U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Safety, Codes & Standards Program Area Plenary Poster

Laura Hill, Project Manager – Fuel Cells Technology Office

2018 Annual Merit Review and Peer Evaluation Meeting

June 13-15, 2018 – Washington DC

Safety, Codes & Standards Goals & Objectives

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

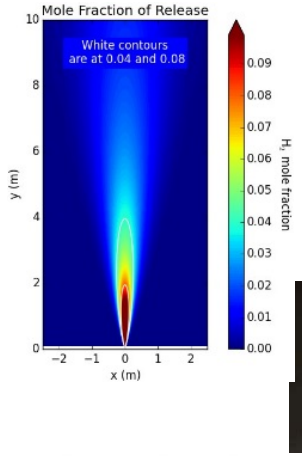
Codes & Standards

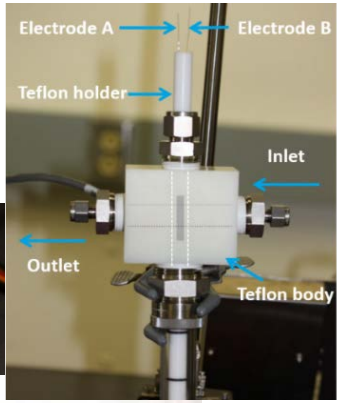
- Conduct **R&D to provide critical data** and information needed to define requirements in developing codes and standards.
- Support and facilitate development of **essential codes and standards** to **enable widespread deployment** of hydrogen and fuel cell technologies and completion of essential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





Current Strategy and Barriers

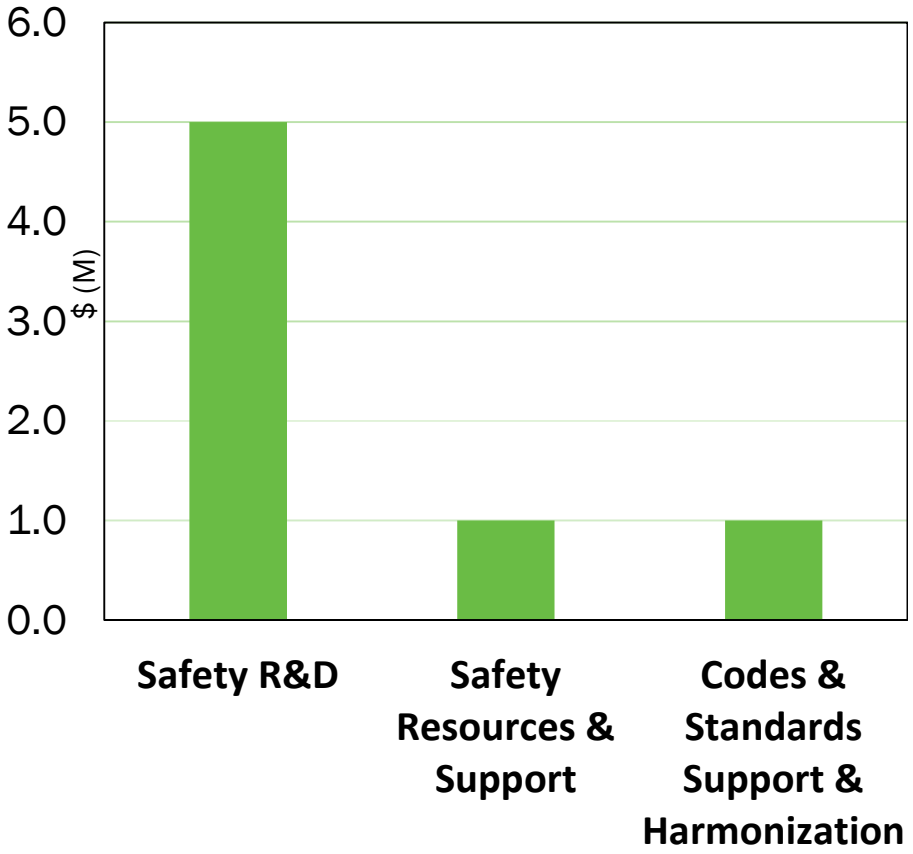
Focus areas	Barriers*	Objectives
Hydrogen Behavior	Insufficient data for code revision (e.g.-large station footprints)	R&D to provide the science & engineering basis for the release, ignition, and combustion behavior of hydrogen across its range of use
Risk Assessment	Usage and access restrictions; Limited reliability data	Develop tools on a scientific foundation to facilitate the assessment of the safety which can be used for various hydrogen applications.
Materials Compatibility	Lack of information on new materials compatibility with H_2	Establish a foundational materials understanding, which will enable and support the C&S development.
Detection & Sensors	High cost and limited commercial availability of products	Develop and deploy safety and fuel quality sensing technologies
Outreach & Support	Limited access and understanding of safety data and information	Support critical stakeholders in understanding hydrogen safety best practices.

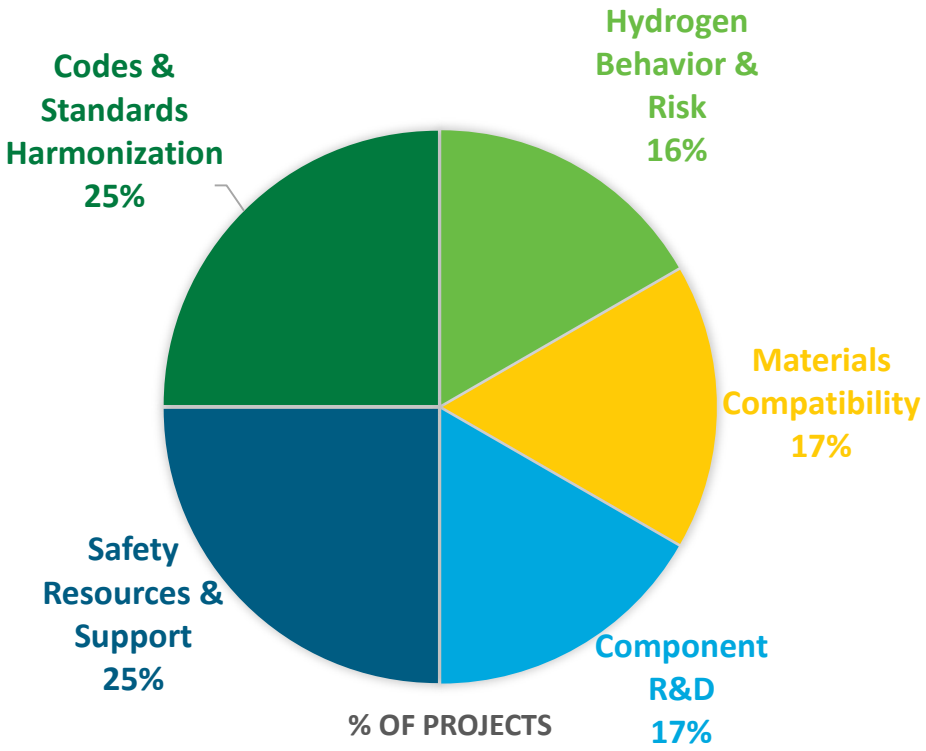
* From Safety, Codes and Standards MYRD&D (June 2015)

