshops in North America and Europe 2012-2013

Summary





- This task is a unique, cost effective, collaborative, task shared activity that combines the efforts of the best hydrogen safety experts toward a common work plan to achieve mutually beneficial objectives.
- Task 31 conducted under an International agreement that links into codes and standards activities in many countries to harmonize them by providing sound, common technical bases.
- Current phase will conclude in October 2013; a follow-on task is anticipated, but not yet defined.
- Activities proceeding according to work plan.

Technical Backup Slides

Hydrogen Safety Stakeholder Workshops – Target Audiences

North American workshop:

- Chairs, conveners and task group leaders of all Standards Development Organizations in the USA and Canada developing codes & standards for hydrogen technologies such as NFPA, ICC, API, CSA America, ASTM, ASME, NIST, CGA, SAE, and BNQ (Canada);
- Chairs and members of US DOE Technical Advisory Groups and CACs (Canada) on relevant ISO and IEC mirror technical committees;
- Technical decision-makers/advisors within US DOE, DOT… and Natural Resources Canada who have input to or funding authority over pre-normative research in the fields of hydrogen and fuel cells.

Hydrogen Safety Stakeholder Workshops – Target Audiences

European Workshop:

- Chairs, conveners and task group leaders of relevant subcommittees and Working Groups of ISO TC 22 Road Vehicles, ISO TC 58 Gas Cylinders, ISO TC 197 Hydrogen Technologies, ISO TC 220 Cryogenic Vessels, IEC TC 31 Equipment for Explosive Atmospheres and IEC TC 105 Fuel Cells, and experts involved in development of relevant EN standards;
- chairs, conveners and technical experts of the European Industrial Gas Association (EIGA) developing requirements for hydrogen use;
- Technical decision-makers/advisors within JTI/JTU of the European Commission who have input to or funding authority over funding of pre-normative research in the fields of hydrogen and fuel cells.