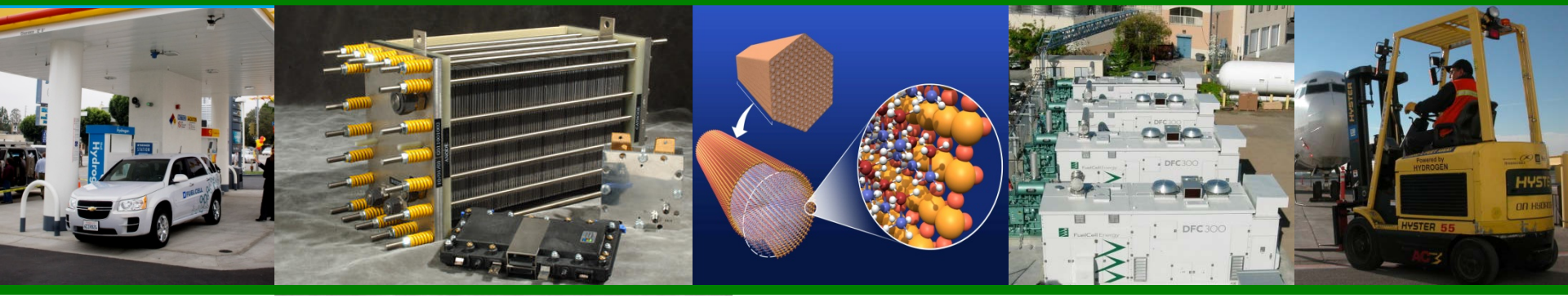
U.S. DEPARTMENT OF ENERGY



Safety, Codes and Standards

- Session Introduction -

Nha Nguyen

On Assignment from US DOT NHTSA

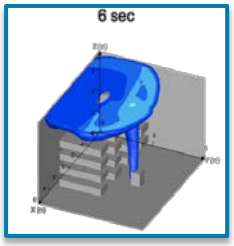
2013 Annual Merit Review and Peer Evaluation Meeting

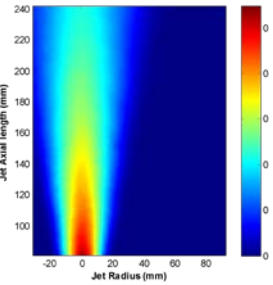
May 14, 2013

Goal & Objectives

U.S. DEPARTMENT OF ENERGY

Enable the widespread commercialization of hydrogen and fuel cell technologies through the timely development of codes and standards





Goals

- Develop and implement safety practices and procedures to ensure the safe operation, handling, and use of hydrogen and fuel cell technology
- Conduct critical R&D needed for the development of technically sound codes and standards and facilitate harmonization of domestic and international regulations, codes, and standards.

Objectives

- Ensure the safety of all projects funded by the DOE Fuel Cell Technologies Program
- Make available safety-related information resources and lessons learned with key stakeholders (first responders, regulators, and others)
- Identify and mitigate risk and understand insurability issues for widespread commercialization.
- Conduct R&D to provide critical data and information needed to define requirements in developing codes and standards.
- Develop and validate appropriate test methodologies for certifying hydrogen and fuel cell systems and components.

Challenges

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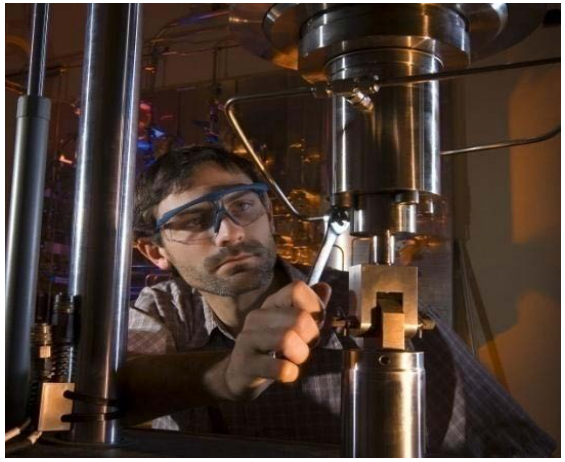
Data needed for the development of critical codes and standards to enable the widespread commercialization of hydrogen and fuel cell technologies



Lack of…

- Synchronized codes and standards development and adoption with technology deployment and commercialization needs
- Continued coordination of R&D with codes and standards development cycle and revision schedule
- Continued domestic and international harmonization in code and standard development
- Adoption of the latest developed codes and standards
- Standardization of the permitting process for hydrogen infrastructure through updating with technology advancement