Budget

FY 2018 Appropriation = $ 7M

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

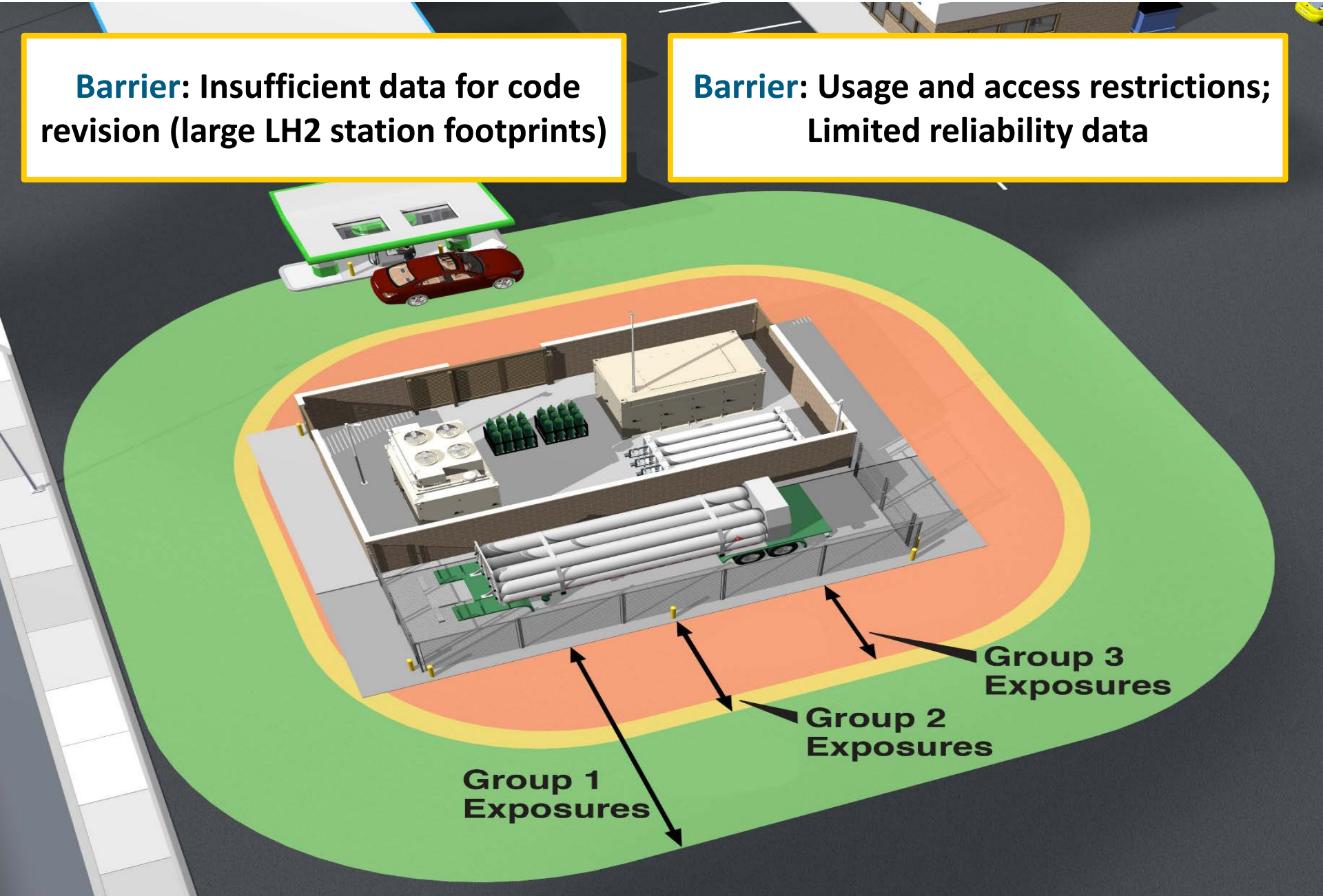




Barrier: LH2 Separation Distances

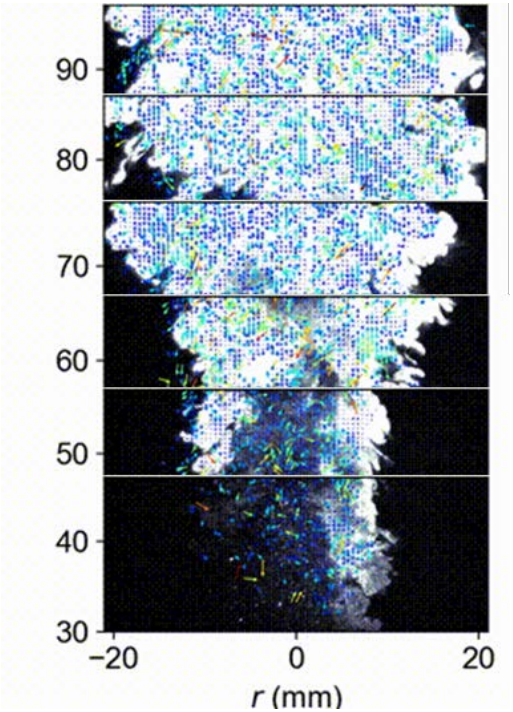
Barrier: Insufficient data for code revision (large LH2 station footprints)

