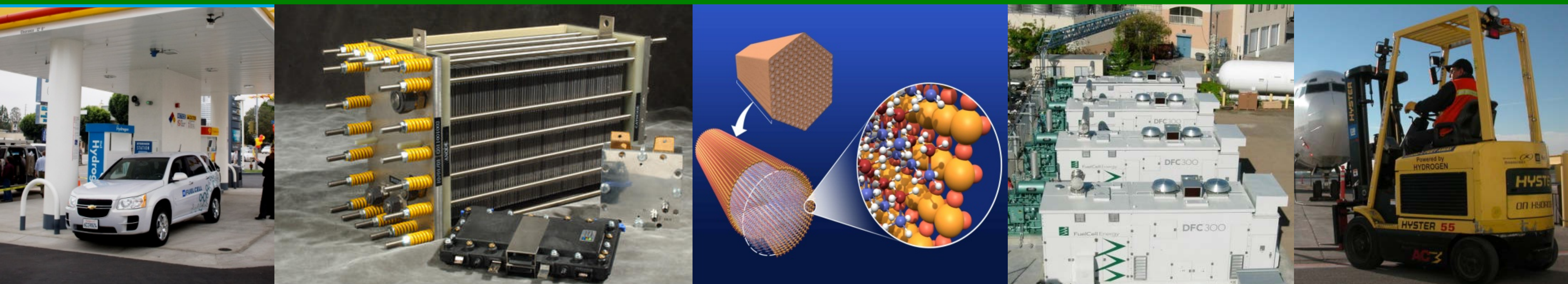
U.S. DEPARTMENT OF
ENERGY



Safety Codes & Standards

- Plenary -

Will James

Fuel Cell Technologies Office

2015 Annual Merit Review and Peer Evaluation Meeting

June 8 - 12, 2015

SCS Program Goal and Objectives

Codes & Standards Objectives:

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

Hydrogen Safety Objectives:

- Ensure that best safety practices underlie research, technology development, and market deployment activities supported through DOE-funded projects.
- Develop and enable widespread sharing of safety-related information resources and lessons learned with first responders, authorities having jurisdiction (AHJs), and other key stakeholders.

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

Safety, Codes & Standards Program Strategy

Research & Development

- Hydrogen Behavior
- Hydrogen Risk Assessment
- Materials Compatibility
- Fuel Quality
- Component Testing
- Sensors (both Safety and Contaminant Detection)

Codes & Standards Support and Implementation

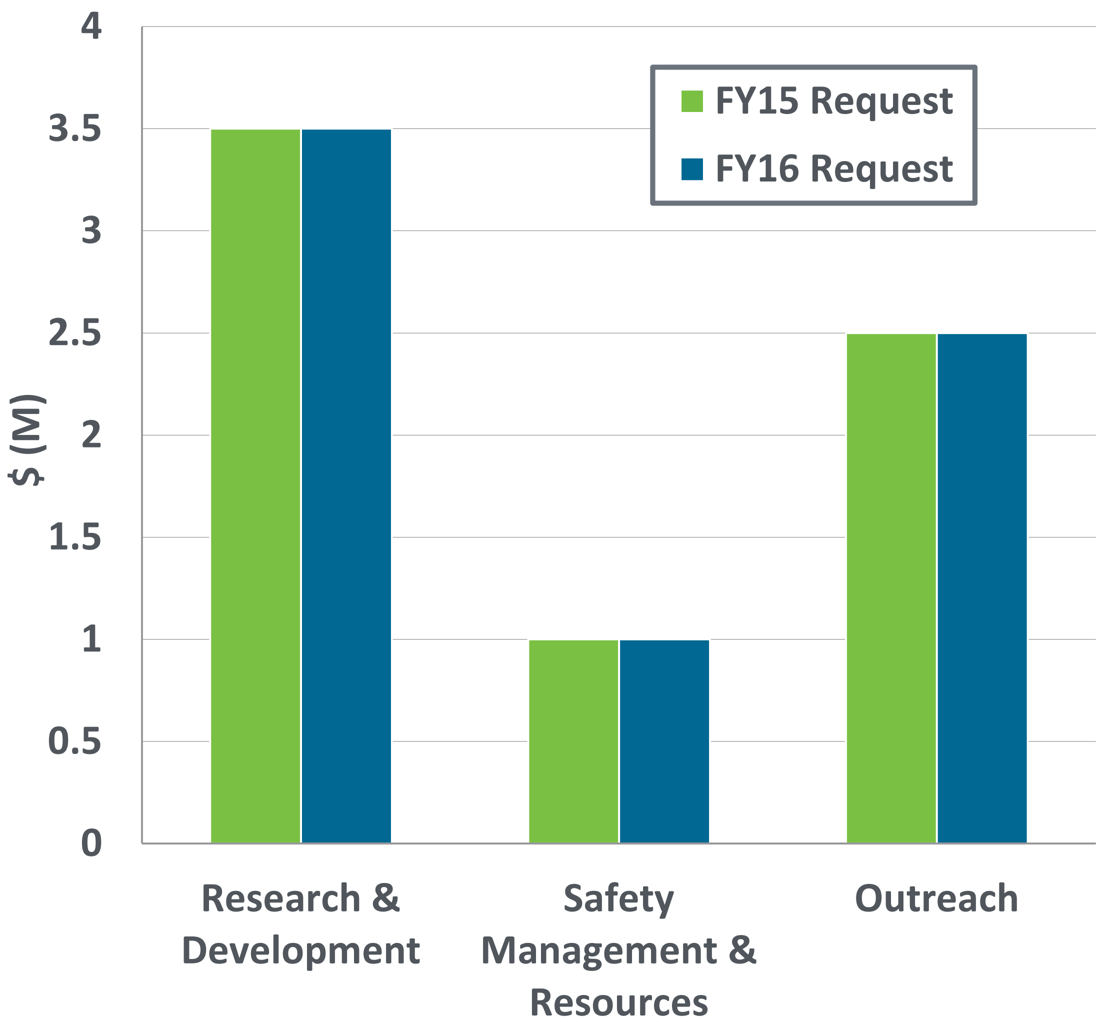
- Domestic and International CDO and SDO participation and support
- Hydrogen Risk Assessment Models (HyRAM)
- Alternative Code Compliance Methods
- Continuous Codes and Standards Improvement
- Sensor Validation (industry engagement)