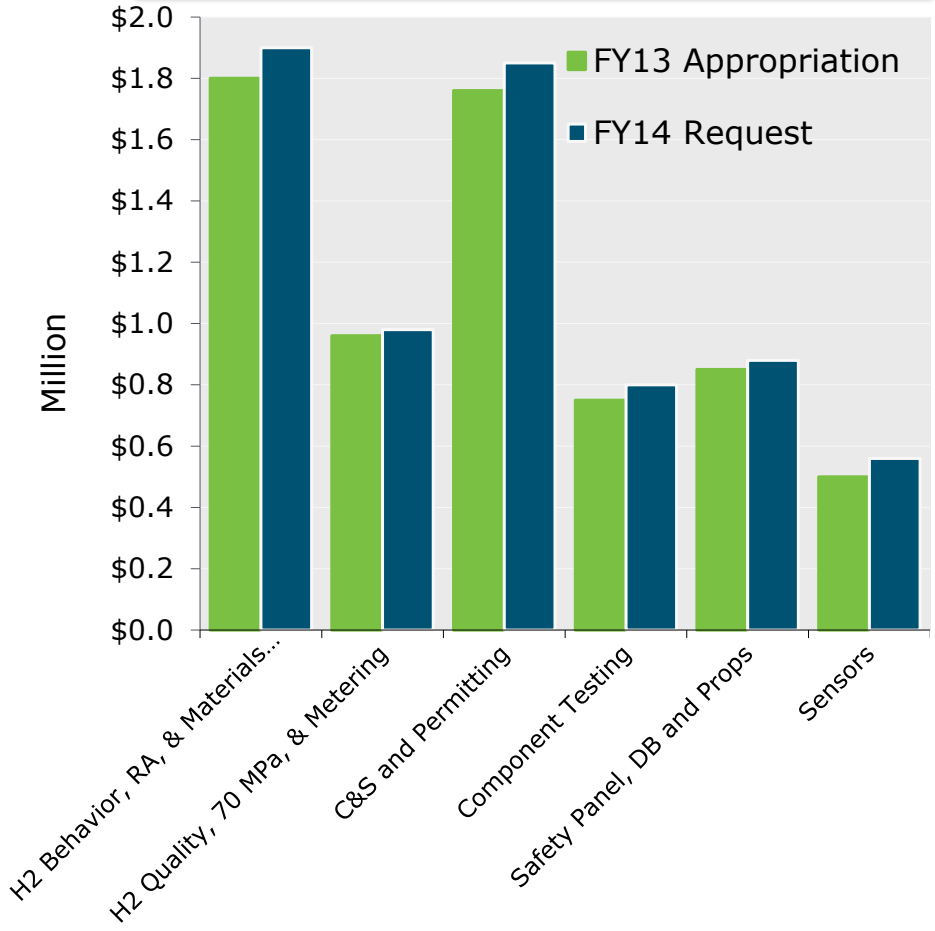
Safety, Codes and Standards Budget

U.S. DEPARTMENT OF ENERGY

FY 2014 Request Allows for Continued Emphasis on Critical RCS and RD&D

FY 2014 Request = $7M

FY 2013 Appropriation = $6.62M



Emphasis:

- Develop technical information and performance data to enhance codes and standards
- Facilitate the permitting of hydrogen fueling stations and early market applications
- Test, measure and verify hydrogen fuel specification
- Assess risks and establish protocols to identify and mitigate risk
- Harmonize test protocols for qualification and certification
- Harmonize hydrogen fuel quality and other key international standards
- Disseminate hydrogen “best practices” and safety information

Safety, Codes & Standards – Approach

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Deploying an approach to impact C&S allows for critical RCS to be addressed

Approach

Identify R&D needs

- Lead stakeholder workshops, develop R&D roadmaps
- Analyze existing codes and standards, safety knowledge
- Participate in technical working groups

Perform High-Priority R&D

- Understand foundational hydrogen behavior
- Quantitative Risk Assessments
- Compatible materials and components
- Develop and harmonize test protocols

Impact Codes and Standards

- Participate in and lead technical committees to develop requirements
- Publish R&D results

Harmonize Internationally

Global Technical Regulation (GTR Phase)

International Standards Development Organizations(e.g., ISO, SAE, IEC)

International Partnerships and Agreements (IPHE, IEA)

Progress – Regulations, Codes, & Standards

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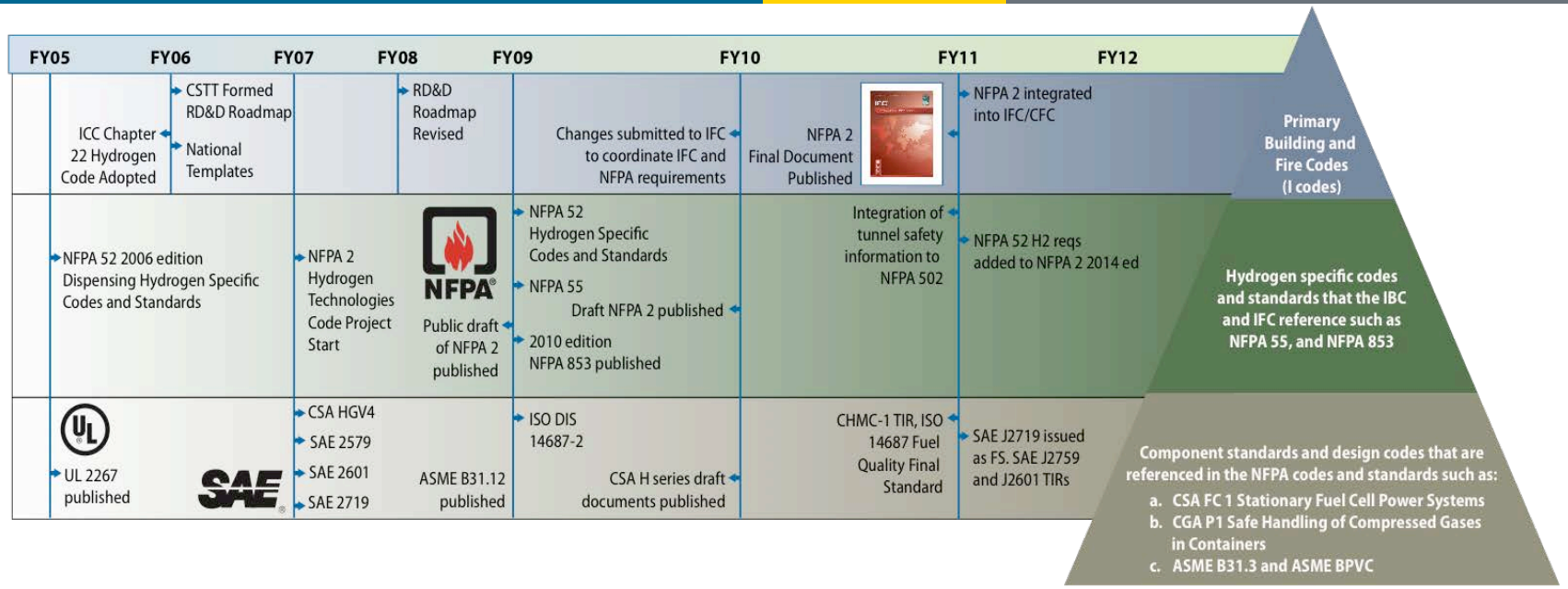
Timeline of Hydrogen Codes and Standards to enable critical RCS



