U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Safety, Codes & Standards (SCS) Program Area Plenary Poster

Laura Hill, Project Manager – Fuel Cells Technology Office

2018 Annual Merit Review and Peer Evaluation Meeting

April 29 – May1, 2019 – Crystal City, VA

SCS Goals & Objectives

Mission: Fund R&D needed to develop science-based codes and standards, thereby enabling the safe deployment of H_2 and fuel cell technologies

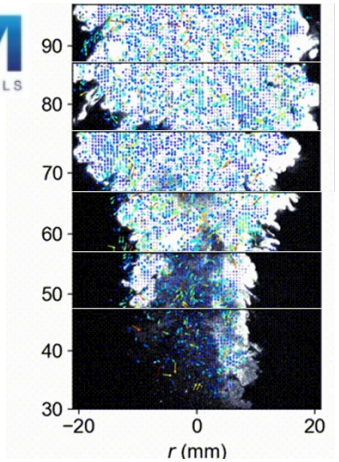
Codes & Standards

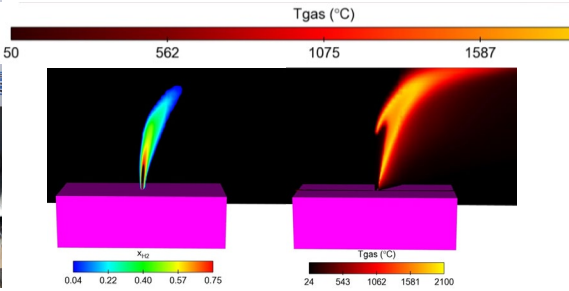
- Conduct **R&D to provide critical data** and information needed to define requirements in developing codes and standards.
- Support and facilitate development of **essential codes and standards** to **enable widespread deployment** of hydrogen and fuel cell technologies and completion of essential regulations, codes and standards (RCS).

Safety

- Ensure that **best safety practices** underlie activities supported through DOE-funded projects.
- Enable **widespread sharing** of **safety-related information resources** and lessons learned with key stakeholders.