Barrier: Usage and access restrictions; Limited reliability data



R&D Accomplishment: Separation Distances

- **Hydrogen Behavior (SCS010)**
  - Completed the first ever nearfield measurement and validation of temperature, concentration and velocity of cryogenic plumes at 50K

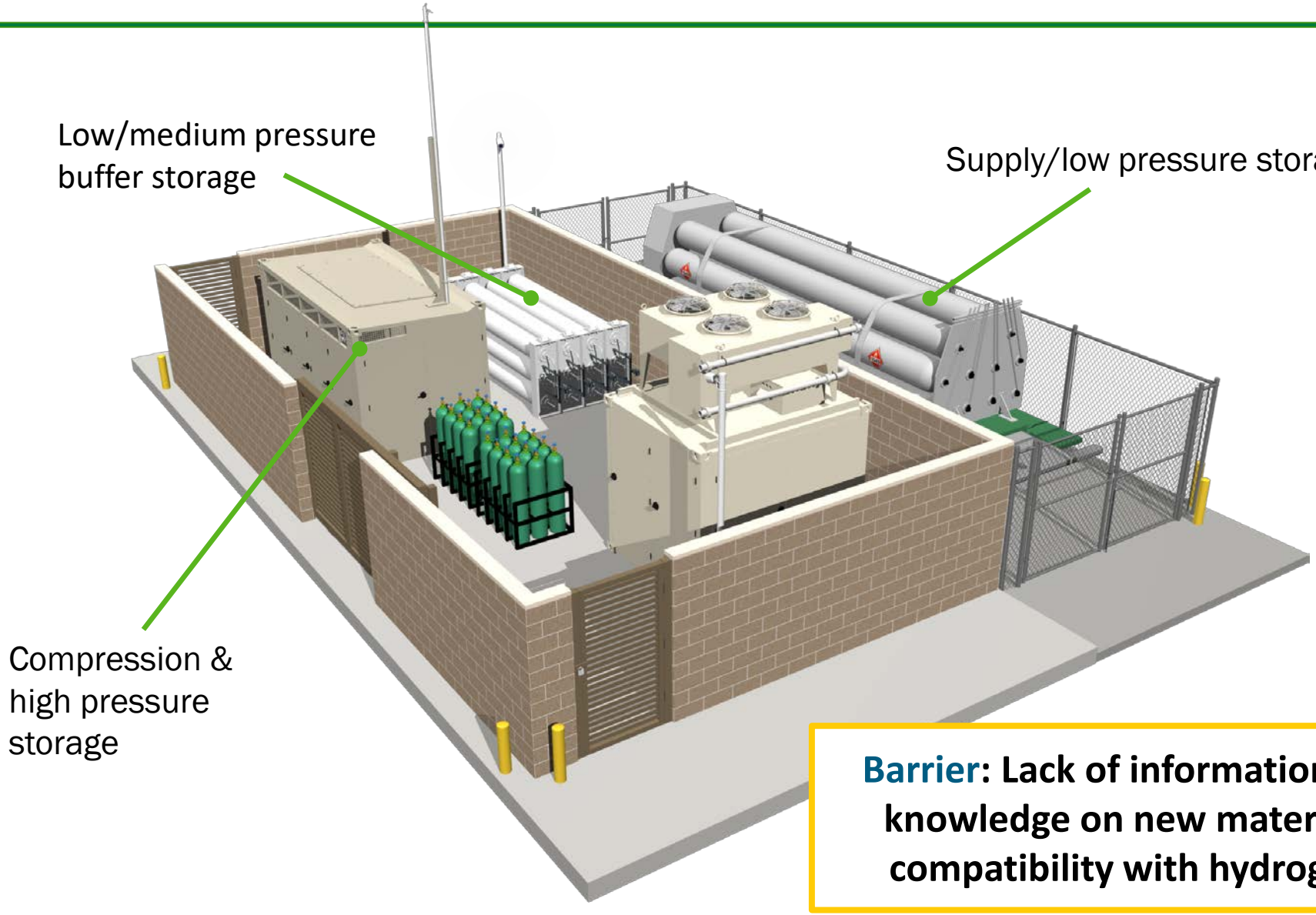


- **Quantitative Risk Assessment (SCS011):**
  - Converted backend HyRAM code to increase model efficiency and future enhancements
  - Identified and prioritized four areas of risk relating to hydrogen materials based on level of resources required and potential impact to the field

- **Enable Hydrogen Infrastructure through Science-based Codes and Standards (SCS025)**
  - Initiated CRADA to employ HyRAM (Hydrogen Risk Assessment Models) and other analysis to real-world acceptance of risk-based alternate means for code compliance

HyRAM
HYDROGEN RISK ASSESSMENT MODELS

Barrier: Hydrogen Compatibility of Materials



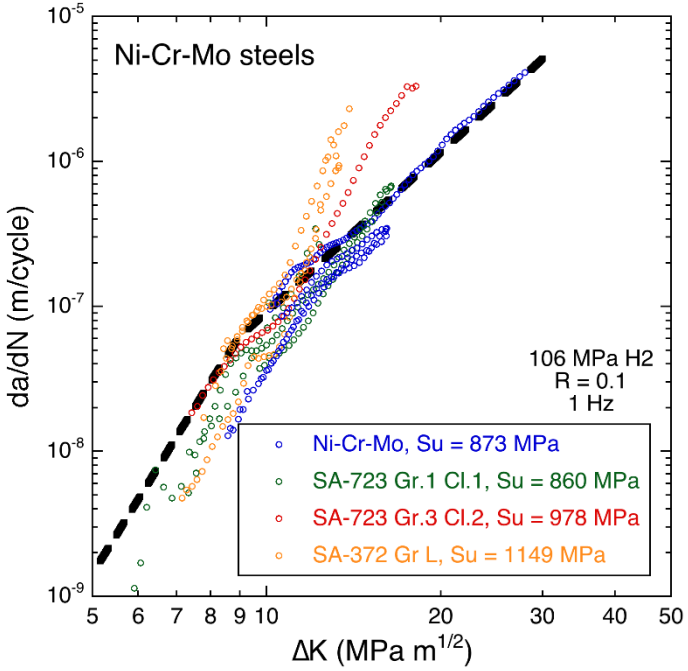
Barrier: Lack of information and knowledge on new materials compatibility with hydrogen

