DOE Hydrogen Codes and Standards Technology Team

Presentation to

Hydrogen Technical Advisory Committee

May 16, 2007

Patrick Davis - US DOE

Jesse Schneider - DaimlerChrysler

CSTT Key Goals

- Assess sufficiency of US and international hydrogen and fuel cell codes and standards that are established and in the process of being established. **Complete R&D to support essential Codes and Standards by 2010.**
- Identify and prioritize areas where information is needed to advance codes & standards
- Ensure that information and safety best practices are developed under the FreedomCAR and Fuel Partnership and are made available to responsible standards setting organizations as appropriate. Assist in Implementation of best practices.

Support the Partnership Goal for demonstrated hydrogen refueling with developed commercial codes and standards and diverse renewable and non-renewable energy sources with a cost of energy from hydrogen equivalent to gasoline at market price, assumed to be $2.00-3.00 per gallon gasoline equivalent produced and delivered to the consumer independent of pathway by 2015

Codes & Standards Technical Team Membership

Energy Company

- John Lemen (Chevron)
- Jim McGetrick (BP)
- Jonathan Otero (BP)
- Brad Smith (Shell)
- Nick Burkhead (Shell)
- Michael Boyea (ExxonMobil)

Auto Company

- Sheral Arbuckle (Ford)
- Jesse Schneider (DaimlerChrysler)*
- Scott Freeman (DaimlerChrysler-BPG)
- Mike Steele (GM)
- Britta Gross (GM)
- Jerry Rogers (GM-Triad)
- George Mitchell (DaimlerChrysler)

Government & Labs

- Jay Keller (SNL)
- Jim Ohi (NREL)
- Cathy Gregoire Padro (LANL)
- Patrick Davis (DOE)*
- Phyllis Yoshida (DOE)
- Barbara Hennesey (DOT)
- William Hollowell (DOT)
- Antonio Ruiz (DOE)

*CSTT Co-Leads

Dave Austgen (Shell) – FOG Liaison

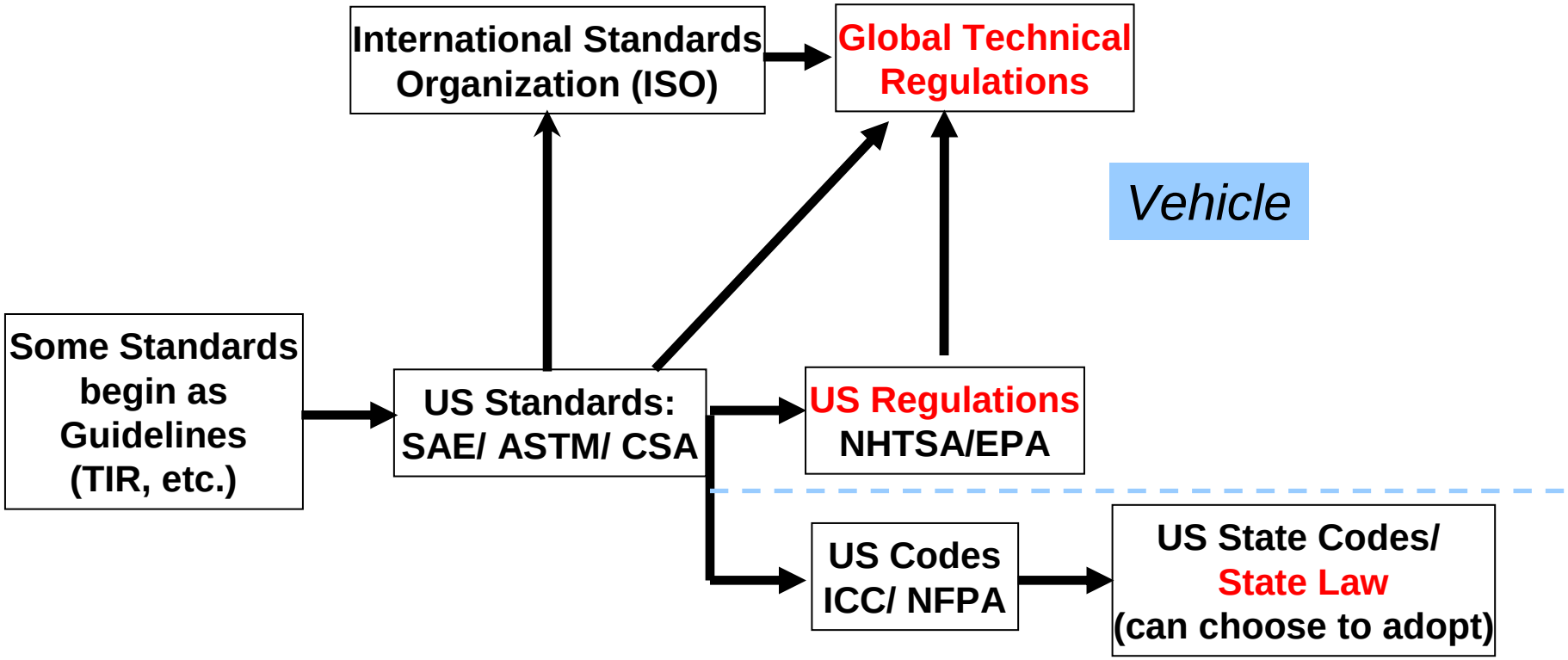
How the Tech Team contributes to Codes and Standards Development