HyRAM
HYDROGEN RISK ASSESSMENT MODELS

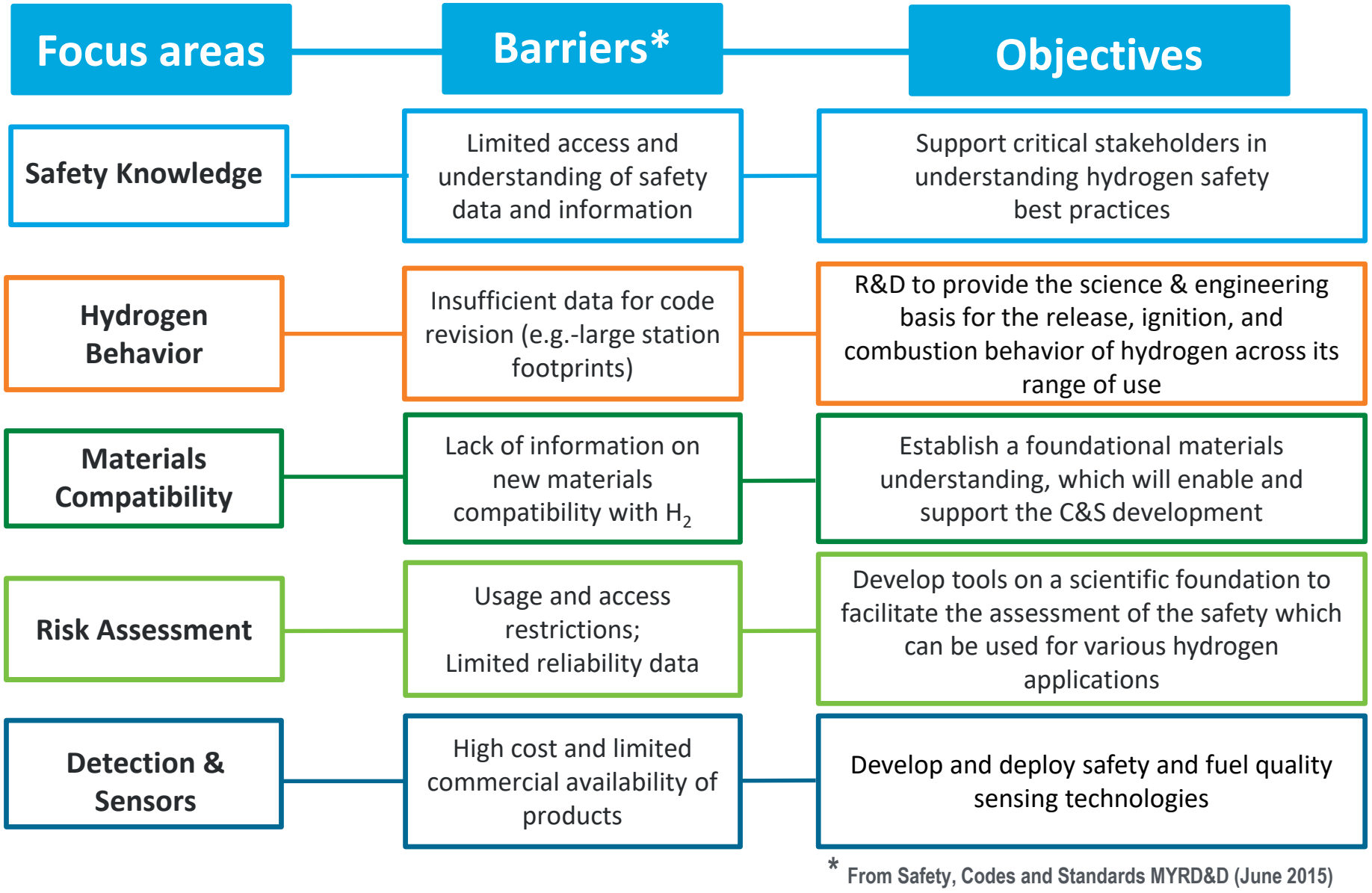




CENTER FOR Hydrogen SAFETY

An AIChE Technical Community • A Global Resource On Hydrogen Safety

Current Strategy and Barriers



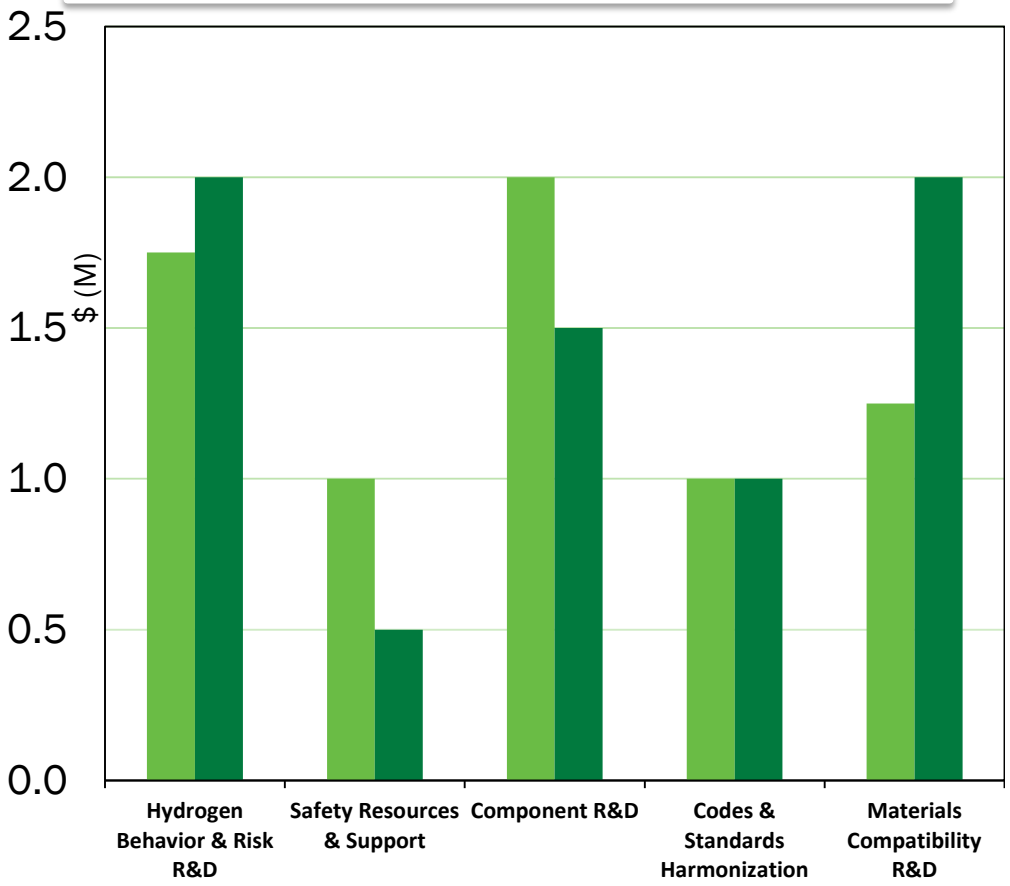
* From Safety, Codes and Standards MYRD&D (June 2015)