Outreach

- Hydrogen Safety Panel
- Codes Official Training
- First Responders Training
- State Engagement and Support (e.g. – California and 8 State MOU)
- International Collaboration (e.g. – IPHE RCSWG, IA-HySAFE)
- Resource Development and Dissemination (training prop, H2Tools.org)

An integrated approach to safety, codes and standards: research and development informs codes and standards implementation efforts, which support outreach efforts

SCS Budget



FY 2016 Request = $7M

FY 2015 Appropriation = $7M

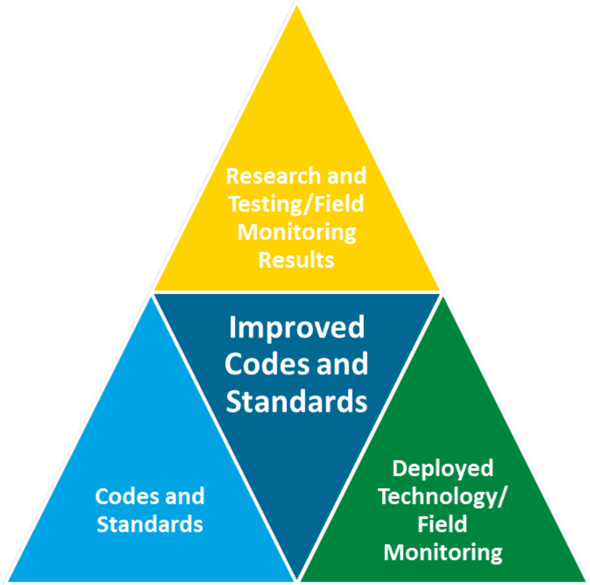
Emphasis

- **R&D Activities:** H_2 Behavior, Risk Assessment/Mitigation, Materials Compatibility, H_2 Fuel Quality, Metering, Sensors, Component Testing
- **Safety Management & Resources:** Hydrogen Safety Panel, Databases, and Training Props
- **Outreach:** Codes & Standards and Permitting, Continuous Codes and Standards Improvement, Resource Dissemination

FY 2016 request maintains stable funding and allows for continued emphasis on critical RCS and safety

Approach: Continuous Codes and Standards Improvement (CCSI)

Barrier	Action
1. Increase HRS performance and reliability to level required for deployment	Continue testing and support RCS development by engaging with component manufacturers, system designers and CDOs/SDOs.
2. Simplify RCS to the level to support deployment	Use field data through CCSI to streamline the RCS process
3. Provide SCS information that is accessible and useable to the infrequent user	Provide easily accessible information that would quickly provide the necessary requirements to the user



Examples of Utilizing CCSI:

- Hydrogen Code Improvement (HCI) Team (thru FCHEA Transportation Working Group)
- Joint NFPA 2/55 Task Group to address separation distances for gaseous and liquid hydrogen storage

CCSI encourages the safe and rapid growth of hydrogen fueling infrastructure

Approach: Support of Lab to Full Scale H_2 Testing

Mechanical Testing

- Fundamental mechanical testing to determine root-cause failure modes
- **Advantages:** Flexibility of design, root-cause isolation
- **Limitations:** Difficulty in scaling, requires test apparatus

Sub-Component Level Testing

- Reliability and sub-component life testing (such as compressor valves)
- **Advantages:** uses the actual equipment, lower-cost than full-scale component testing
- **Limitations:** higher cost than mechanical testing, harder to isolate failure mode

Component-Level Testing

- Reliability and accelerated life testing at full component level
- **Advantages:** use of real hardware, laboratory control environment
- **Limitations:** costly experimentation, hard to isolate failure modes, degradation