- Tech Team focuses on data required by the codes and standards process
- Members also participate in the process
  - Coordination (National Hydrogen and Fuel Cell Codes and Standards Coordinating Committee, with NHA and USFCC)
  - Members of specific committees
  - Crosscutting teams focusing on critical topics (e.g., hydrogen quality)
  - Significant progress has been made in the development of codes and standards through leveraging of limited resources
    - 9 active US Codes and Standards Organizations working on hydrogen
    - 22 C&S published, 10 of which are under revision
    - 28 draft C&S under preparation/review
    - 4 International C&S published, 13 under preparation/review
    - See www.fuelcellstandards.com

C&S Challenges

- Limited historical data / insufficient technical data to develop standards
- Large number of Authorities Having Jurisdiction
- Need for uniform training of officials
- Need for standard practices for safety assessments
- Need for integrated, coordinated approach among C&S Organizations
- Need for harmonization of domestic and international standards
- Limited government influence on C&S process

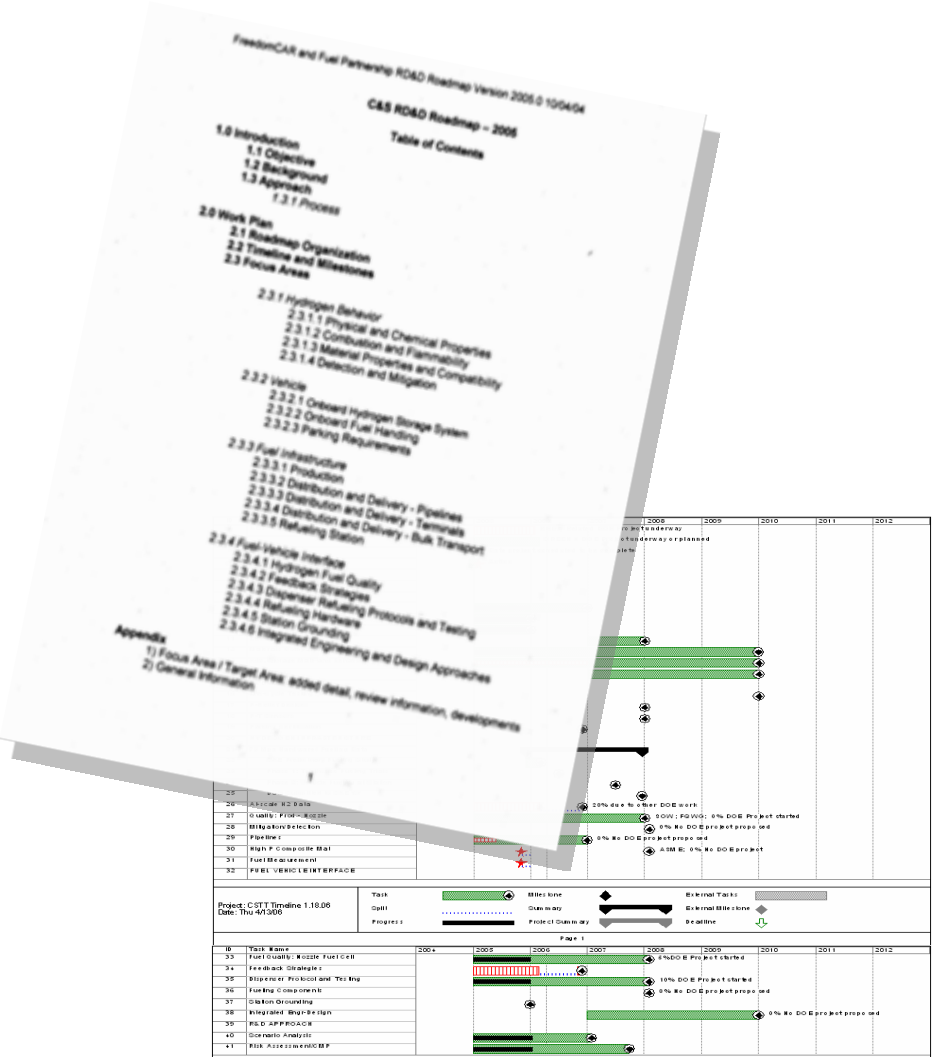
H_2 Standards & Codes Lead to Regulations & Laws