FY 2013 RCS Accomplishments

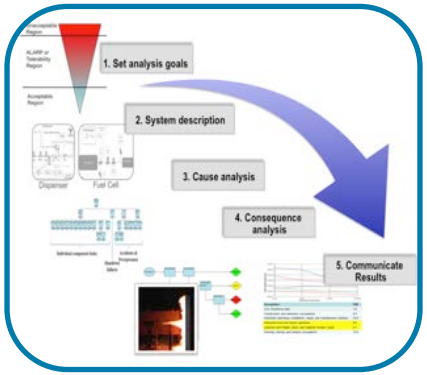
- Initial approval of the **Global Technical Regulation** (GTR) at the U.N. GRSP under WP.29 in Dec. 2012. Full Acceptance targeted in June 2013. The GTR will become U.S. Federal Motor Vehicle Safety Standard (FMVSS).
- Standard **SAE J2579**, Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles, was published in March 2013
- International Standard on hydrogen fuel quality, **ISO 14687-2**, Hydrogen Fuel–Product Specification– Part 2: Proton Exchange Membrane (PEM) Fuel Cell was approved in Dec 2012

Accomplishment – Quantitative Risk Assessment

U.S. DEPARTMENT OF ENERGY

Advanced QRA Process for Development of Toolkit for AHJs

Apply risk assessment techniques to identify risk drivers and associated consequences in step-out hydrogen technologies



Develop integrated algorithms for conducting QRA for GH_2 facilities and vehicles

Engage with stakeholders (industry, OEMs, government, SDOs) to build awareness of QRA and related activities to reduce risk

Consequence models (from SCS010 Task) provide reduced order information (ignition, radiation, overpressure) for accurate depiction of physical behavior of unintended releases

Accomplishment – H_2 Behavior

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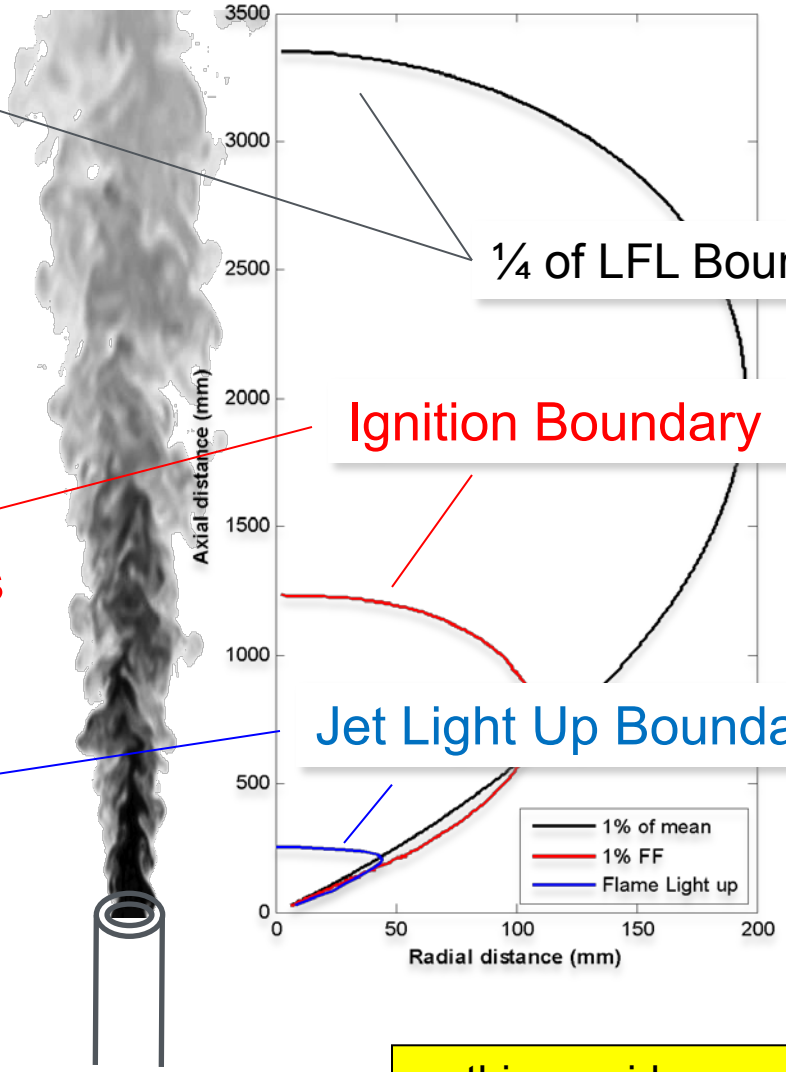
3.4 meters

1.25 meters

0.25 meters

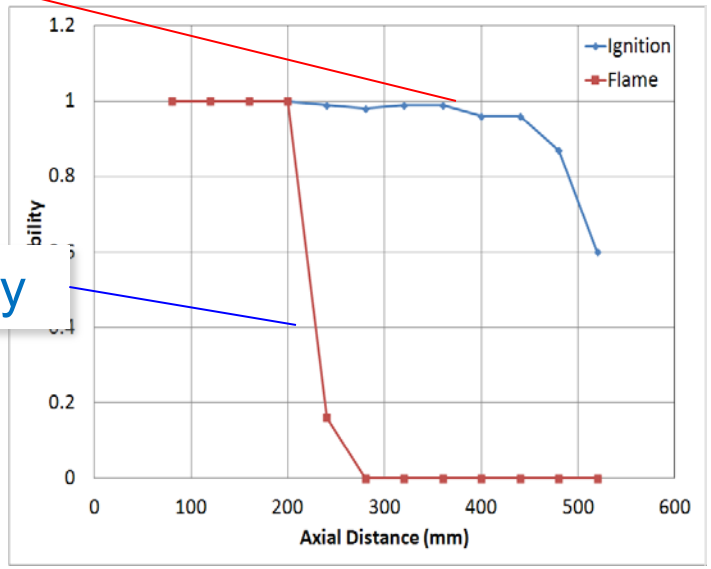


¼ of LFL Boundary (Basis of Sep. Dist.)