System-Level Field Testing

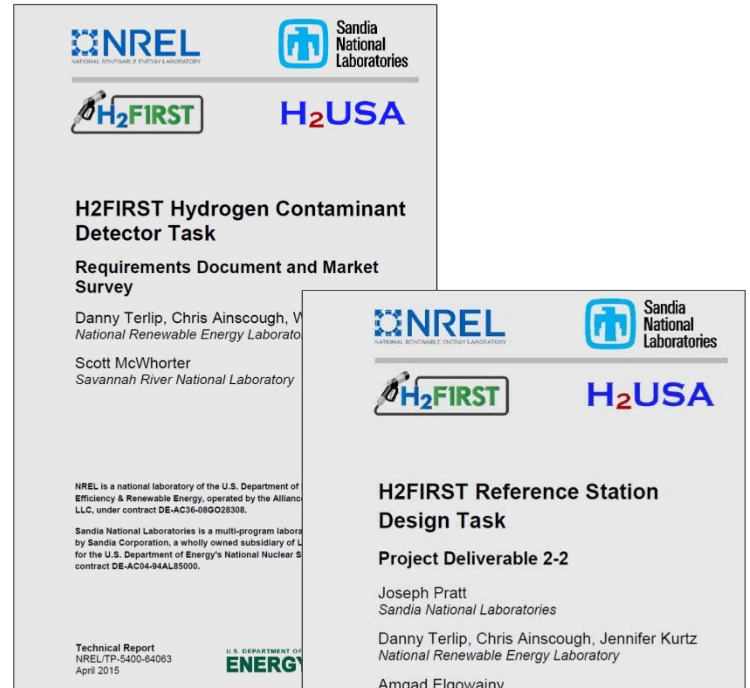
- Data from hydrogen demonstration and fueling station installations
- **Advantages:** large sample size, real-life stresses
- **Limitations:** limited control of test parameters

SCS supports a bottom-up component research approach, covering testing from the material level to system – level field testing

H2FIRST Activities

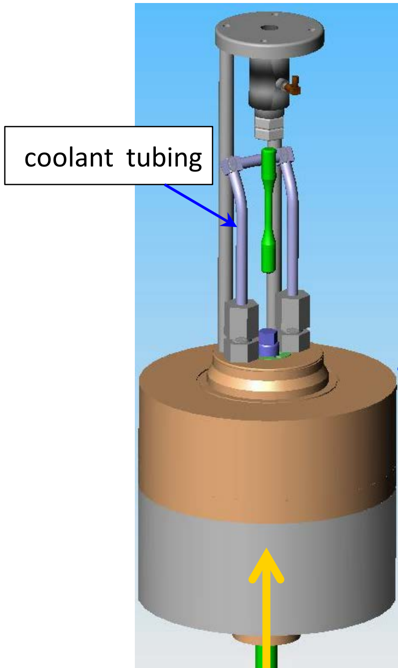
SCS involvement with the H2FIRST project, in support of the goals of H2USA

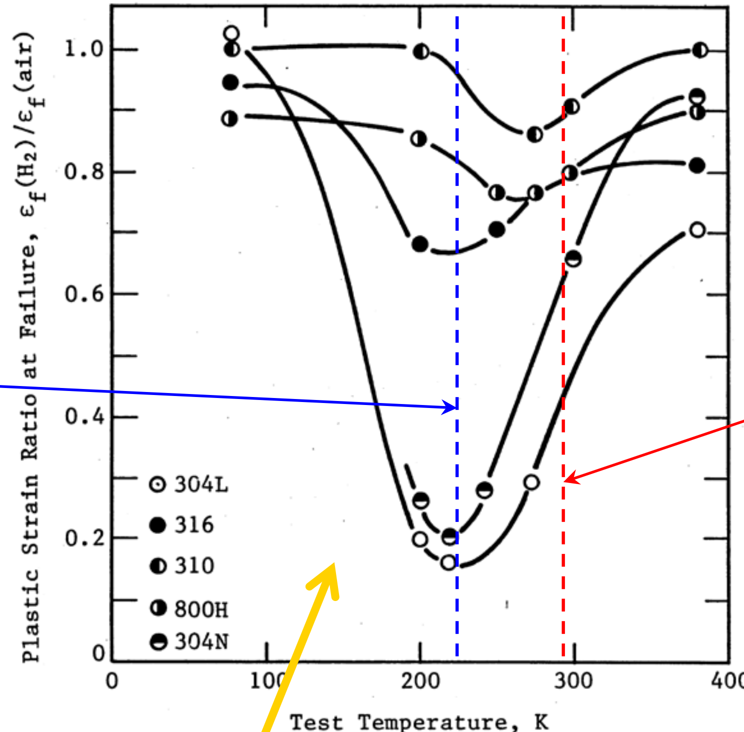
- **Hydrogen Contaminant Detector Task**: report and highlights
  - **Hydrogen Contaminant Detection Report,** published in April 2015, describes the current commercial state of the art technologies in contamination detection. The report is available at: http://www.nrel.gov/docs/fy15osti/64063.pdf
- **Reference Station Design Task**: report and highlights
  - **Reference Station Design Report,** published in April 2015, evaluates station economics using HRSAM and includes detailed schematics which include piping and instrumentation designs, bills of material, and descriptions of layouts that ensure compliance with the National Fire Protection Association. These reference designs are meant to help stakeholders quickly evaluate the station configurations that best suit their applications. The report is available at: http://www.nrel.gov/docs/fy15osti/64107.pdf
- **Hydrogen Station Equipment Performance (HyStEP) Device**:
  - Objective is to accelerate commercial hydrogen station acceptance by developing and validating a prototype device to measure hydrogen dispenser performance according to CSA HGV 4.3/SAE J2601.