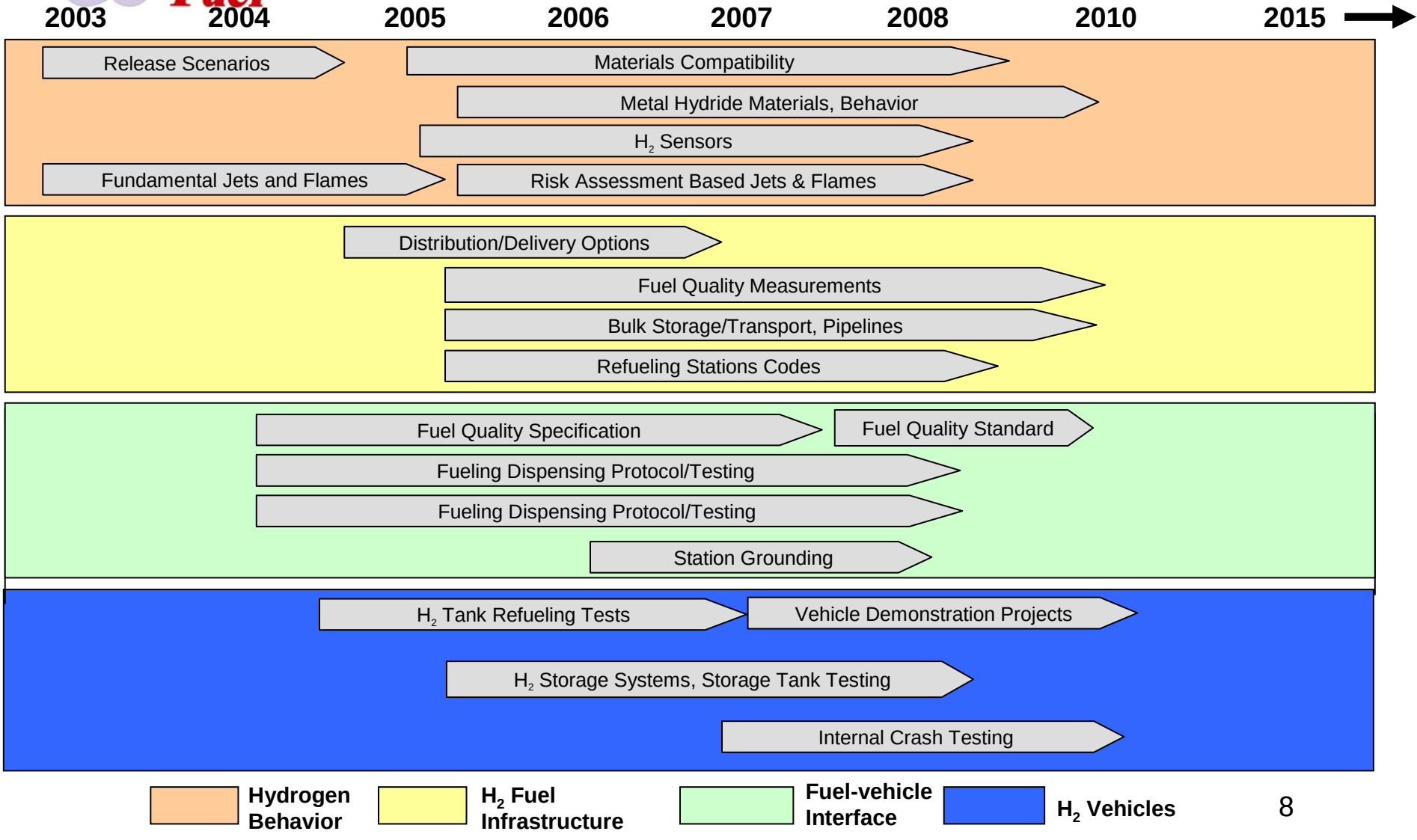
It is important to have timely implementation of performance based C&S which establish a safety baseline & enable technology.