Ignition Boundary

Jet Light Up Boundary

Ignition and Jet Flame Probability



Obtained high confidence in identifying the boundaries of the jet flame hazard for all ***circular*** unintended releases…

… this provides a pathway for reduced separation distances through integrated QRA process

D = Ø1.901mm

Flow = 100slm H_2

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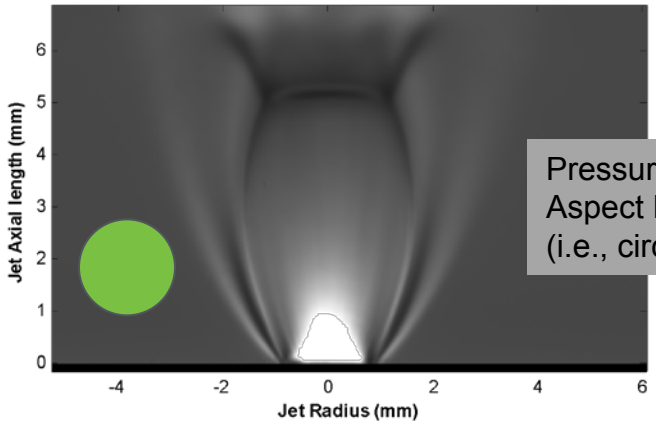
Accomplishment – H_2 Behavior

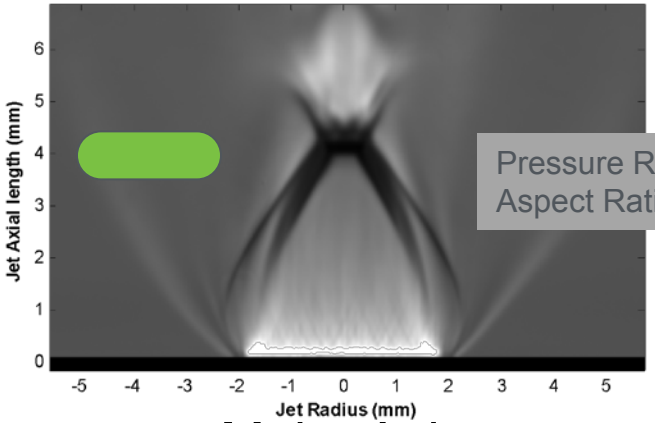
U.S. DEPARTMENT OF ENERGY

Conducted experiments using non-circular openings

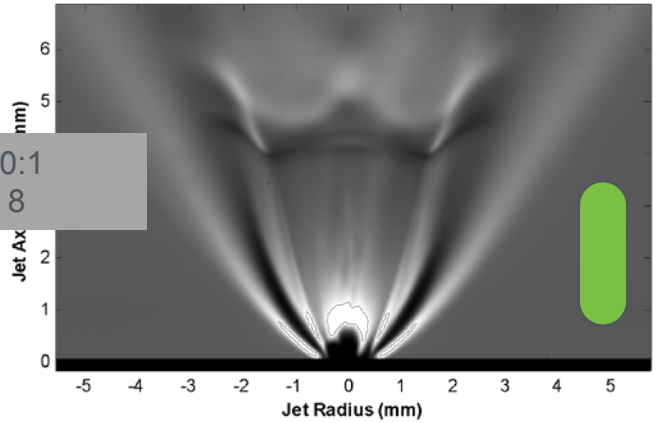
Shown: Schlieren images of jet shock structures at two aspect ratios



Pressure Ratio = 10:1
Aspect Ratio (AR): 1
(i.e., circular)



Pressure Ratio = 10:1
Aspect Ratio (AR): 8



Major Axis

Minor Axis (faster jet spreading rate)

Discussion: Containment vessel or component housing cracks, leaky fittings, etc. (high aspect ratio releases) are likely to have different dispersion characteristics current QRA modules do not account for these differences – Reduced accuracy must be considered error thus reducing the accuracy of the QRA result

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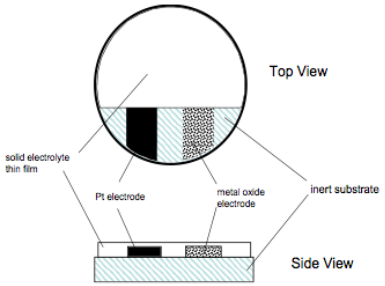
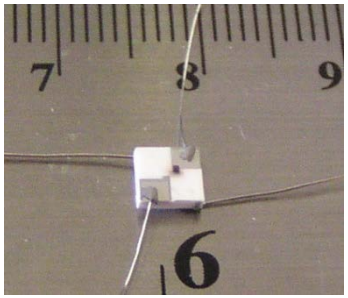
Progress – Safety Sensors

U.S. DEPARTMENT OF ENERGY

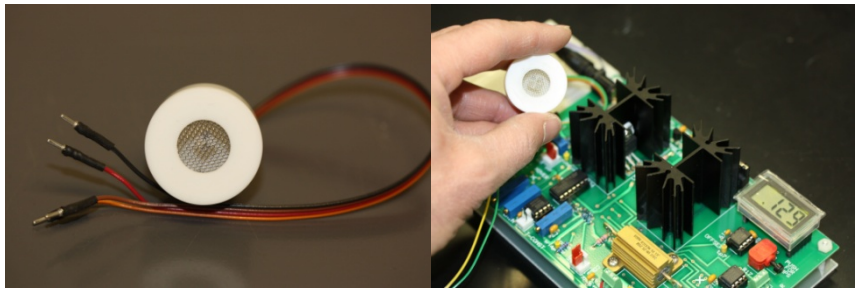
- Objective: Develop a low-cost, durable, and reliable **hydrogen safety sensor** for vehicle, stationary and infrastructure applications using technology approach that addresses the foremost limitation impacting commercially available systems today: sensor drift leading to false positives and false negatives.
- TRL of electrochemical, mixed potential sensors has been significantly advanced by National Laboratory and commercial partners through Safety Codes and Standards funding.
- Robust, ceramic-based electrochemical platform derived from automotive Lambda sensor technology with properties ideally suited for numerous critical application roles.
  - Frequent calibration not required, a non-drifting sensor baseline that prevents false alarms.