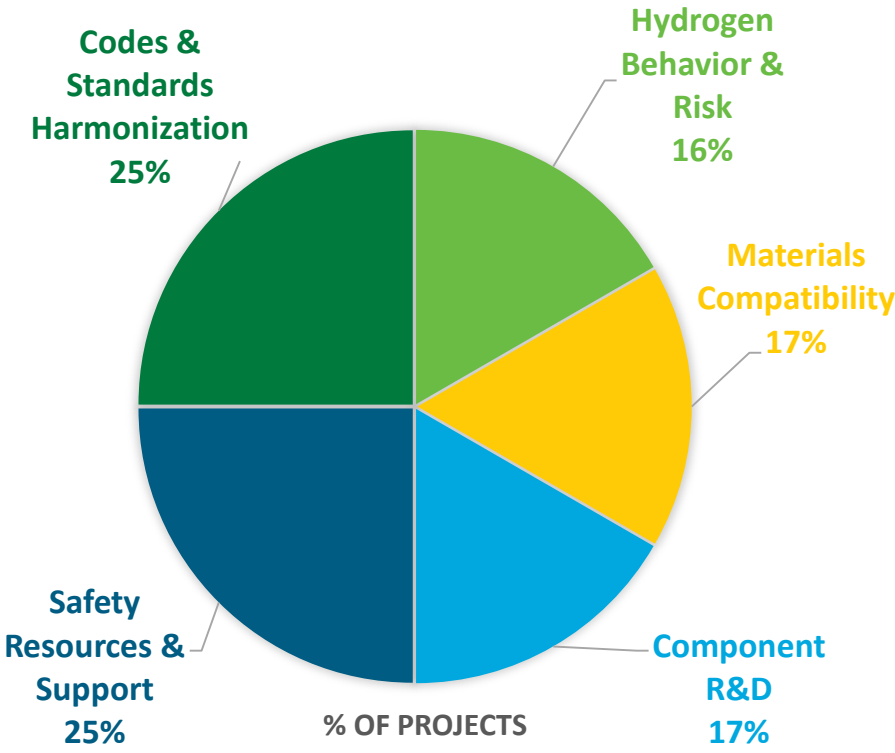
Budget

FY 2018 Appropriation = $ 7M

FY 2019 Appropriation = $ 7M

Emphasis: R&D to enable science-based codes & standards and to support H_2 safety best practices





Barrier: Limited Access and Availability of Safety Data and Information

Accomplishment: PNNL and AIChE Partner to Establish the Center for Hydrogen Safety

The CHS is a not-for-profit, global, membership organization within the American Institute of Chemical Engineers (AIChE) that promotes the safe operation, handling, and use of hydrogen and hydrogen systems across all installations and applications. The CHS identifies and addresses concerns regarding the safe use of hydrogen:

- As a sustainable energy carrier
- In commercial and industrial applications
- In hydrogen and fuel cell technologies

Membership Benefits Include…

- Access to the U.S. HSP for reviews and support
- Education (continuing education units [CEUs]), training, and outreach materials
- Provide leadership and facilitation of hydrogen safety issues
- Conferences and networking opportunities

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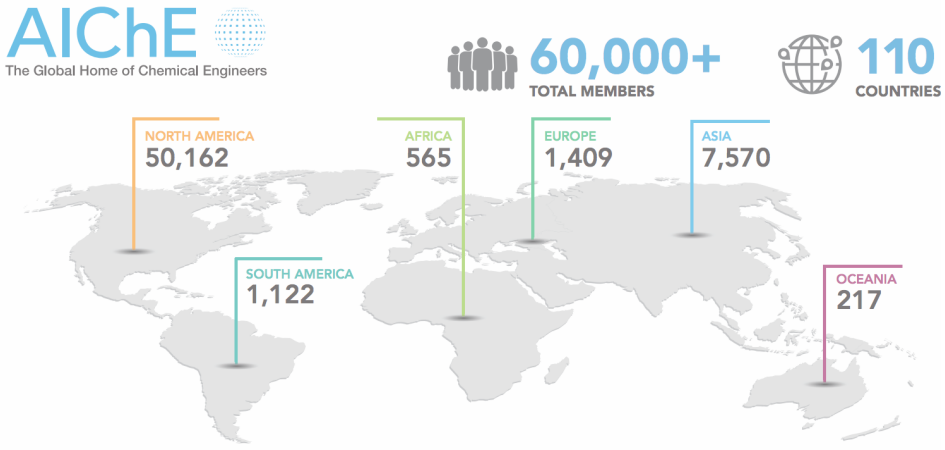

www.aiche.org/chs

SCS019

Accomplishment: Expanded HyRAM QRA flexibility

Expanded HyRAM flexibility and availability as a research tool

- Expanded QRA flexibility in **HyRAM version 2.0** will allow for hydrogen safety analysis for new H2 technologies
  - Updated methodology enables users to alter the risk analysis for different applications
- **Developing AltRAM** to incorporate risk and physics models for CNG, LNG and propane
- Pursuing an **open source license** to expand HyRAM as a research tool
  - Will allow researchers to view and download the source code
  - Changes made by users can now be added back to HyRAM