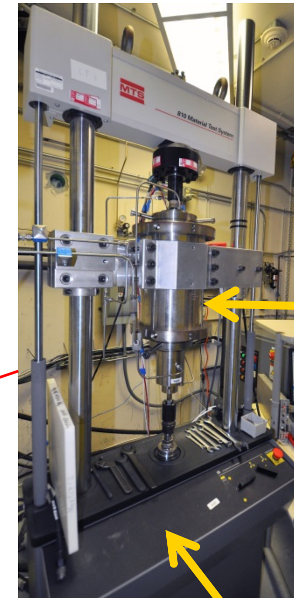

NREL
Sandia National Laboratories
H2FIRST
H2USA
H2FIRST Hydrogen Contaminant Detector Task
Requirements Document and Market Survey
Danny Terlip, Chris Ainscough, W
National Renewable Energy Laborato
Scott McWhorter
Savannah River National Laboratory
NREL is a national laboratory of the U.S. Department of Efficiency & Renewable Energy, operated by the Allianc LLC, under contract DE-AC36-08GO28308.
Sandia National Laboratories is a multi-program labora by Sandia Corporation, a wholly owned subsidiary of L for the U.S. Department of Energy's National Nuclear S contract DE-AC04-94AL85000.
Technical Report
NREL/TP-5400-64063
April 2015
U.S. DEPARTMENT OF ENERGY

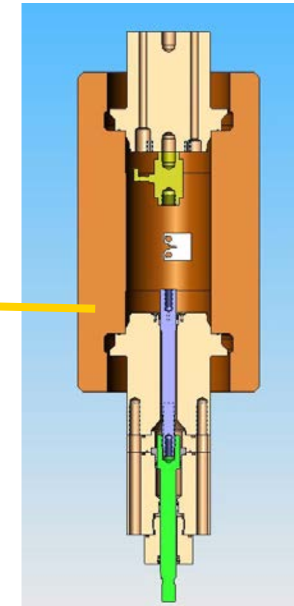
NREL
Sandia National Laboratories
H2FIRST
H2USA
H2FIRST Reference Station Design Task
Project Deliverable 2-2
Joseph Pratt
Sandia National Laboratories
Danny Terlip, Chris Ainscough, Jennifer Kurtz
National Renewable Energy Laboratory
Amgad Elgowainy

Progress: Low-Temperature Materials Testing Capability (SNL)









Low-temperature pressure vessel internal structure

Ductility of stainless steels in H2 gas normalized by ductility in air

Current capability for fatigue testing in high-pressure H2: room temperature only

New capability developed for testing hydrogen embrittlement of stainless steels at sub-ambient temperature

Progress: H2 Behavior and Risk Assessment

Cold Hydrogen Release Laboratory

Validate liquid H_2 (LH_2)models enable risk assessment tools. New cryo-temperature laboratory will bring a science-based approach to LH2 at the code committees.

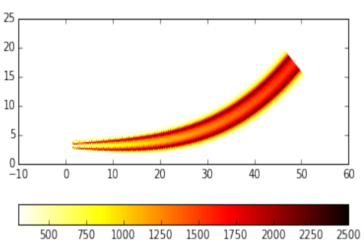
Hydrogen Risk Assessment Models (HyRAM)

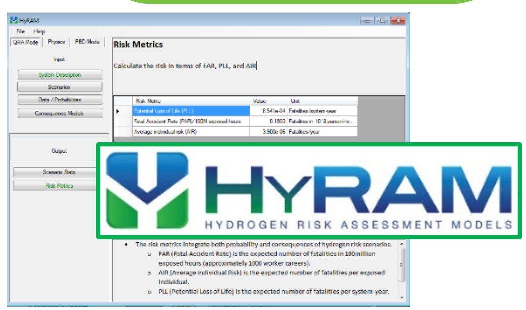
Quantitative risk assessment (QRA) utilizes engineering models to produce risk metrics which enable performance-based design.

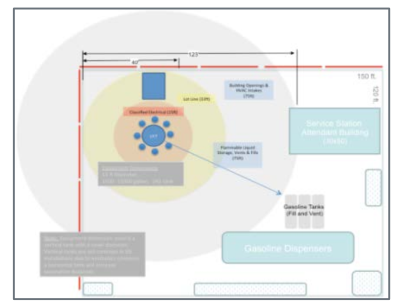
Alternative Compliance Methods

Performance-based design is a risk-enabled (via QRA), NFPA 2 - compliant option for station design.