Mixed potential sensor in planar configuration (US Pat #, 7,264,700).



Nat'l Lab technology in pre-commercial prototype form fabricated by ESL.



Packaged mixed potential H_2 safety sensor and prototype electronics.

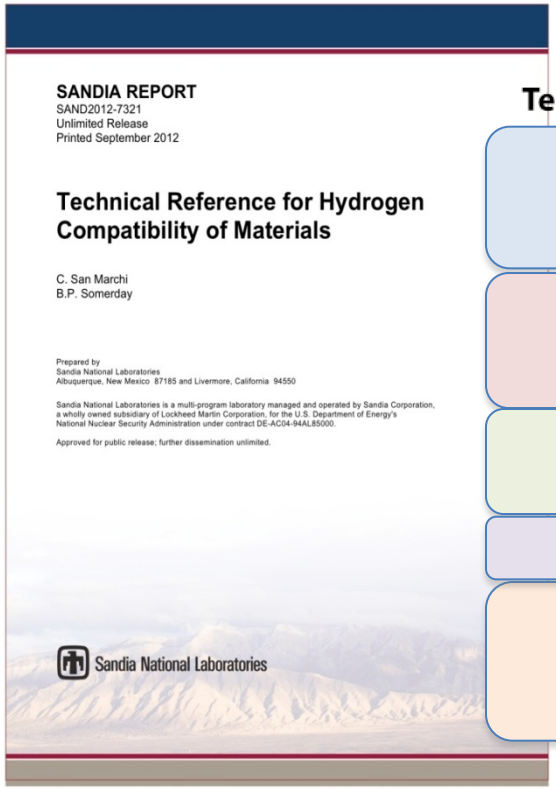
- **Future focus of Safety Sensor R&D: technology is ready for field trials in infrastructure applications in collaboration with commercial H_2 partners.**

Los Alamos NATIONAL LABORATORY EST.1943 | Lawrence Livermore National Laboratory | Custom Sensor Solutions, Inc. | ESL ElectroScience | NREL NATIONAL RENEWABLE ENERGY LABORATORY

Accomplishment – Materials

U.S. DEPARTMENT OF ENERGY

- Information placed on OpenEI website: http://en.openei.org/wiki/Gateway:Hydrogen
  - Updated full public report on Technical Reference for Hydrogen Compatibility of Materials (SAND2012-7321), 292 pages
  - Datasets for fatigue crack growth of materials in gaseous hydrogen


SANDIA REPORT
SAND2012-7321
Unlimited Release
Printed September 2012

Technical Reference for Hydrogen Compatibility of Materials

C. San Marchi
B.P. Somerday

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Approved for public release; further dissemination unlimited.

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Technical Reference	Technical Database
1100 Carbon steels └ 1100: C-Mn alloys	1100 Carbon steels ├ CIA85: tension, fracture, fatigue ├ SAN10: fracture, fatigue └ SAN11: fracture fatigue
1200 Low-alloy steels ├ 1211: Cr-Mo alloys └ 1222: Ni-Cr-Mo alloys	1200 Low-alloy steels └ NIB10: fracture, fatigue
1400-1800 High-alloy steels └ 1401: 9Ni-4Co	1400-1800 High-alloy steels
2000 Austenitic steels	2000 Austenitic steels
3000 Aluminum alloys ├ 3101: Pure aluminum ├ 3210: 2xxx-series alloys └ 3230: 7xxx-series alloys	3000 Aluminum alloys └ SAN11: fracture, fatigue

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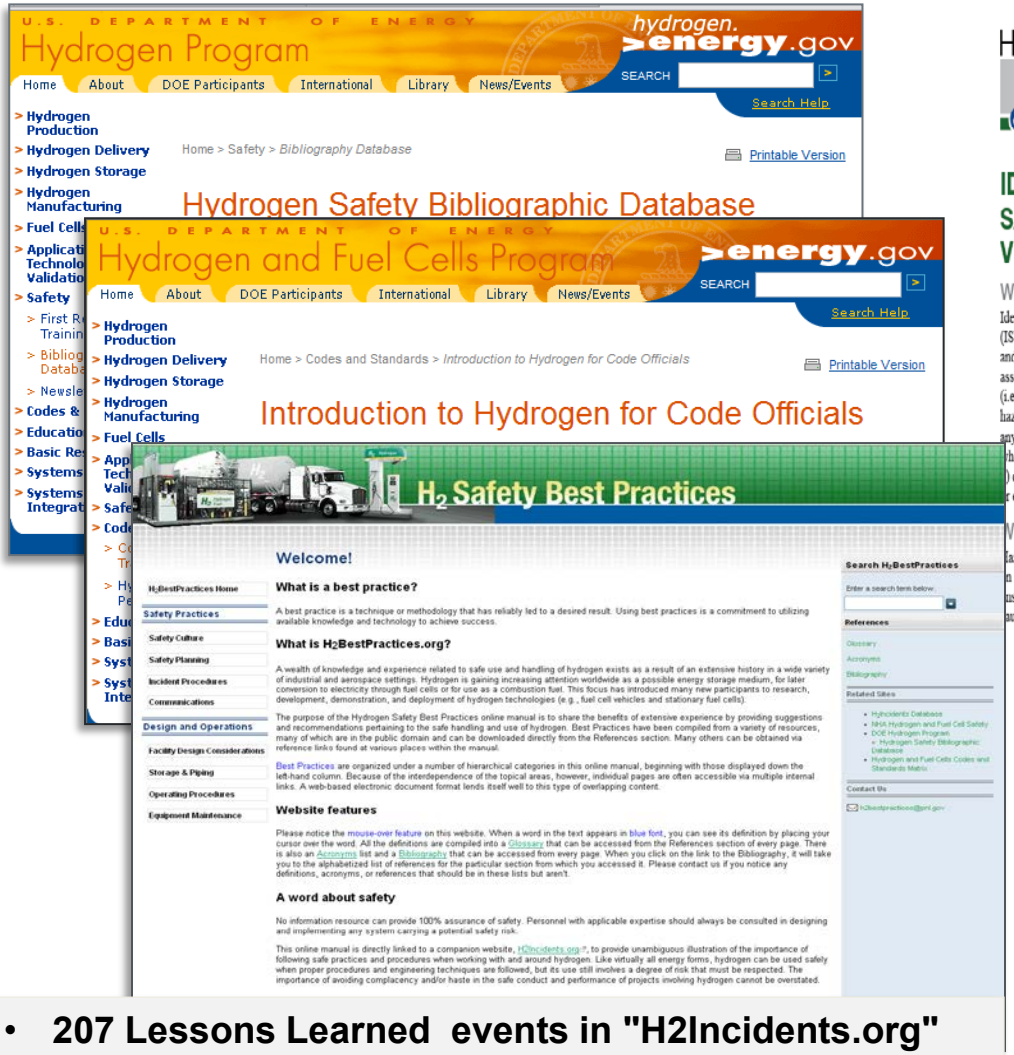
Progress – Safety Knowledge Tools