Risk Metrics | Scenario Ranking | Cut Sets | Plots

	Rank	Scenario	End State Type	Avg. Events/Year	Branch Line Probability	PLL Contribution
▸	1	000.01% Release	Shutdown	0.0313728769	90.00000000%	0.00000000%
	2	000.01% Release	Jet fire	0.0000278870	0.08000000%	0.17909659%
	3	000.01% Release	Explosion	0.0000138320	0.03968000%	0.04406063%
	4	000.01% Release	No ignition	0.0034441563	9.88032000%	0.00000000%
	5	000.10% Release	Shutdown	0.0045062884	90.00000000%	0.00000000%
	6	000.10% Release	Jet fire	0.0000040056	0.08000000%	0.02572480%
	7	000.10% Release	Explosion	0.0000019868	0.03968000%	0.00632871%
	8	000.10% F				
	9	001.00% F				
	10	001.00% F				
	11	001.00% F				
	12	001.00% F				
	13	010.00% F				
	14	010.00% F				
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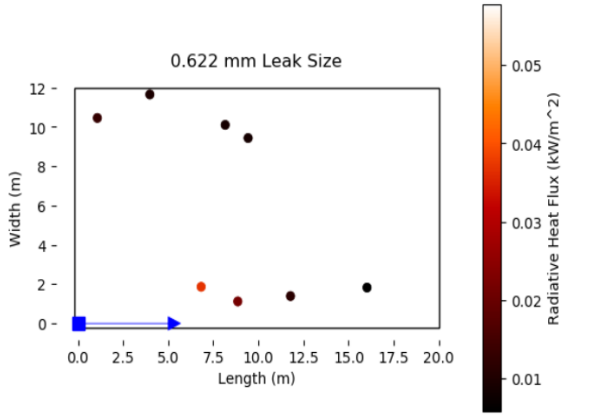


Latest release can be found at http://hyram.sandia.gov

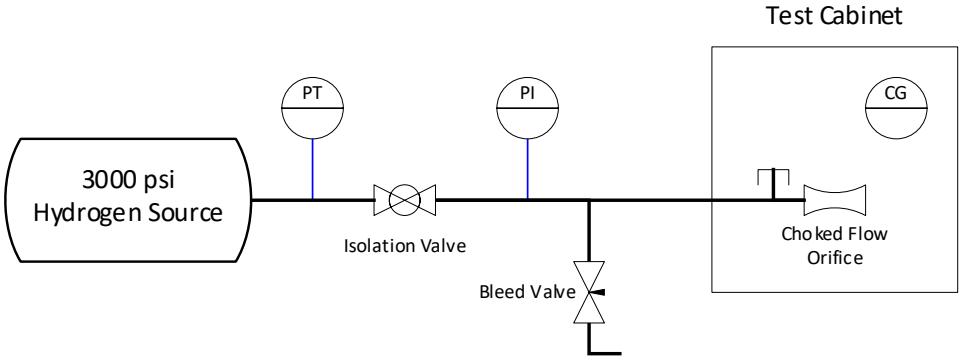
SCS011

Accomplishment: Component Failure Analysis

Initiated Effort To Obtain Essential Component Failure Data

- Secured two stations operators to provide field-failed components for root-cause failure analysis
- Produced project plan to analyze failed components
- Collected key failed hydrogen fueling station components for root-cause analysis
- Developed a preliminary test plan to measure leak rates from key station components

Field-failed 700 bar inlet valve



Proposed leak rate measurement system diagram

SCS001

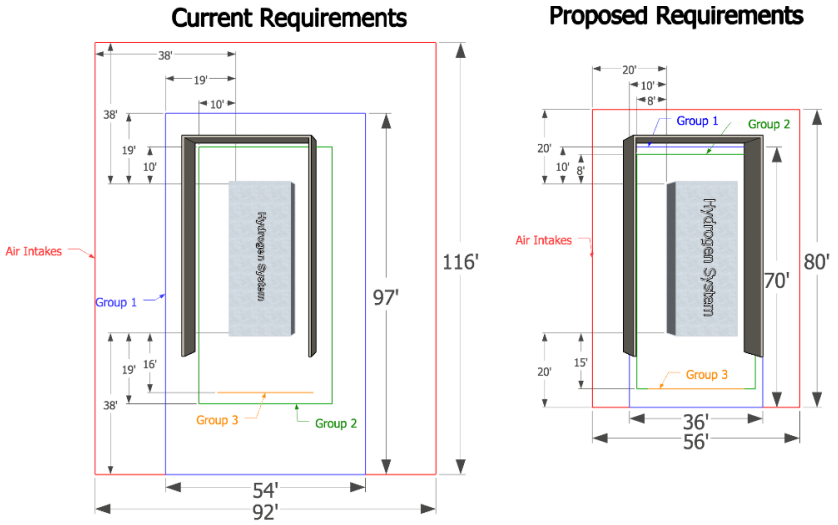
Barrier: Insufficient Technical Data to Revise Standards

Accomplishment: Reduced Separation Distances

Pending changes to the NFPA 2 Hydrogen Technologies Code (2020 Edition) will result in reduced setback distances for gaseous hydrogen storage systems.