Station Deployment



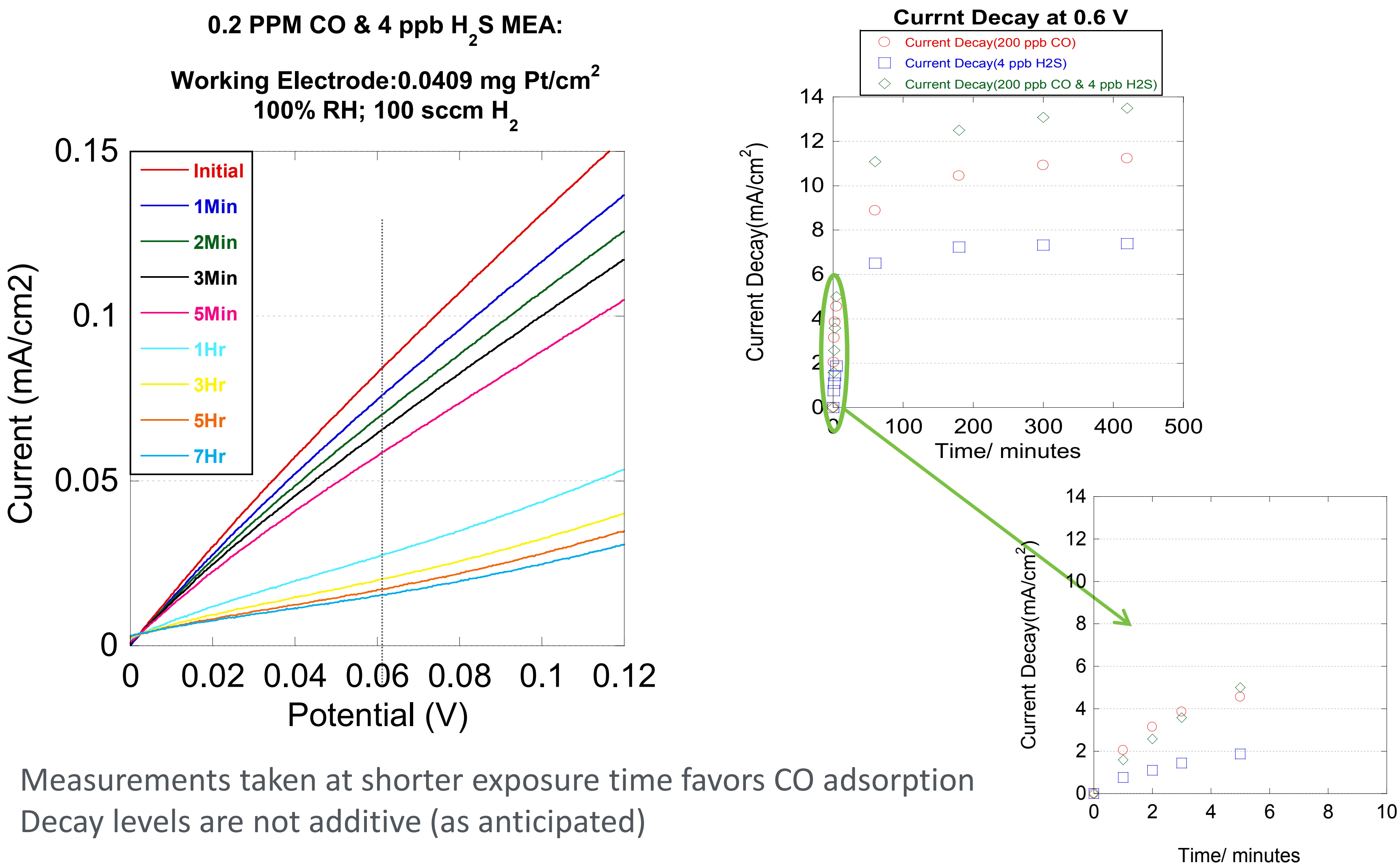




- **New DOE Record #15006:** DOE research has demonstrated up to a 50% reduction in separation distances (for GH_2)
- Design Brief Template developed to demonstrate the performance-based design process

Leveraging science to enable infrastructure through understanding hydrogen behavior, analyzing risk, and implementing inherently safe design options

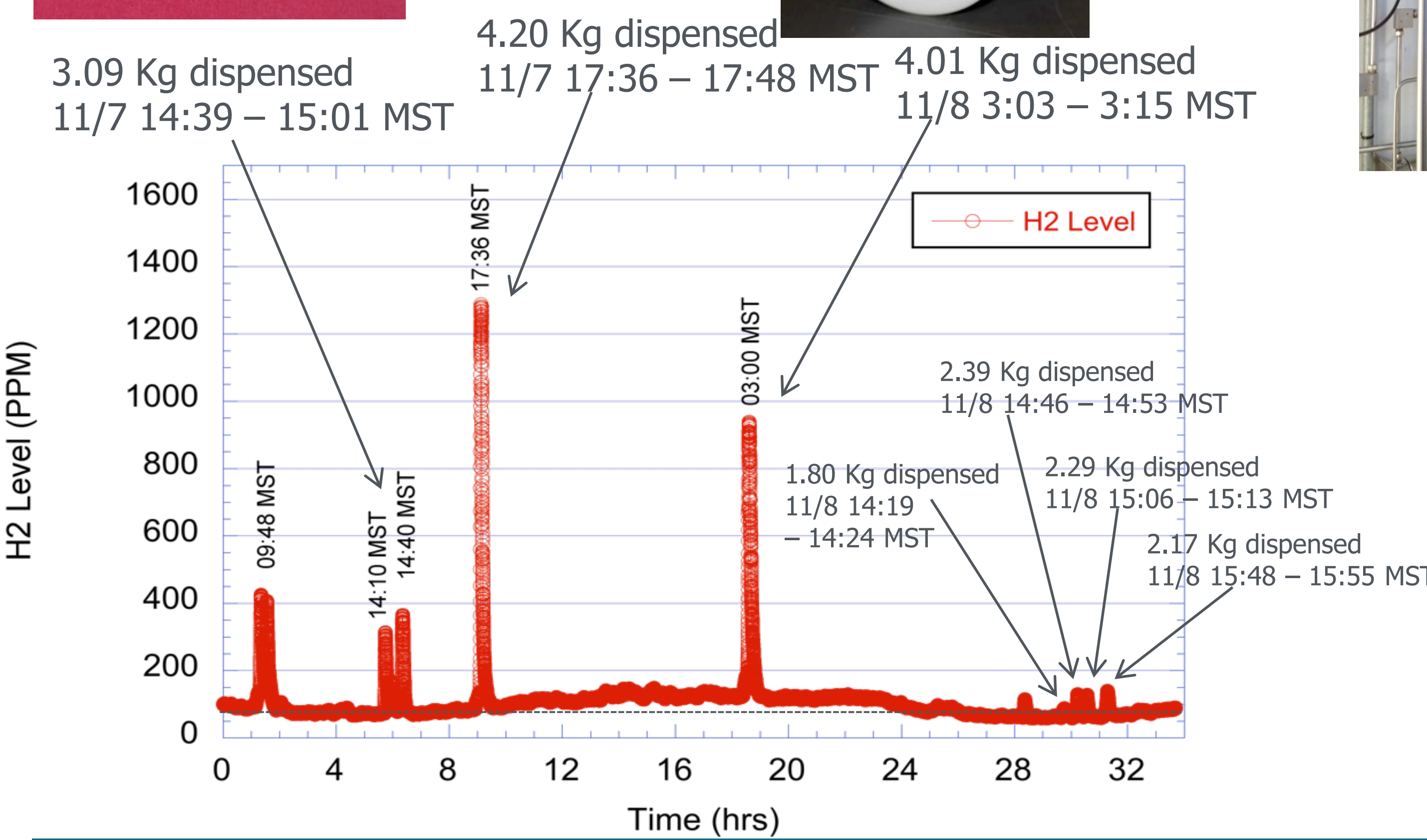
Accomplishment: Fuel Quality Analyzer (LANL)