- **207 Lessons Learned events in "H2Incidents.org"**
- **Approximately 750 entries in the Hydrogen Safety Bibliographic Database**

Developed training material for first responders, code officials.

Educated > 26,000 to-date (online & in-person)*

www.eere.energy.gov/hydrogenandfuelcells/codes/

**SCS015, First Responder Training*

Accomplishment – Public Outreach

U.S. DEPARTMENT OF ENERGY

Discovering New Ways to Share Safety Knowledge

- **First mobile app being developed for the Fuel Cell Technologies Office**
  - Integrates H_2incidents.org and H_2bestpractices.org into a single, searchable, iPad and iPhone application
  - Features include safety planning guidance and checklists
  - All tools (except H_2incidents.org) are available without a data connection
- **New safety knowledge content**
  - 6 safety events added to H_2incidents.org (207 total)
  - H_2bestpractices.org updated to include the safety checklist developed by the HSP

Progress – Regulations, Codes and Standards (RCS) Tools

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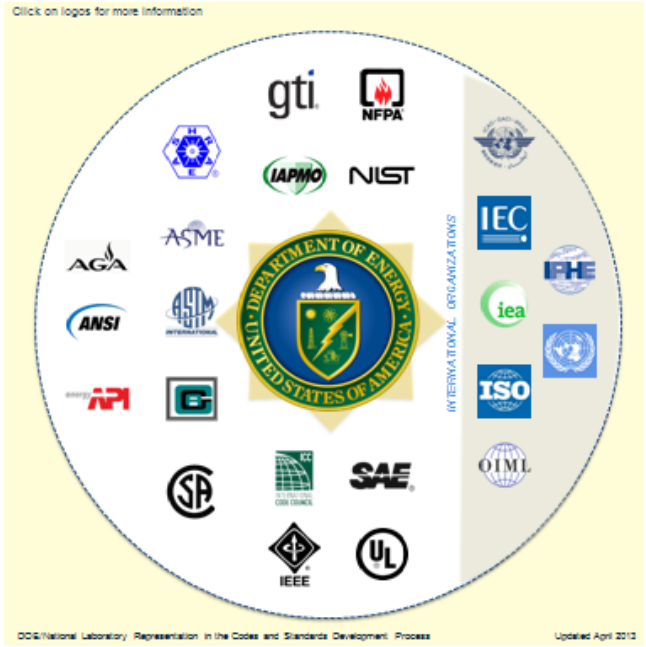
NREL's Codes and Standards Outreach and Coordination continue to help with commercialization and deployment



NREL's Codes and Standards coordinating tool
(Updated April 2013)

- Supported the integration of NFPA 2 into the International Fire Code (IFC) and Uniform Fire Code (UFC) to effectively create a national hydrogen code
- Published NREL Technical Report No. TP-5600-56223 Regulations, Codes, and Standards (RCS) Template for California Hydrogen Dispensing Stations.
- Published NREL Technical Report No. TP-5600-56177 Onboard Hydrogen/Helium Sensors in Support of the Global Technical Regulation: An Assessment of Performance in Fuel Cell Electric Vehicle Crash Tests
- Published NREL Technical Report No. JA-5600-55065 Inter-Laboratory Assessment of Hydrogen Safety Sensors Performance under Anaerobic Conditions. International Journal of Hydrogen Energy. Vol. 37(22)
- Supported infrastructure deployment for hydrogen fuel cell vehicles by developing guidance documents for the California Fuel Cell Partnership to assist interested parties in permit development and review

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Progress – Continued Outreach

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Polymer & Composites Meeting

Share information on the use of polymer and composite material in hydrogen application motivated by safety, performance, and reliability concerns.

Sandia National Laboratories, Washington, D.C.

www1.eere.energy.gov/hydrogenandfuelcells/mtg_poly_comp_materials.html October 18-19, 2012

Metallic Materials Compatibility Meeting

Laboratory operators share experience in conducting material testing in hydrogen gas, highlighting equipment, procedures, and safety.

Sandia National Laboratories, Livermore, CA April 9-10, 2013

Material Characterization of Storage Vessels for Fuel Cell Forklifts Webinar

Focused on the fatigue life of steel pressure vessels, commonly used for the transport of pressurized gases including gaseous hydrogen.

Daniel Dedrick and Chris San Marchi, Sandia National Laboratories

www1.eere.energy.gov/hydrogenandfuelcells/webinar_archives_2012.html#date081412 August 14, 2012

Hydrogen Refueling Protocols Webinar

Presented current refueling methods including the TIR guideline, SAE TIR J2601, and the MC Method.