Technology Roadmap

- Initial Version: Completed 2004
- Updated in May 2006 – includes detailed Gantt charts with milestones
- Details Needs & Gaps in each Target Area to meet 2010 timeline

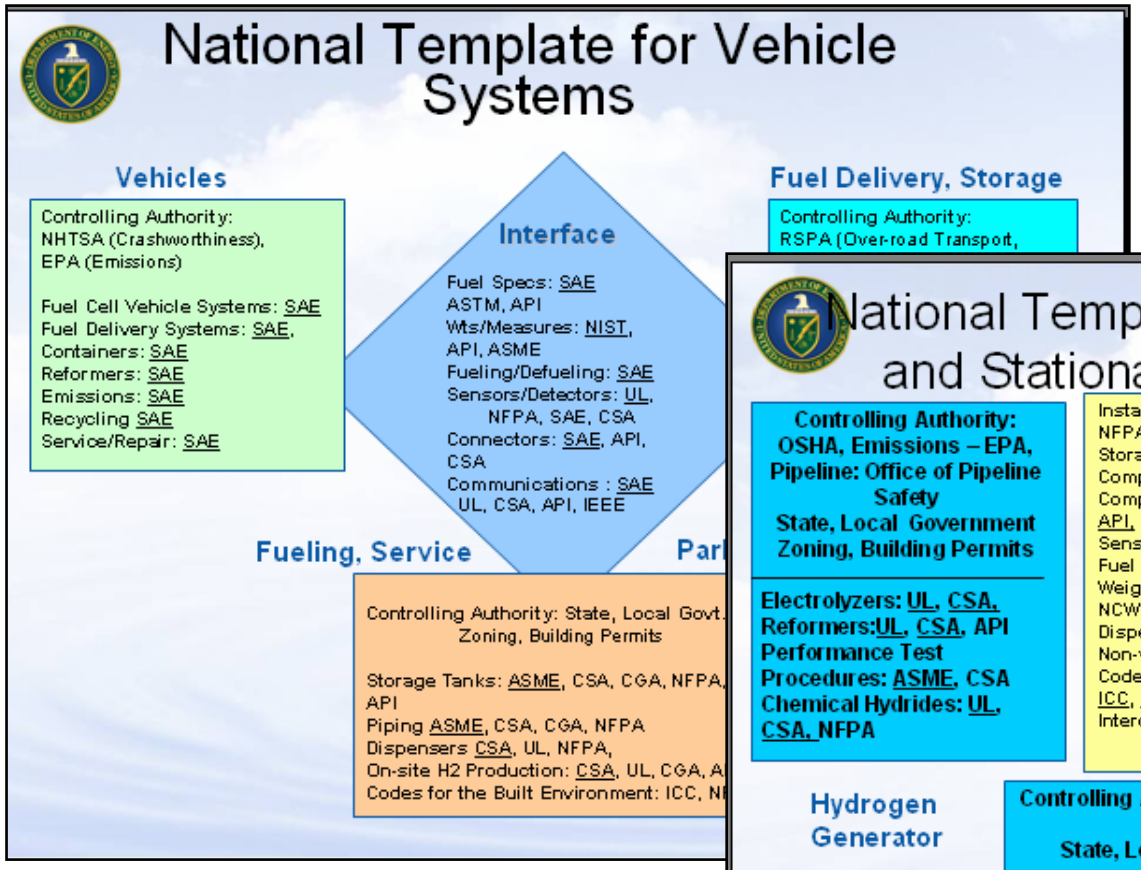


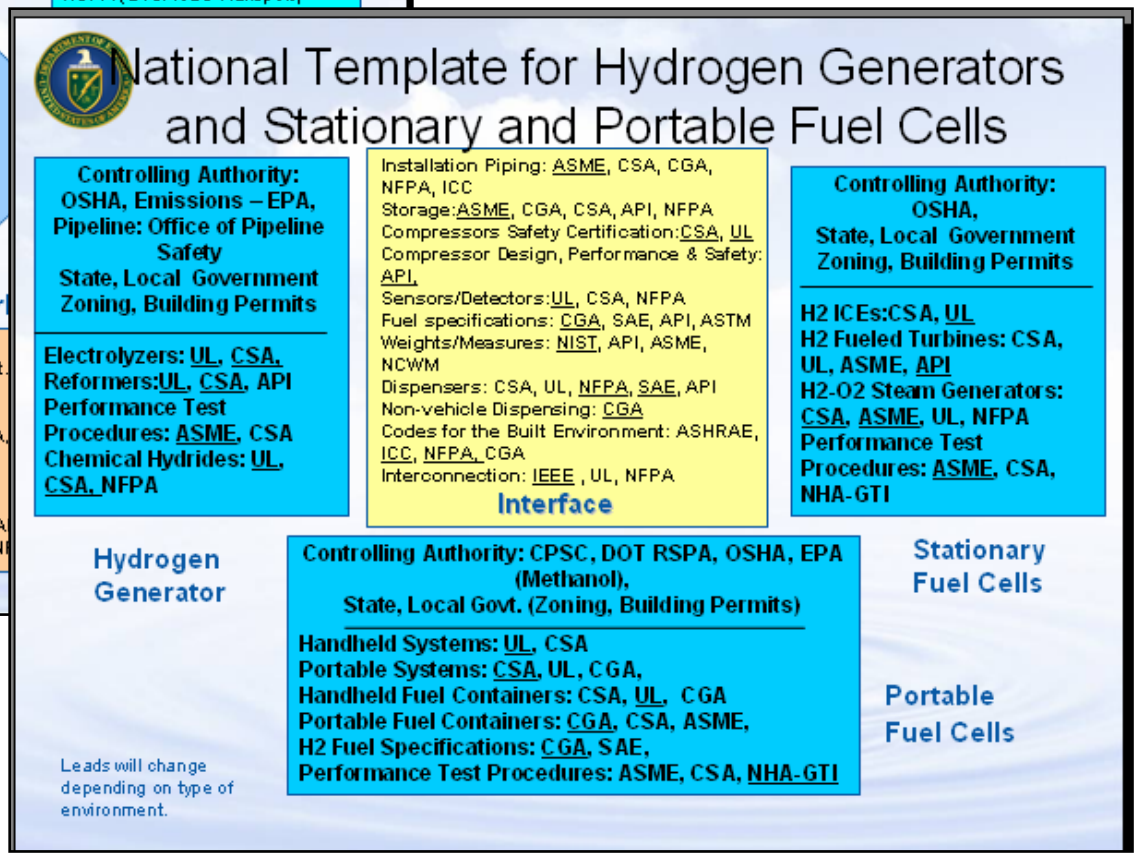
Codes and Standards Commercialization Data Timeline