	2016 Edition	2020 Edition
	GH2 - ft (m)	GH2 - ft (m)
Group 1 Exposures (lot lines, air intakes, openings, ignition sources)	34 (10)	16 (5)
Group 2 Exposures (exposed persons, parked cars)	16 (5)	13 (4)
Group 3 Exposures (buildings, flammable gas storage, combustibles, etc.)	14 (4)	13 (4)

- **Sandia National Laboratories**: Completed rigorous analysis characterizing footprint of conventional and potential future fueling station designs, and identifying technologies that can **enable up to 20% reduction**.
- **National Renewable Energy Laboratory**: Led efforts to implement **new hydrogen setback distances** in the 2020 Edition of the NFPA 2 Hydrogen Technologies Code.

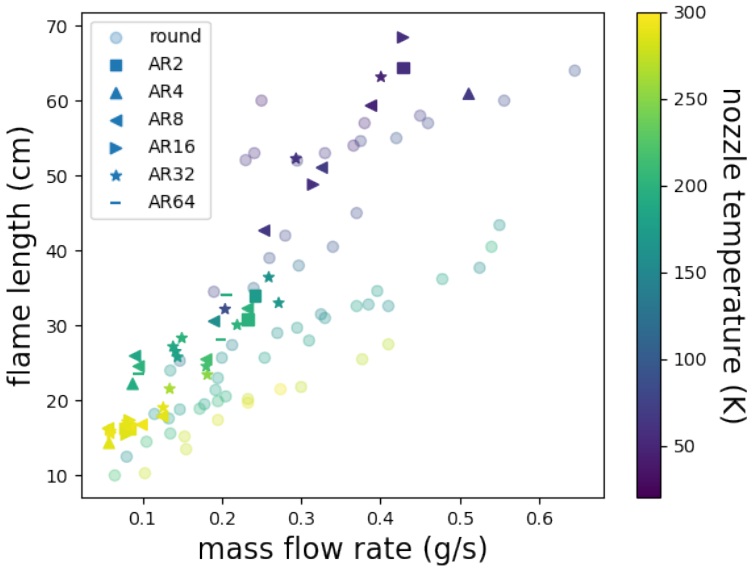


SCS001, SCS010, SCS011

Accomplishment: Demonstrated large scale release measurement capability

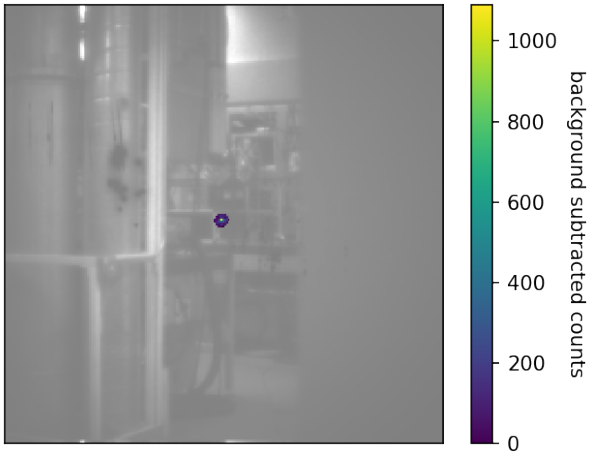
Measured how flame length and heat flux scale at cryogenic temperatures

- Cryogenic temperatures increase mass flow through nozzles
- For a given mass flux, heat flux *increases* at cryogenic temperatures
- Accurate model prediction of these behaviors is essential for QRA