- Measurements taken at shorter exposure time favors CO adsorption
- Decay levels are not additive (as anticipated)

Sensitivity of 200 ppb CO and 4 ppb H_2S achieved at short time scales

Field Validation: Hydrogen Safety Sensors (LANL)

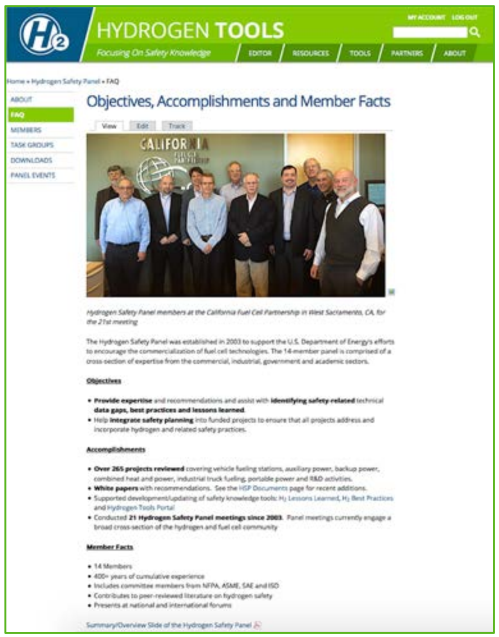


Investment since 2008 has turned the LANL/LLNL-developed solid state electrochemical safety sensor into a commercially-ready technology

Safety Outreach & Resource Dissemination

Hydrogen Safety Panel continues to support best hydrogen safety practices through project plan reviews, site visits, and other activities:

- March 2015 Panel Meeting in Sacramento, CA, which included a project review during the meeting
- **18 project reviews since last AMR** (412 total)
- Assisting the H2USA market acceleration working group to remove barriers
- Supporting the California Governor's Office and CA Green Team