R&D 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

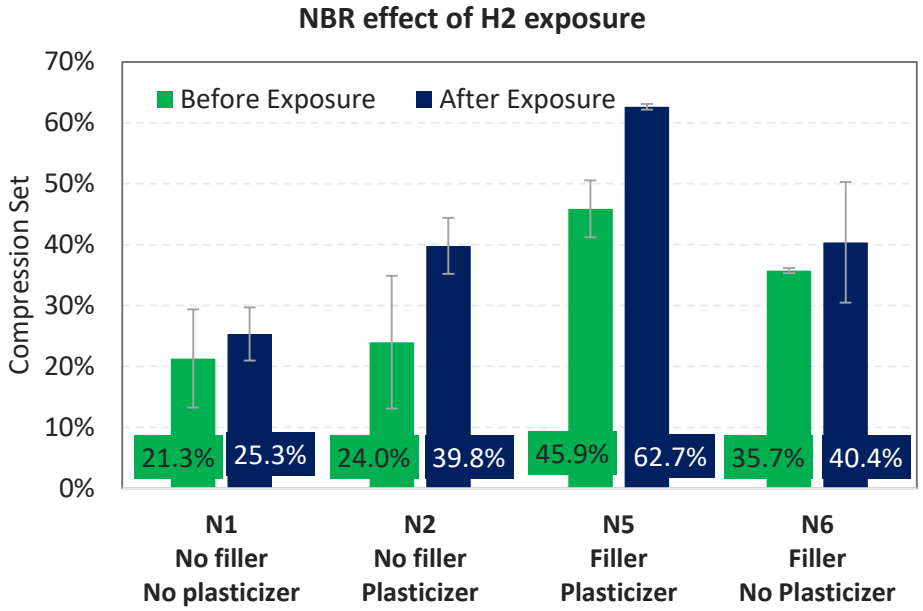
Metallic Materials Compatibility (SCS005)

A universal fatigue crack growth curve was developed to capture the general behavior of pressure vessel steels



Non-Metallic (Polymer) Compatibility (SCS026)

Initiated testing program of model elastomer compounds to understand behaviors of various polymers



Barrier: Safety Sensors

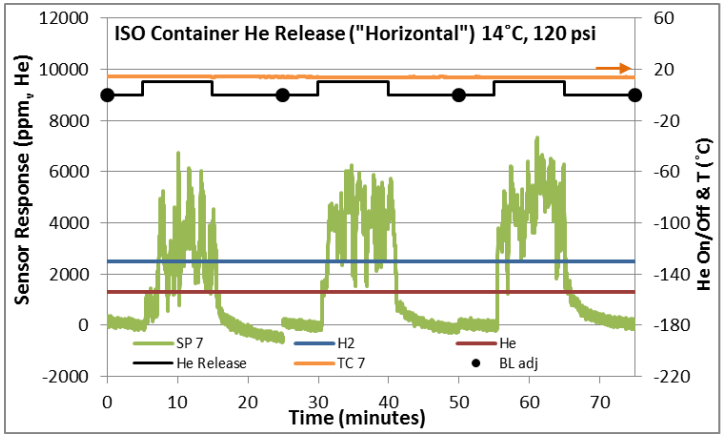
R&D Accomplishment: Safety Sensors

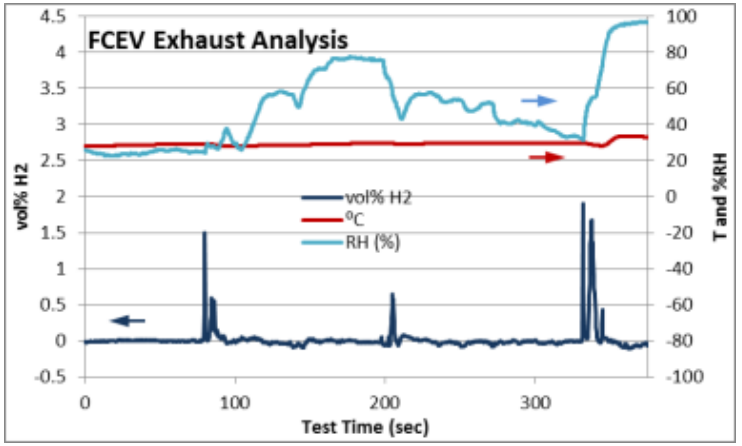
Comprehensive knowledge on safety sensor behavior is improving safety for FCEVs, infrastructure, and repair garages; all critical components of hydrogen technology.