Imaged hydrogen from **40 foot standoff distance** in the laboratory

- Uniquely fast optics enable collection of small Raman signal



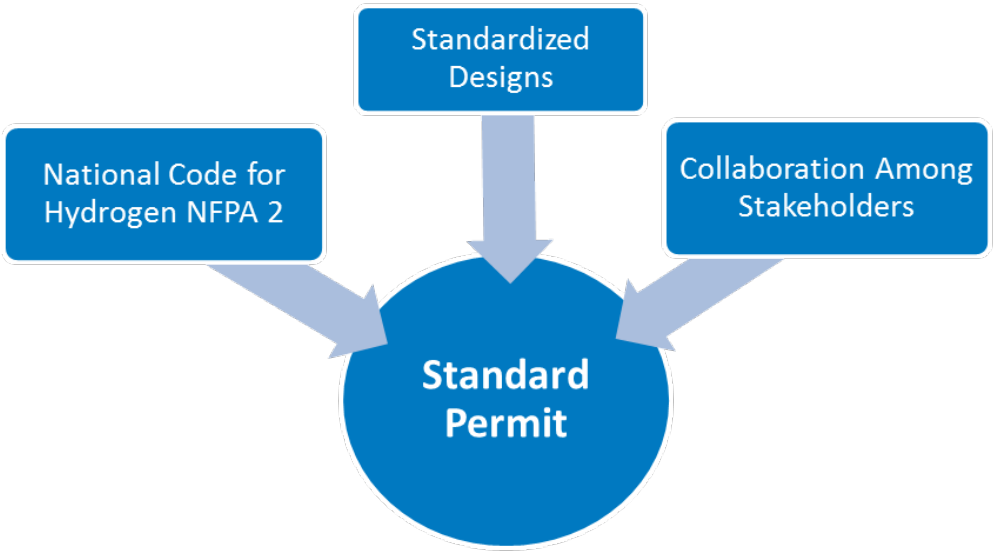
Raman signal overlaid on laboratory scene

SCS010

Barrier: Usage and access restrictions; Lack of Hydrogen Knowledge by AHJs

Accomplishment: Developed Standard Permit for Hydrogen Storage

Leveraging DOE research, particularly unused R&D assets, can support major code proposals and enable advances in public safety.



- NFPA 2 Standard Permit Task Group identified hydrogen stations with gaseous/liquid storage as the key application for standard permits
  - Standard permit completed January 2019
- Task group will continue to develop standard permits for other applications based on industry and safety needs

SCS001

Barrier: Lack of information on new materials compatibility with hydrogen

Accomplishment: H_2 Materials Compatibility

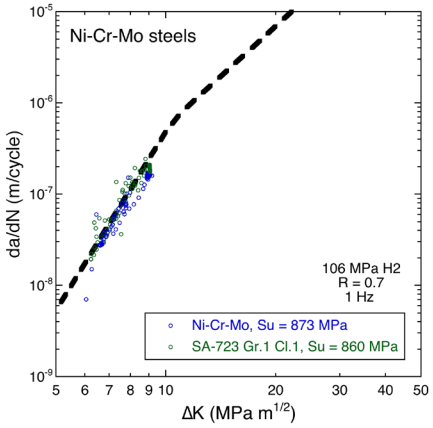
Performing critical materials R&D to understand material behavior in high pressure hydrogen, which will enable RCS in support of infrastructure deployment

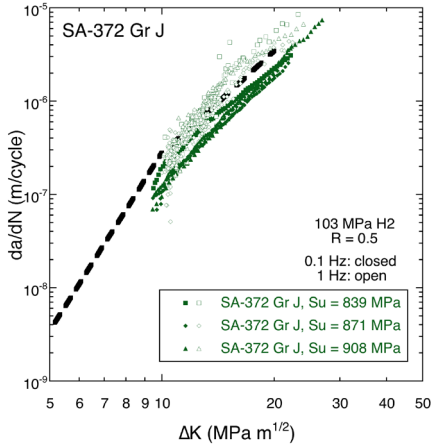
Simple performance requirements established for SAE J2579 based on relevant design space (proposed to GTR IWG)

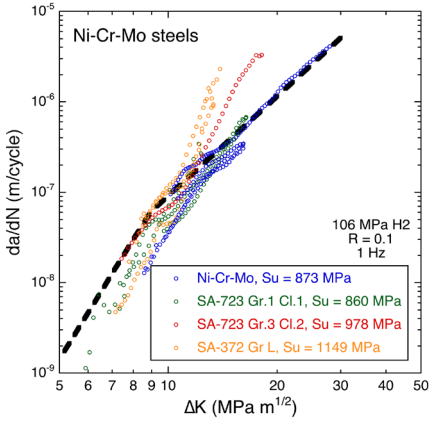
- Test requirements have substantially evolved to simple **performance-based metrics to demonstrate suitability** for application (e.g., fatigue life test conducted at room temperature only)