Accomplishments

National Templates for Hydrogen Codes and Standards

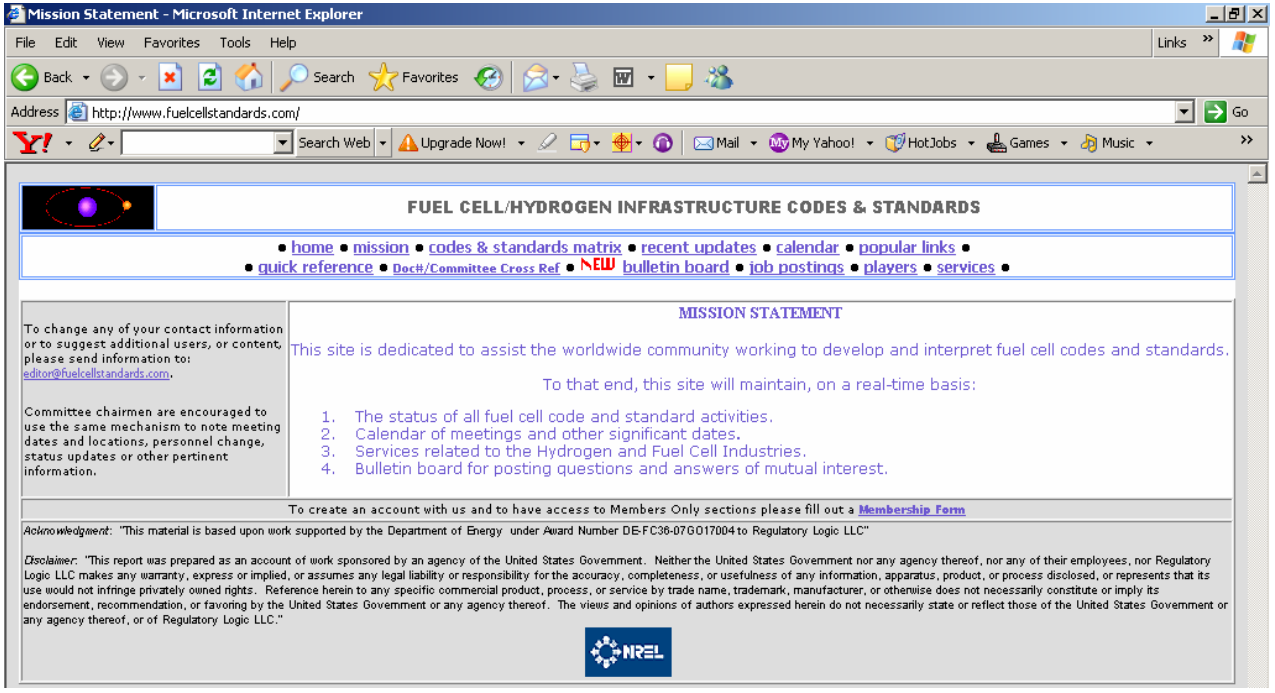




www.fuelcellstandards.com

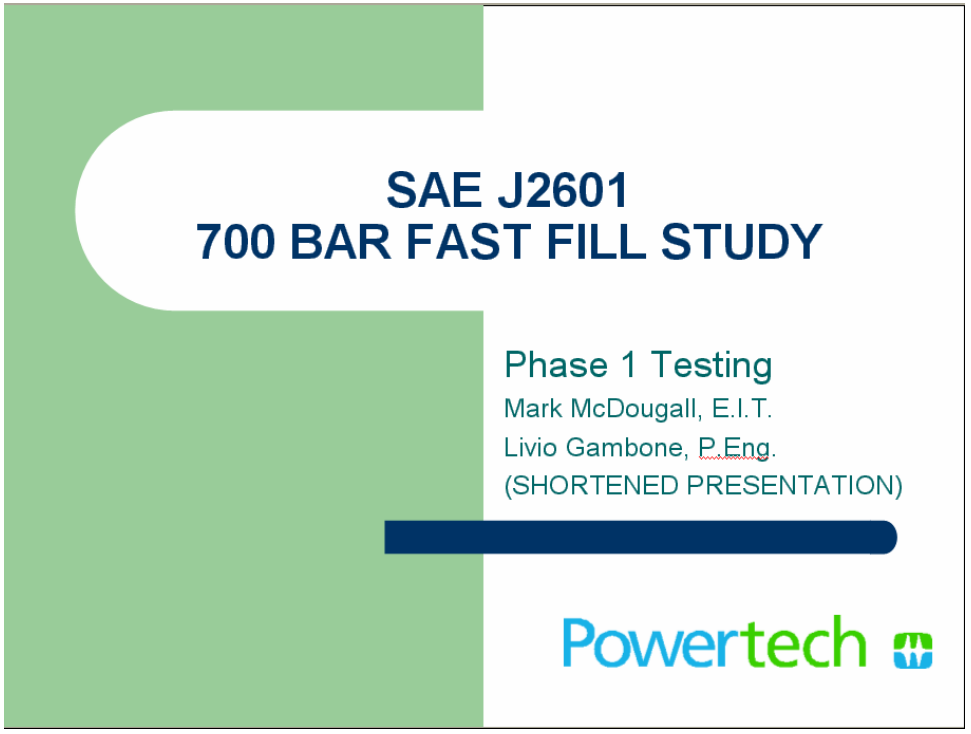
Web site maintains:

- The status of all fuel cell codes and standards activities
- Calendar of meetings and other significant dates
- Bulletin board for posting questions and answers