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

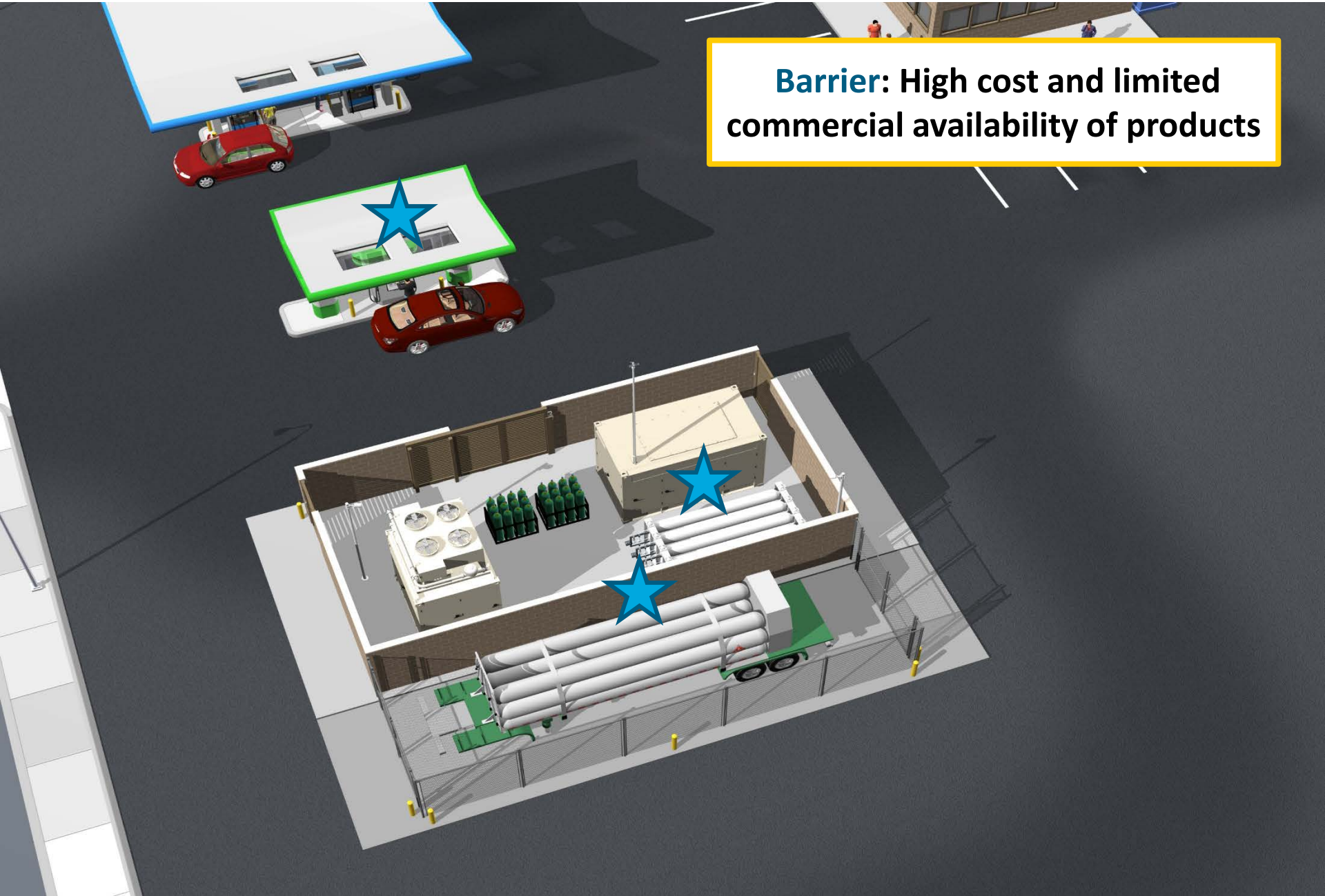
1. **Indoor Placement Study**: CFD modelling and empirical verification of indoor hydrogen releases
   - Empirical verification using the NREL HyWAM
   - Good agreement between model and measurement Independent CFD verification ongoing

2. **Vehicle Tailpipe H_2 Emissions**: Collaboration with DOT NHTSA in support of Global Technical Regulation (GTR)
   - Developed FCEV Exhaust Analyzer for verification of GTR-13 requirements.
   - Performance verified in the laboratory and vehicle; Field tested on FCEV; detected hydrogen successfully





Barrier: Fuel Quality Assurance



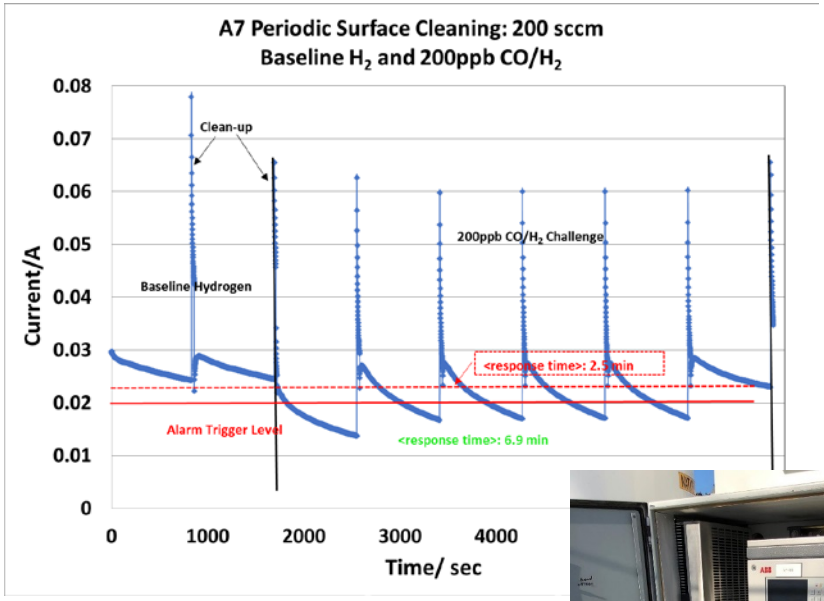
Barrier: High cost and limited commercial availability of products

R&D Accomplishment: Fuel Quality and Fuel Quality Assurance

A means of detecting contaminants in the hydrogen fuel stream is vital to ensure quality according to SAE J2719 and prevent damage to the fuel cell.

Hydrogen Fuel Quality (SCS007)

- Initiated fuel testing of in-line hydrogen contaminate detector with improved baseline stability
- Response time goal met for both 100 sccm and 200 sccm hydrogen flows
- **Patent application filed for analyzer prototype.**
- Analyzer installed and field tested
- Will test analyzer response to 1ppm CO/H2 test gas and calibrate response and verify baseline recovery after cleanup potential is applied