ASME Code Case 2938 approved

- "Technical basis for **proposed master curve for fatigue crack growth of ferritic steels in high-pressure gaseous hydrogen** in ASME section VIII-3 code" (PVP2019-93907), Proceedings of the 2019 ASME Pressure Vessels & Piping Conference, 14-19 July 2019, San Antonio TX. (manuscript in review)







$$\frac{da}{dN} = C\left[\frac{1 + C_H R}{1 - R}\right]\Delta K^m$$

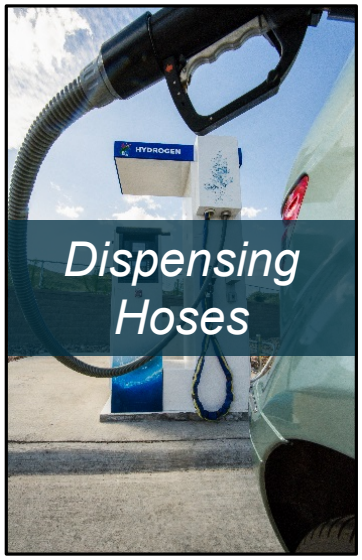
SCS005

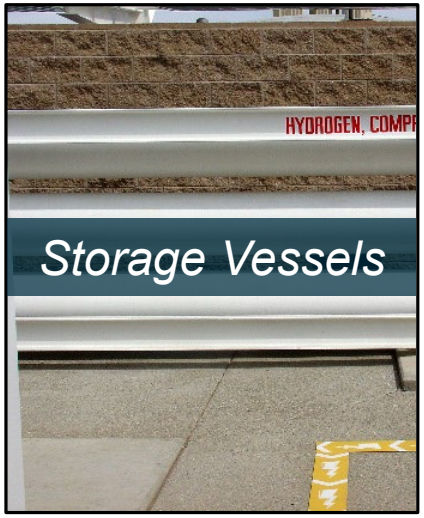
Accomplishment: Launched R&D Consortium on Materials Compatibility

H-Mat SM Hydrogen Materials Compatibility Consortium

H-Mat R&D focuses on hydrogen effects on polymers and metals

Joint effort between Infrastructure; Safety, Codes, & Standards; Hydrogen Storage





Focuses of current activities include:

1) **Reduce expansion of seals in hydrogen by 50%.**
2) **Enhance life of vessels by 50% through improved understanding of crack nucleation.**
3) **Enhance fracture toughness of high-strength (>950 MPa) steels by 50%.**

For more information, please visit https://www.energy.gov/eere/fuelcells/h-mat-hydrogen-materials-consortium or contact h-matinfo@pnnl.gov

Barrier: High Cost and Limited Commercial Availability of Products

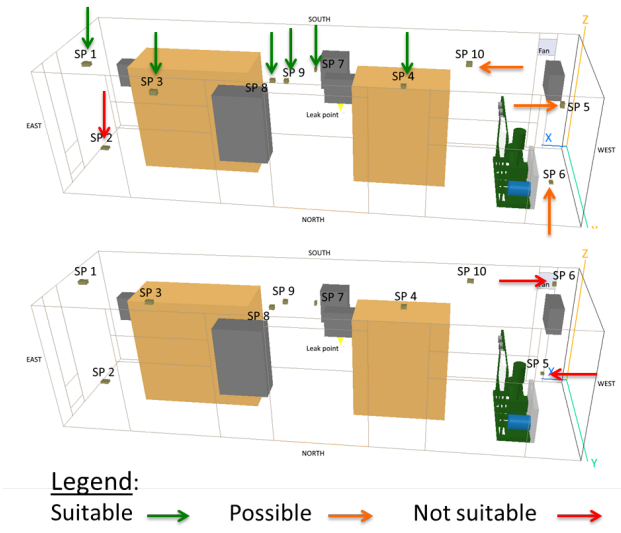
Accomplishment: Safety Sensors

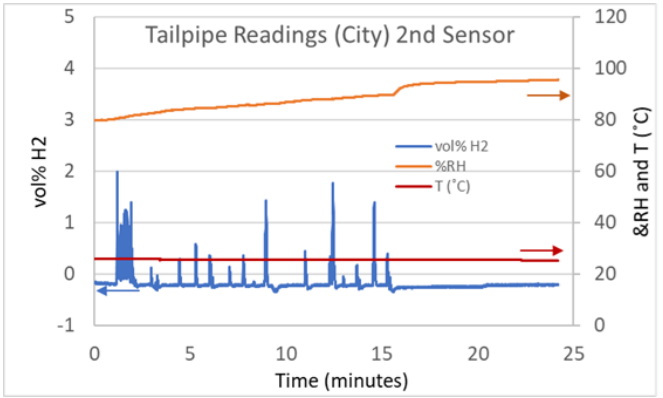
Comprehensive knowledge on safety sensor behavior is improving safety for FCEVs, infrastructure, and repair garages; all critical components of hydrogen technology.