70MPa Fueling Initial Results

- Developed extensive 70MPa Statement of Work
- Completed preliminary tests at Powertech, follow-on work underway (funded by broad industry participation)

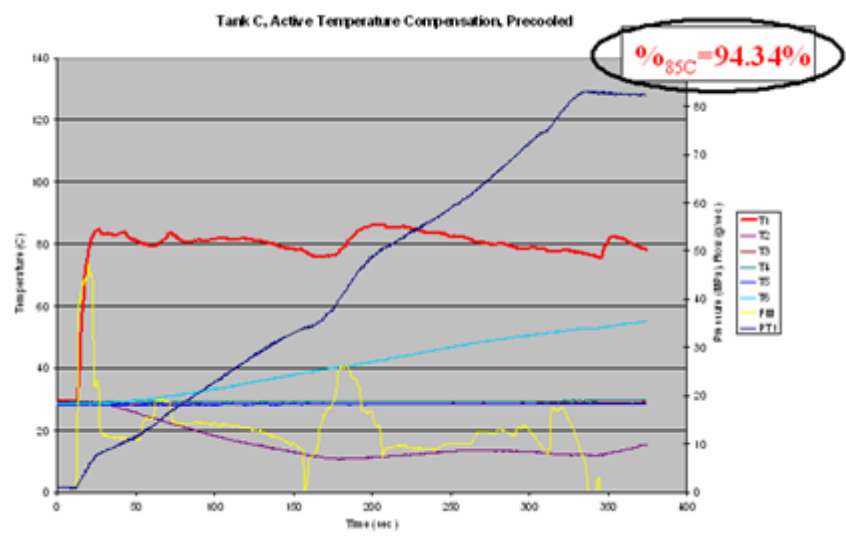


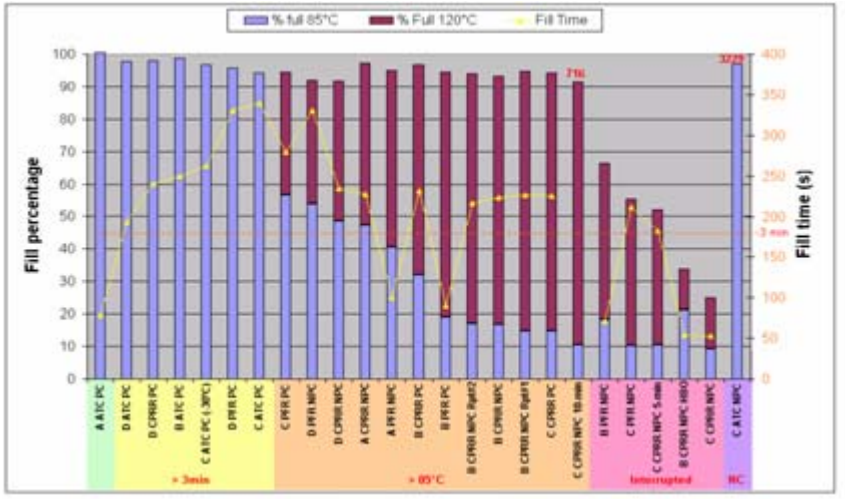
<u>Evaluate Targets:</u>
Time: 3 minutes
Fill: 98-100%