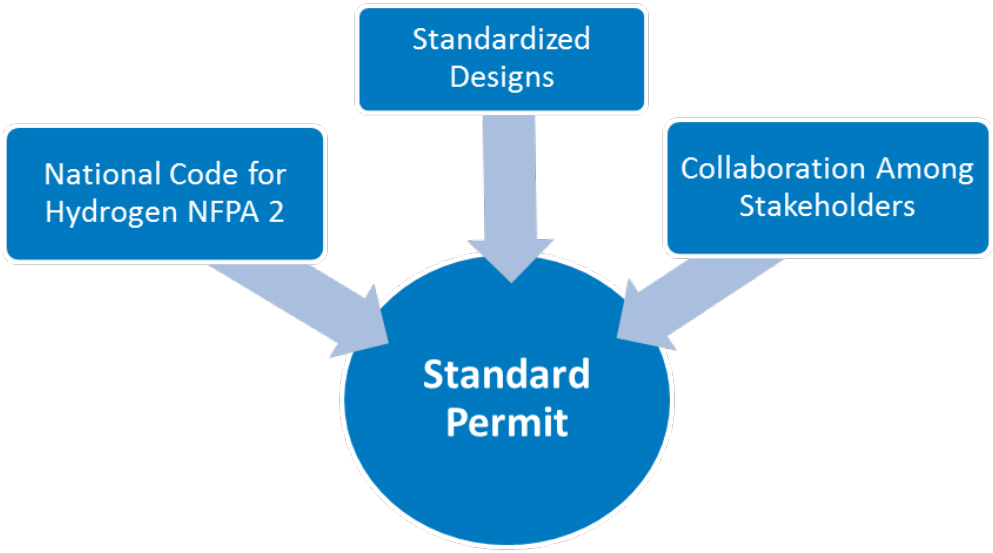


R&D Accomplishment: Developed Standard Permit for Hydrogen Storage

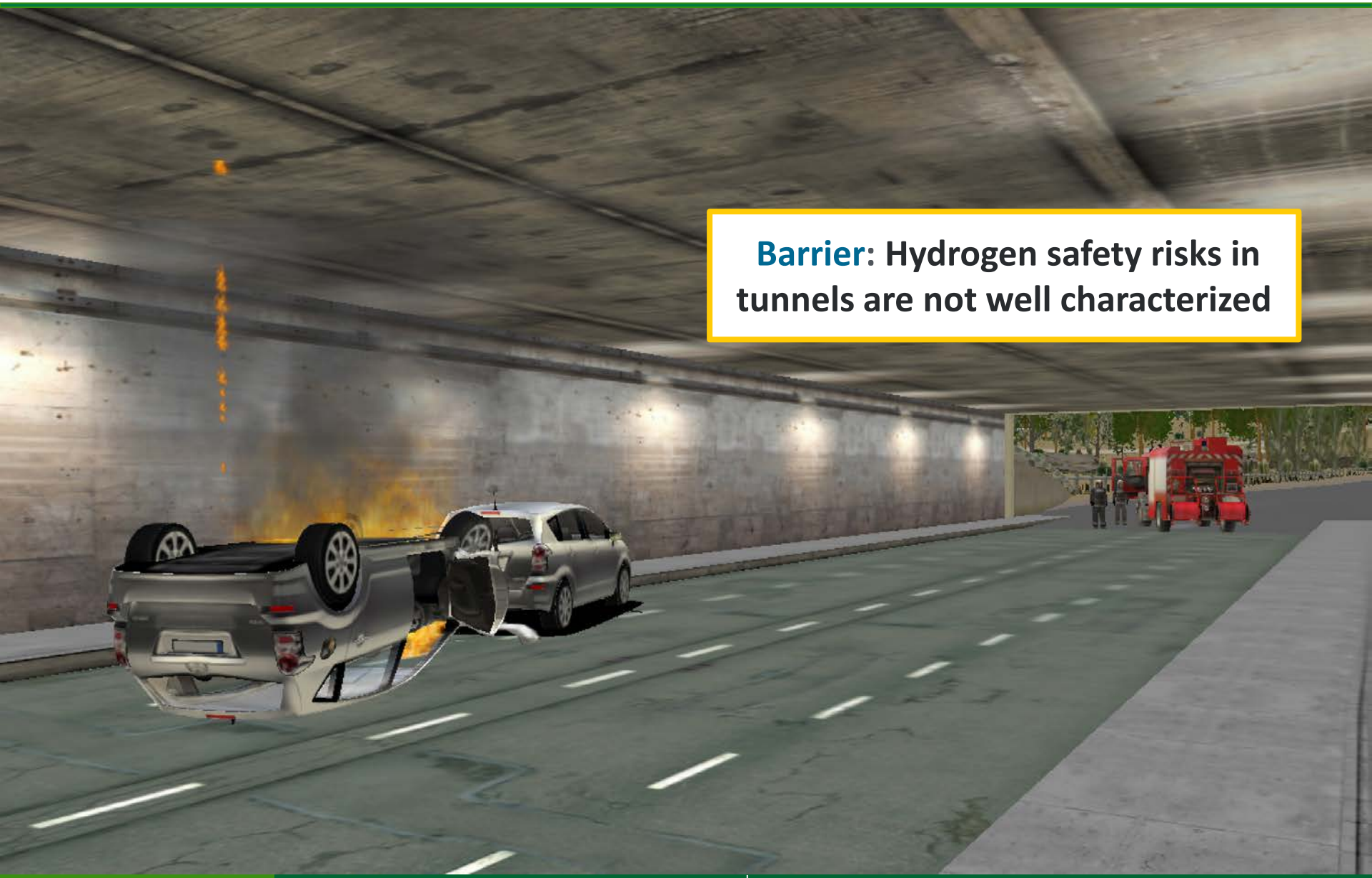
Leveraging DOE research, particularly unused R&D assets, can support major code proposals and enable advances in public safety.

Codes and Standards Deployment and Outreach (SCS001):

- Based on industry requests, facilitated development of a Standard Permit for Hydrogen Fueling Stations to enable a more efficient permitting process
- Standard permit for gaseous/liquid HFSs submitted to NFPA 2 to be added to annex text
- Maintained Permitting tolls on H2Tools
- Presented Webinar on permitting tools to streamline hydrogen infrastructure permitting and standard permitting