Objective: **Develop low cost, low power, durable, and reliable H_2 safety sensor for vehicle and infrastructure applications.**

1. **Indoor Placement Study**: CFD modelling and empirical verification of indoor hydrogen releases
   - Developed preliminary guidance document for sensor placement and facility design
     - Goal: Inclusion into NFPA2

2. **Vehicle Tailpipe H_2 Emissions**: Collaboration with DOT NHTSA in support of Global Technical Regulation (GTR)
   - Performance verified in the laboratory and vehicle; Field tested on FCEV; detected hydrogen successfully
   - NREL FCEV Analyzer meets the GTR metrological requirements for compliance verification





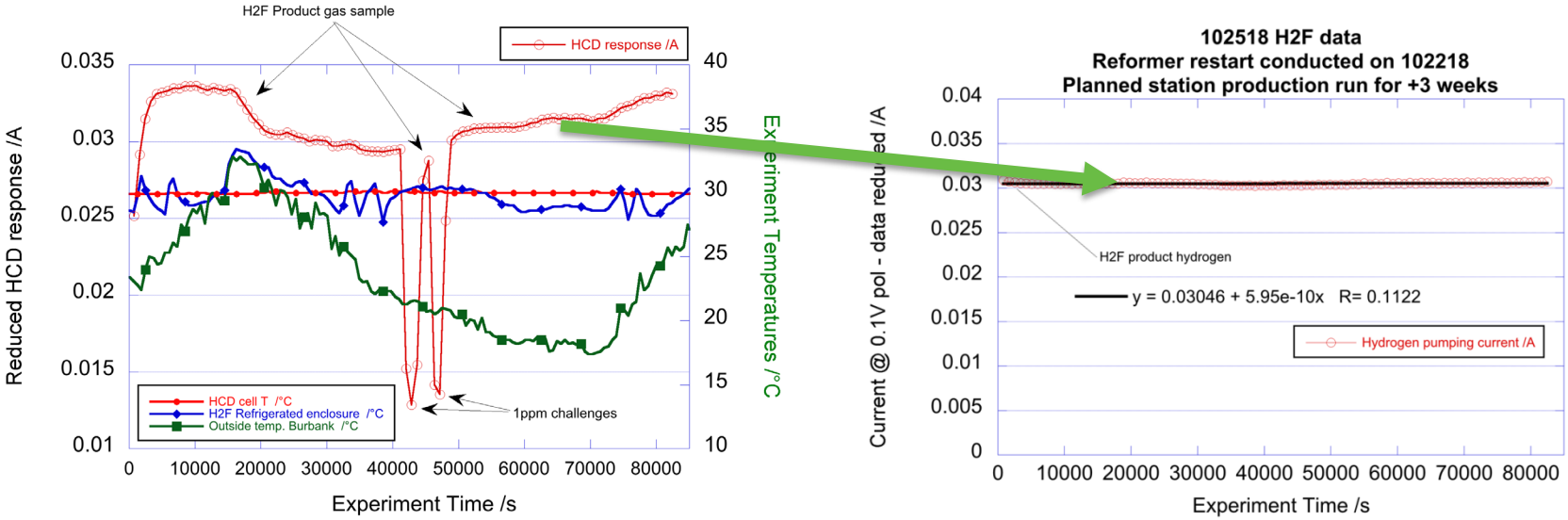
H_2 transients in FCEV exhaust operating under load, as measured by the NREL FCEV Exhaust Analyzer

SCS021

Accomplishment: Fuel Quality and Fuel Quality Assurance

Field-demonstrated In-Line Hydrogen Contaminant Detector capable of <1ppm CO detection

- Installed in-line Hydrogen Contaminant Detector (HCD) at an existing hydrogen fueling station (H2 Frontier, Burbank CA)
  - Obtained real-world performance of the in-line analyzer
  - Demonstrated improved baseline stability
- Analyzer is capable of detecting <1ppm CO with an order of magnitude in response time (<1 minute) in a dry hydrogen stream.



SCS007

LANL HCD installed at H2F, Burbank,CA

Collaborations

International

- CHS – Center for Hydrogen Safety
- IPHE - International Partnership for Hydrogen & Fuel Cells in the Economy
  - 18 countries & EC, 30 projects
- IA HySAFE and ICHS
- Independent Projects (EU, Japan, Korea, etc.)

DOE-EERE

Safety, Codes and Standards

Industry Partnerships & Stakeholder Associations

- Tech Teams (USCAR, energy companies- U.S. DRIVE) – GM, Ford, DOT, CaFCP, Exxon
- California Fuel Cell Partnership
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- Various CDOs & SDOs (SAE, NFPA, ISO, CSA)

National Collaborations (inter- and intra-agency efforts):

State & Regional Partnerships

- **California Fuel Cell Partnership**
- **CT Center for Advanced Technology**
- **Massachusetts Hydrogen Coalition**

National Laboratories

LANL **PNNL**
NREL **SNL**
ORNL

Federal Agencies

DOT **NASA** **DOE-FEMP**

– Interagency coordination: staff-level Interagency Working Group Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.

Thank You

Laura Hill
Project Manager
202-586-8384
laura.hill@ee.doe.gov