Jesse Schneider (BMW North America) and Steve Mathison (Honda North America)

www1.eere.energy.gov/hydrogenandfuelcells/webinar_archives_2013.html#date022213 February 22, 2013

International RCS and Partnerships

U.S. DEPARTMENT OF ENERGY

International Partnerships Critical to RCS Harmonization

International harmonization of codes and standards helps ensure the safe implementation and commercialization of hydrogen and fuel cell technologies. The US is working with other countries, SDOs and CDOs to develop these critical elements.

Key RCS Supported by DOE

- SAE J2579 (Fuel Systems for Fuel Cell and other Hydrogen Vehicles)
- GTR Phase 1 (Hydrogen Vehicle Systems)
- NFPA 2 (Hydrogen Technologies)
- ISO 14687-2 (H2 Fuel Quality)
- CSA HPIT 1 (Compressed Hydrogen Powered Industrial Truck)

IPHE — **International Partnership for Hydrogen and Fuel Cells in the Economy**

iea International Energy Agency — **International Energy Agency — Implementing Agreements**

hySafe INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY — **International Association for Hydrogen Safety**

ICHS International Conference on Hydrogen Safety — **International Conference on Hydrogen Safety**

Progress – IPHE RCSWG Round Robin

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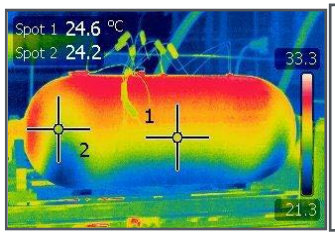
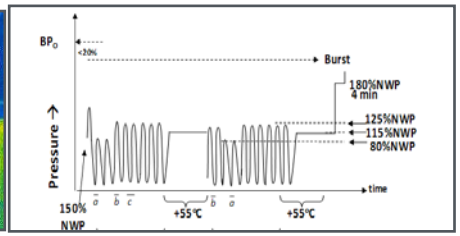
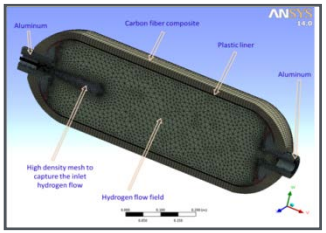
Hydraulic Phase RR on Type IV Tank completed under the International Partnership for Hydrogen and Fuel Cells in the Economy RCSWG (IPHE RCS WG)

- Performed Hydraulic cycle tests (up to 35 MPa)
  - Individually defined test measurement protocols that were combined into a harmonized protocol that will yield consistent results independent of the test facility
  - U.S. testing performed at the NASA WSTF w/real time 24/7 access (VSEE)
  - China testing performed at the Institute of Process Equipment, Zhejiang University w/testing during a site visit from U.S.
  - Lessons learned were implemented in a revised test method protocol for a 2nd tank







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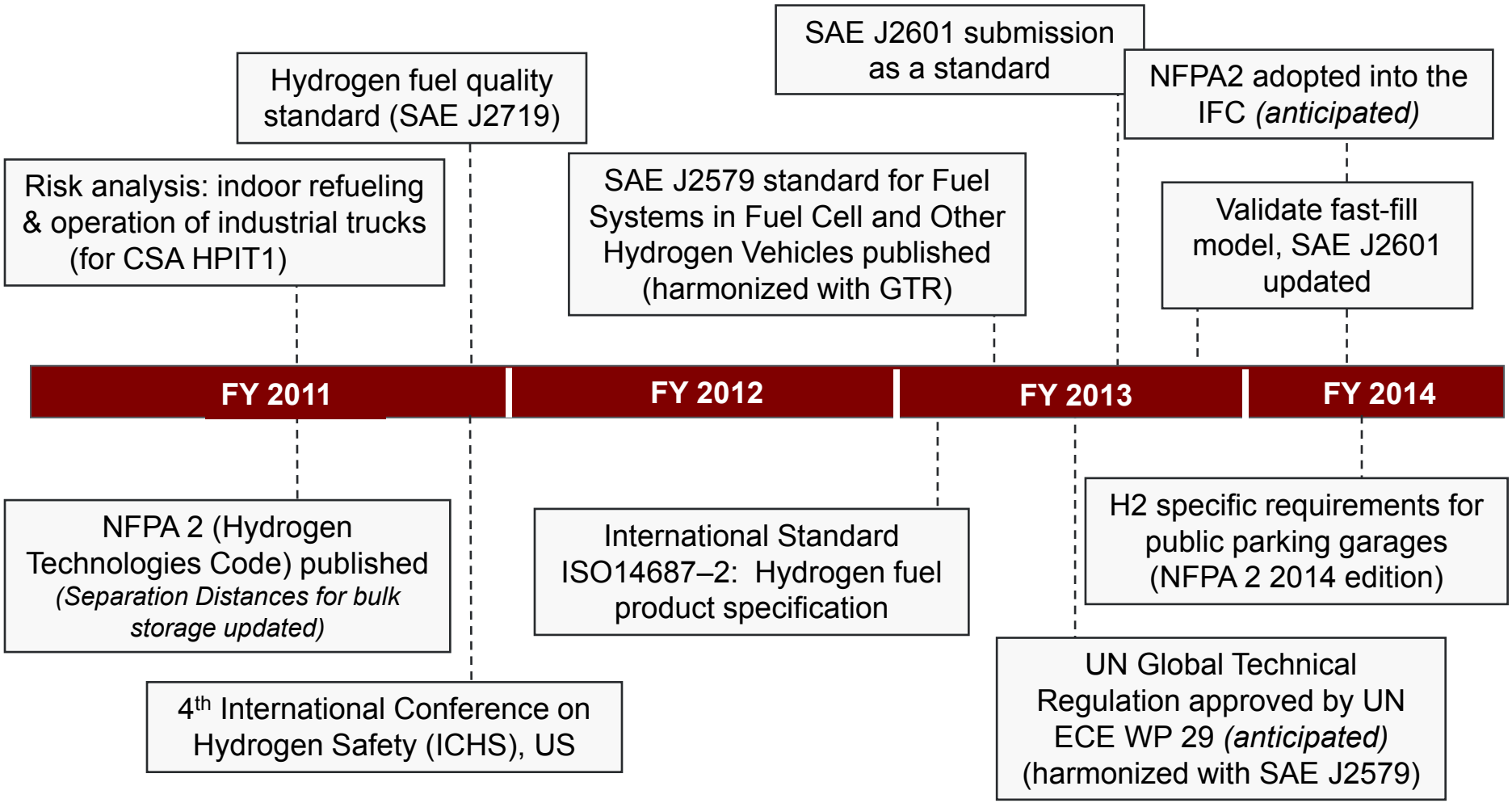
Key milestones and future plans