Cross-cutting Effort: Tunnel Safety Evaluation

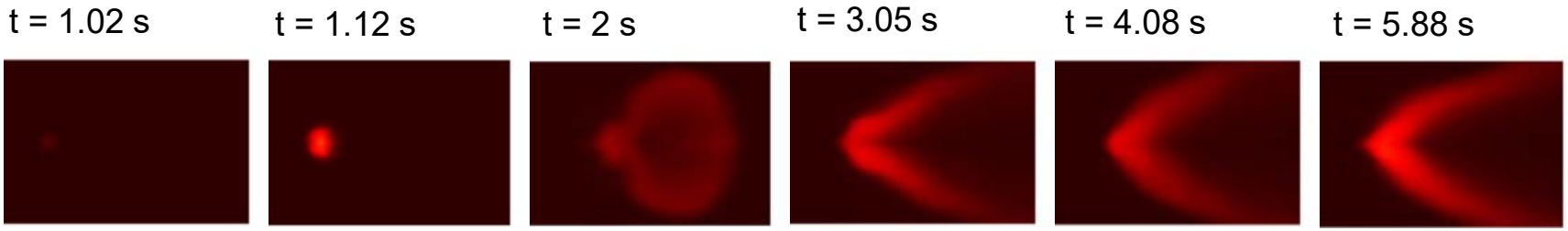


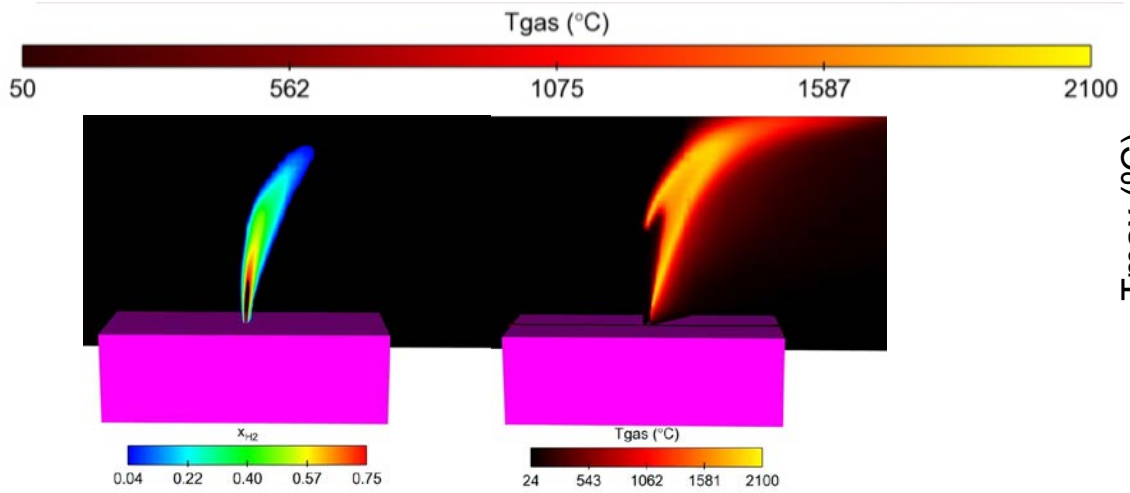
Cross-cutting Effort: Tunnel Safety Evaluation

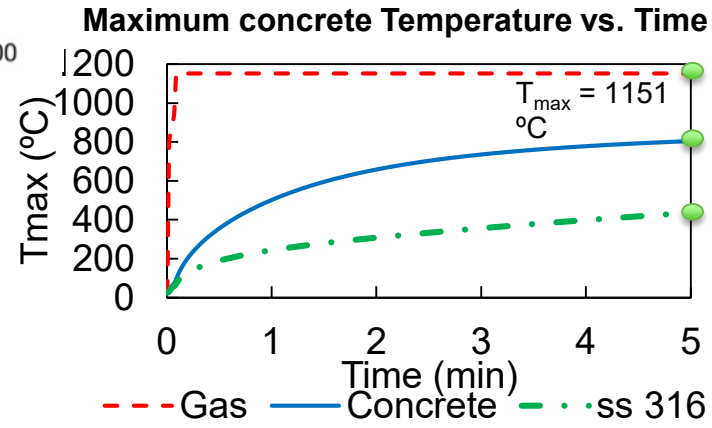
Risk analysis and modeling results will be communicated to code officials to assist in their decision-making on allowing FCEVs in tunnels.

Tunnel Safety Evaluation Accomplishments (SCS025):

- Structural epoxy is not impacted by jet flame or heating effects
- Damage is concrete ceiling panels is extremely localized, shallow and conservative
- No structural impact to load bearing structure due to maximum temperature of steel hangers exposed directly to the hydrogen jet flame







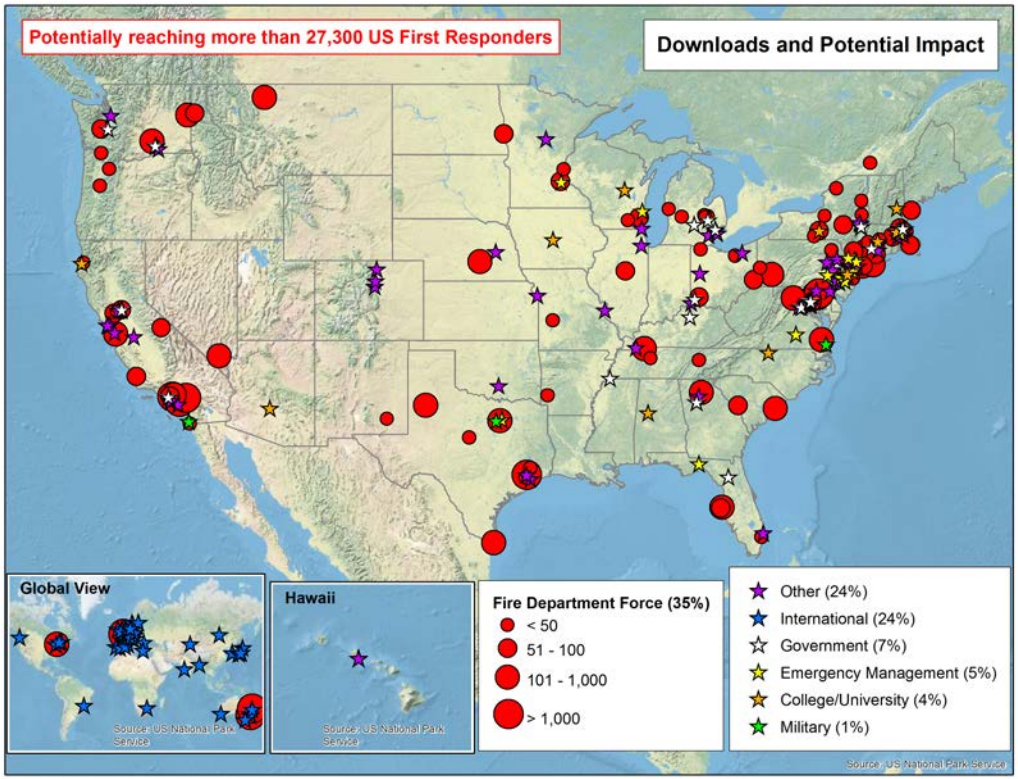
Outreach Resources – Training & Outreach

SCS supports continued code official and first-responder training, both online and in-person, with over 36,000 individuals reached!