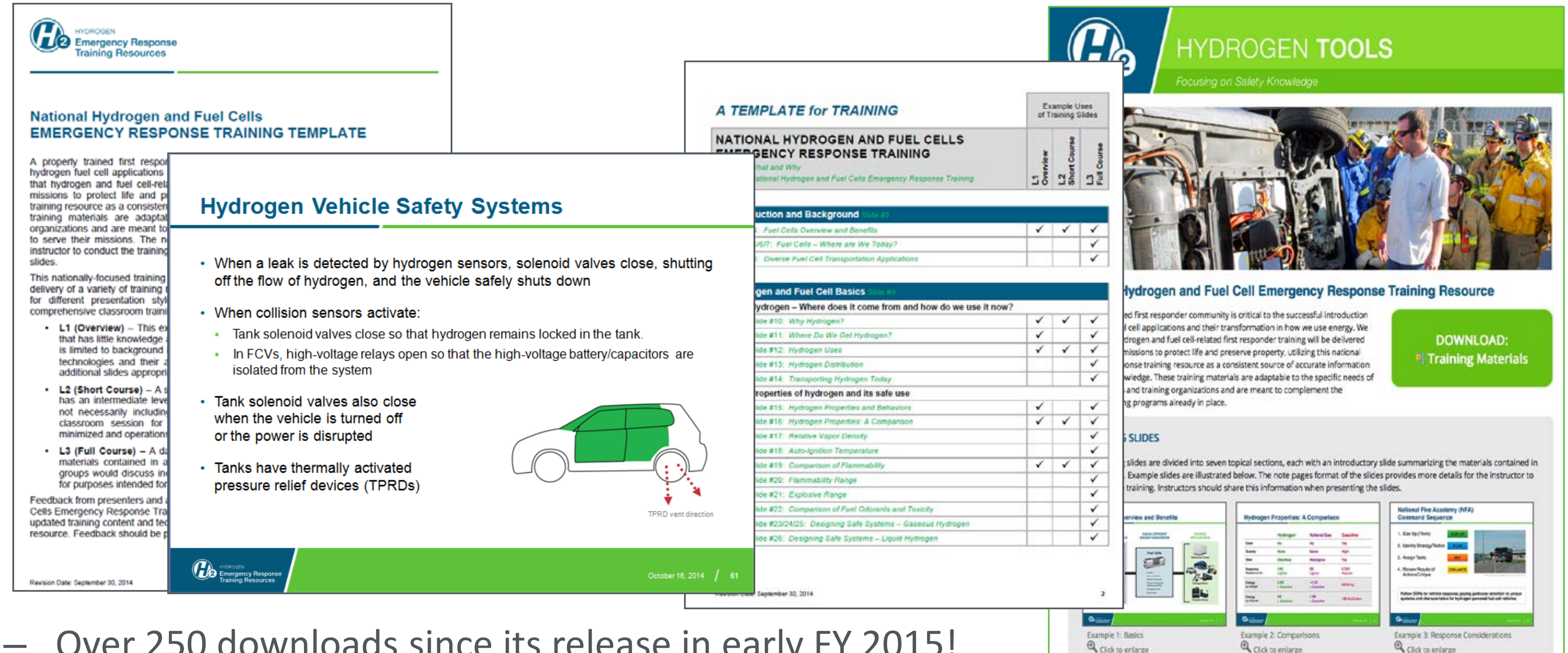
New Website: H2tools.org/hsp

Training Resource	Impact
First Responder Training (in-person)	1,035
First Responder Training (online)	>32,000
Code Official Training (in-person)	565
Code Official Training (online)	1,117
Hydrogen Tools App Downloads	1,272
NEW! Hydrogen & Fuel Cell Emergency Response Training Resource Downloads	257
Hydrogen Researcher Training (online)	179

– Over 2,400 first responders and code officials trained in 2014

SCS supports continued code official and first-responder training, both online and in-person, with over 35,000 individuals reached!

Accomplishment: National First Responder Training Resource (PNNL)

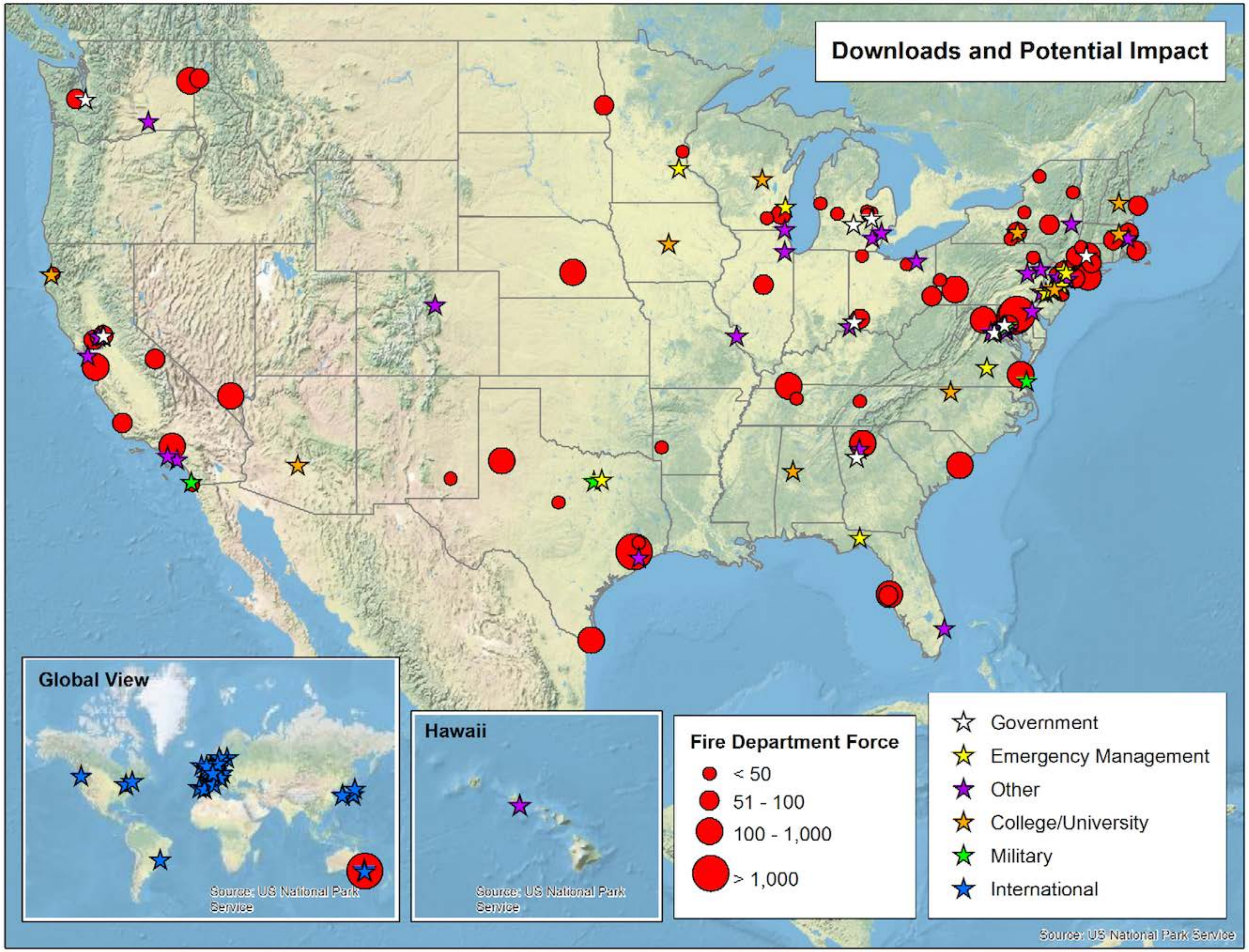


- Over 250 downloads since its release in early FY 2015!
- Designed to be delivered by local trainers and complements existing training programs and adaptable to specific needs of first responders
- Updated regularly with the latest information
- Overview webinar held March 2015 (accessible at http://energy.gov/eere/fuelcells/2015-webinar-archives)

Training resource can be downloaded at http://h2tools.org/fr/nt/

A properly trained first responder community is critical to the successful introduction of hydrogen fuel cell applications

Accomplishment: National First Responder Training Resource Impact (PNNL)



Clear interest in first responder training resources across the country, including along the northeast corridor!