Participating Organizations

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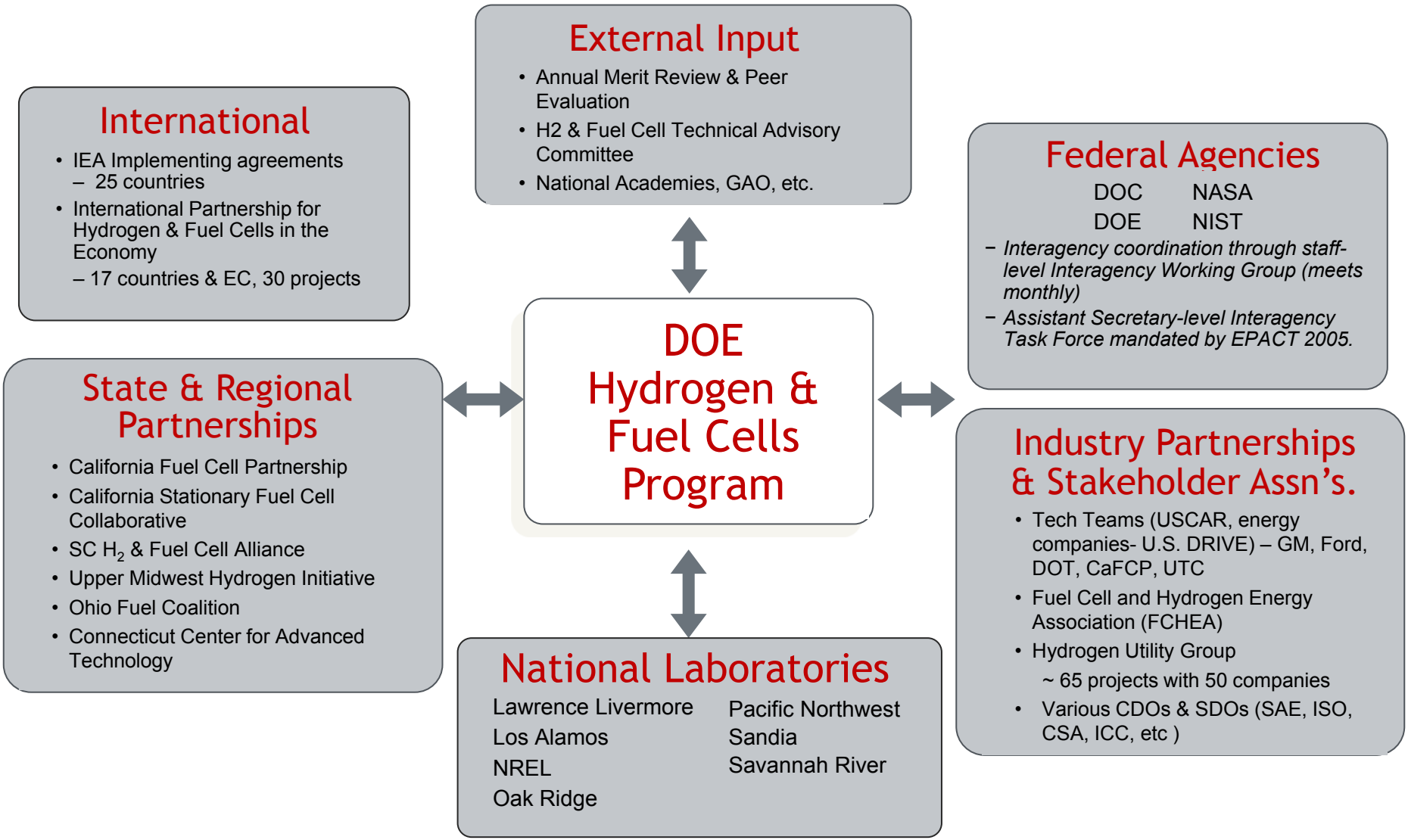

For More Information

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Jim Alkire
Jesse Adams

Technical Support:
Kathleen O'Malley (SRA)
Jay Keller (Consultant)

Session Instructions

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- This is a review, not a conference.
- Presentations will begin precisely at scheduled times.
- Talks will be 20 minutes and Q&A 10 minutes.
- Reviewers have priority for questions over the general audience.
- Reviewers should be seated in front of the room for convenient access by the microphone attendants during the Q&A.
- Please mute all cell phones and other portable devices.
- Photography and audio and video recording are not permitted.

Reviewer Reminders

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- Deadline to submit your reviews is Friday, **May 24th at 5:00 pm EDT.**

- ORISE personnel are available on-site for assistance.
  - **Reviewer Lab Hours:**
    - Monday, 5:00 pm – 8:00 pm (Gateway ONLY)
    - Tuesday – Wednesday, 7:00 am – 8:00 pm (Gateway)
    - Thursday, 7:00 am – 6:00 pm (Gateway)
    - Tuesday – Thursday, 7:00 am – 6:00 pm (City)
  - **Reviewer Lab Locations:**
    - Crystal Gateway Hotel—*Rosslyn Room* (downstairs, on Lobby level)
    - Crystal City Hotel—*Roosevelt Boardroom* (next to Salon A)