Safety outreach in both California and Northeast in FY18: Supporting the safe rollout of hydrogen infrastructure (SCS019)

Accomplishments:

- Substantial update of First Responder training material was completed in February 2018
- Refreshed Online Training in May 2018
- >1,500 attendees at Classroom Training since 2009
- 388 downloads of National Template (+58 in past 12 months)



Enabling Safe Deployment: H2Tools.org

The U.S. is a leader in hydrogen safety; H2Tools.org is a key resource to disseminate safety information

Enable the safe and timely transition to hydrogen and fuel cell technologies through unique and highly impactful safety resources (SCS019)

Site Content

- **3,629** Total Pages
- **2,414** Bibliographic References
- **217** Lessons Learned Pages
- **142** Best Safety Practices Pages

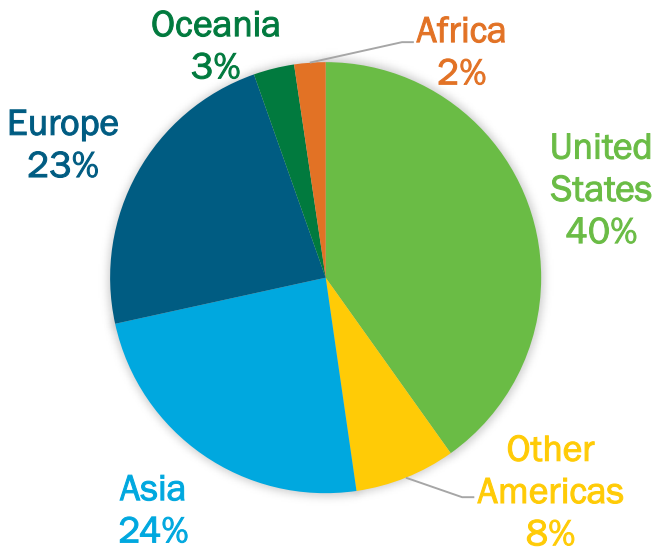
Usage Stats*

- **279,678** Total Pageviews
- **56,951** Sessions

>100% growth since 3/2017

- **4.91** Pages Visited per Session
- **6:36** Minutes per Session

H2Tools.org - A Global Resource!



* Nonbounce statistics through March 31, 2018

Enabling Safe Deployment: AIChE Partnership

Partnership will enable broader access to online and in-person training resources

Codes and Standards Deployment and Outreach (SCS001):

AIChE* is planning to establish a Center for Hydrogen Safety. PNNL will partner with AIChE to expand the HSP's access to new customers by:

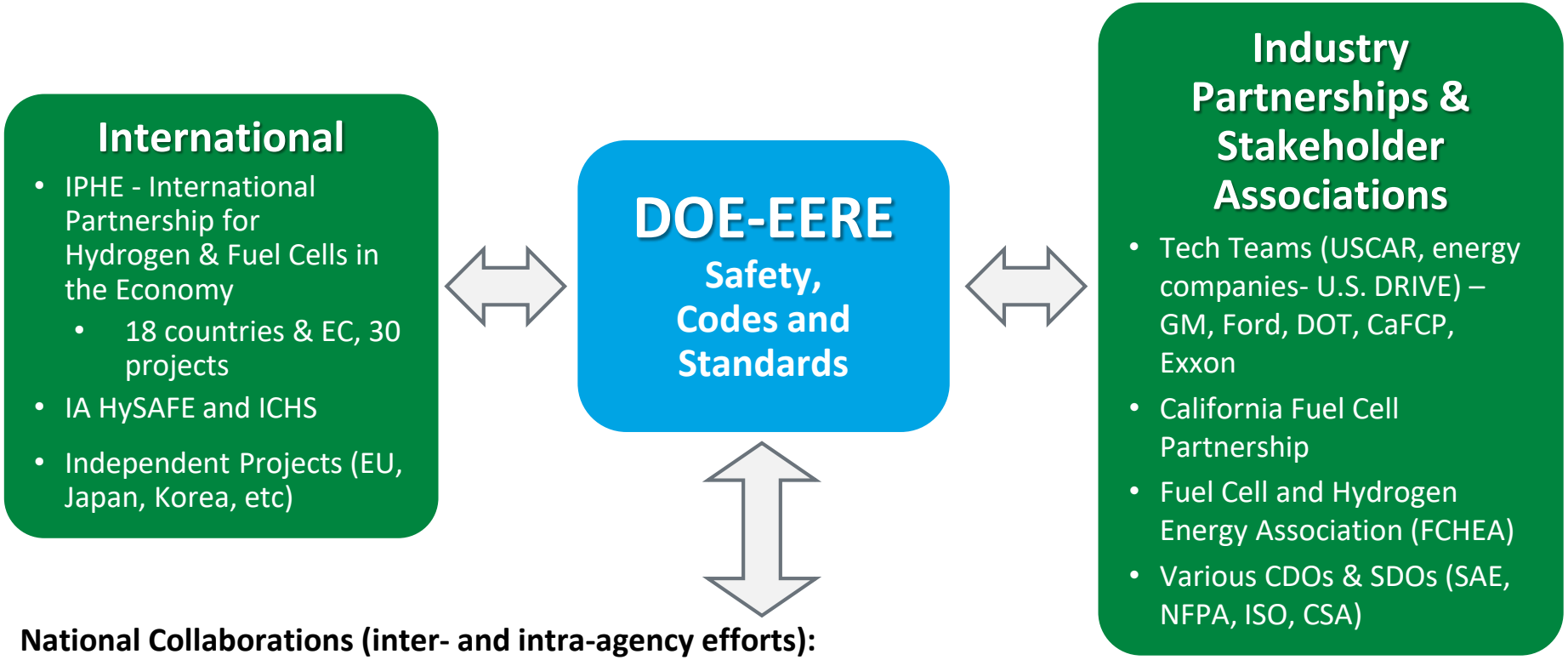
- Making the HSP more readily available to industry, state, and federal government agencies (national and international)
- Enabling less cumbersome/time-consuming contracting efforts
- Enabling broader access to key safety knowledge resources

AIChE
The Global Home of Chemical Engineers
American Institute of Chemical Engineers (AIChE)

Streamlined access to HSP

HYDROGEN Safety Panel

Collaborations



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
NREL
ORNL
PNNL
SNL

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

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