Accomplishment: Safety and Knowledge Resources

With the launch of H2Tools.org, existing safety and knowledge resources are consolidated into a central location, alongside newly added functionality and content

SCS International Collaboration

European Union

- HyCoRa – LANL/ANL, VTT, SINTEF
- MATHRYCE – SNL, VTT, Air Liquide, JRC
- HyResponse – PNNL, ENSOSP, AREVA

Japan

- I2CNER – SNL, Kyushu University
- Materials Compatibility – SNL, AIST-Tsukuba
- FQ Test Method Development – LANL, JARI, CEA

- Active international collaborations with national and foreign labs, universities, private organizations, and energy companies
- Bilateral and multilateral efforts focus on safety training, materials compatibility for high-pressure hydrogen applications, fuel quality, and sensor testing and validation

Leveraging international collaboration allows for the development and promulgation of essential codes and standards to enable widespread deployment

Team Collaborations/Working Groups

International

- IPHE - International Partnership for Hydrogen & Fuel Cells in the Economy
  - 17 countries & EC, 30 projects
- International Energy Agency Hydrogen Implementing Agreement (IEA HIA) Task 37
- Independent Projects (EU, Japan, Korea, etc)

DOE-EERE Safety, Codes and Standards

Industry Partnerships & Stakeholder Assn's.

- Tech Teams (USCAR, energy companies- U.S. DRIVE) – GM, Ford, DOT, CaFCP, Exxon
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- H2USA
- Various CDOs & SDOs (SAE, NFPA, ISO, CSA, ICC, etc)

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

State & Regional Partnerships

- California Fuel Cell Partnership
- California Stationary Fuel Cell Collaborative
- Connecticut Center for Advanced Technology

National Laboratories

Lawrence Livermore
Los Alamos
NREL
Oak Ridge
Pacific Northwest
Sandia
Savannah River

Federal Agencies

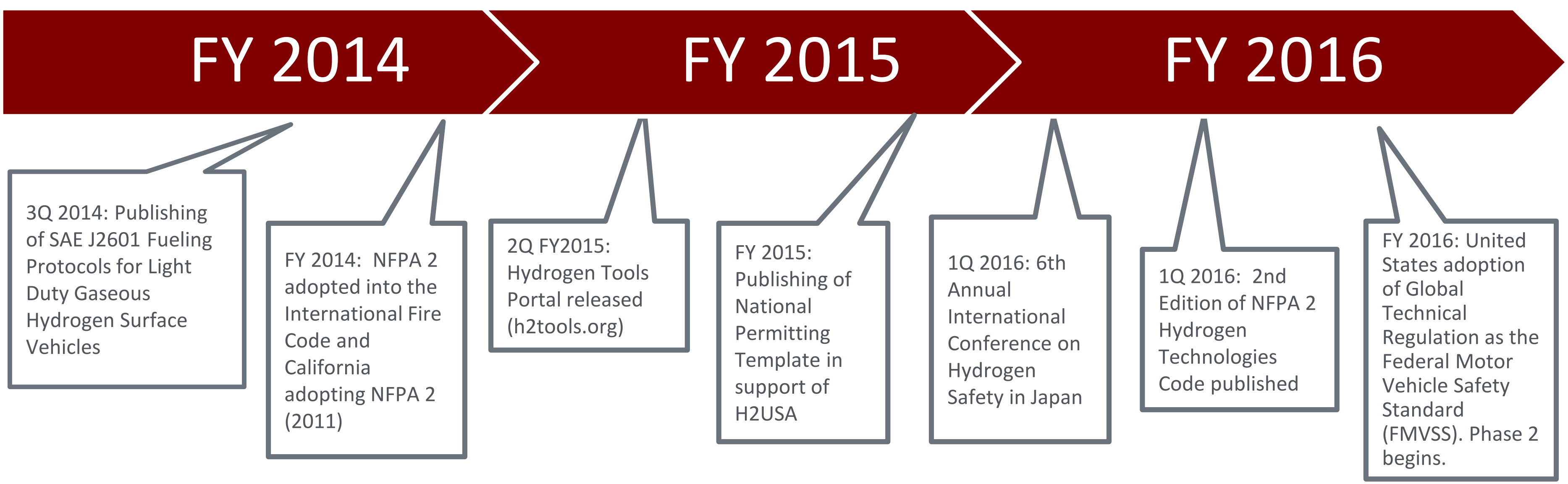
DOT
NASA

- Interagency coordination through staff-level Interagency Working Group (meets monthly)
- Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.

Summary

Summary of activities and upcoming milestones

- Continue efforts in fuel quality and metering to quantify the impact of fast fueling (SAE standard J2601).
- Publish consistent hydrogen fuel quality testing protocols (e.g., PEM stacks) to provide comparable inter-lab results.
- Complete hydrogen fueling station template (including the codes necessary for widespread commercialization of infrastructure).
- Continue outreach and training for relevant stakeholders including code officials and emergency responders
- Develop a predictive engineering model for hydrogen dispersion and ignition.



Thank you

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