25 Trials w/ & w/o
- Pre-cooling
- Communications

2005-6 SAE/Powertech Preliminary Fueling Project

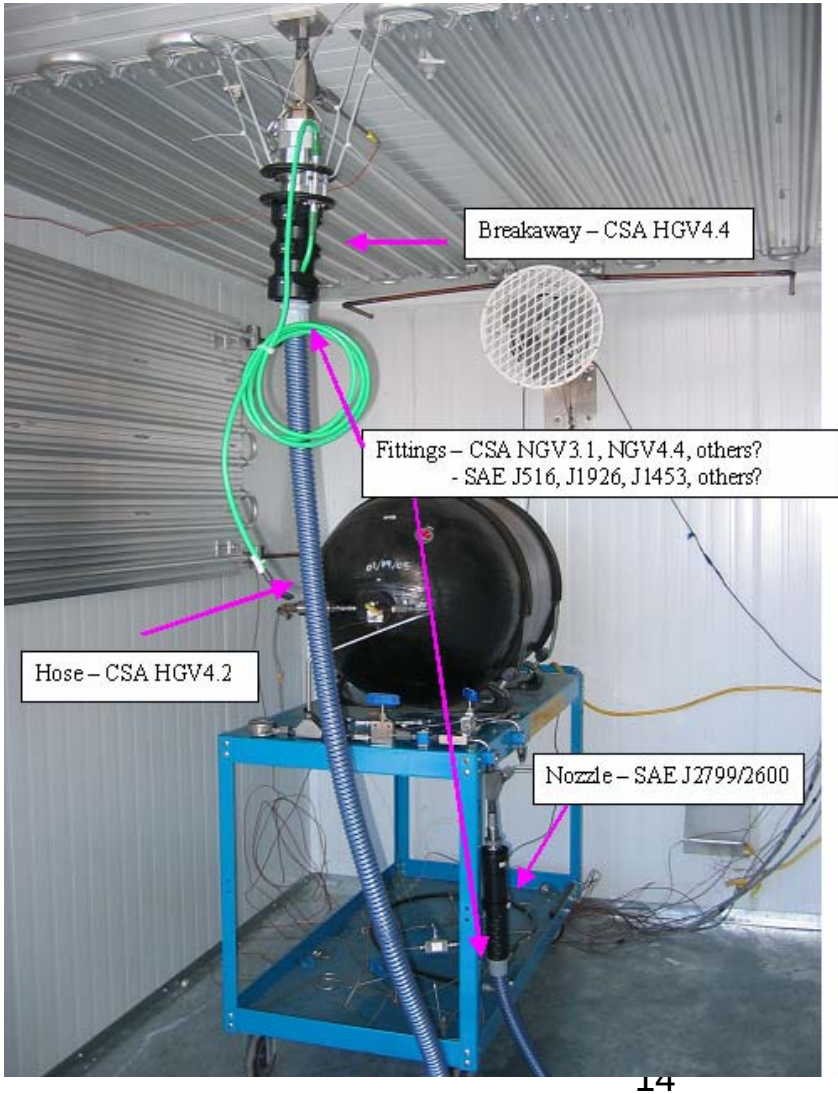
- 25 Fueling Trials at Powertech with 4 individual tanks (not system – type 3 and type 4 tanks used ranging from 34 to 130 liters)
- Evaluated SAE J2601 targets regarding fill density/time changes between different fueling methods w/ and w/out pre-cooling & communications
- Preliminary Results: Precooling is needed to achieve fueling in a short amount of time, in some cases also communications
- Results were used to formulate the follow-on work



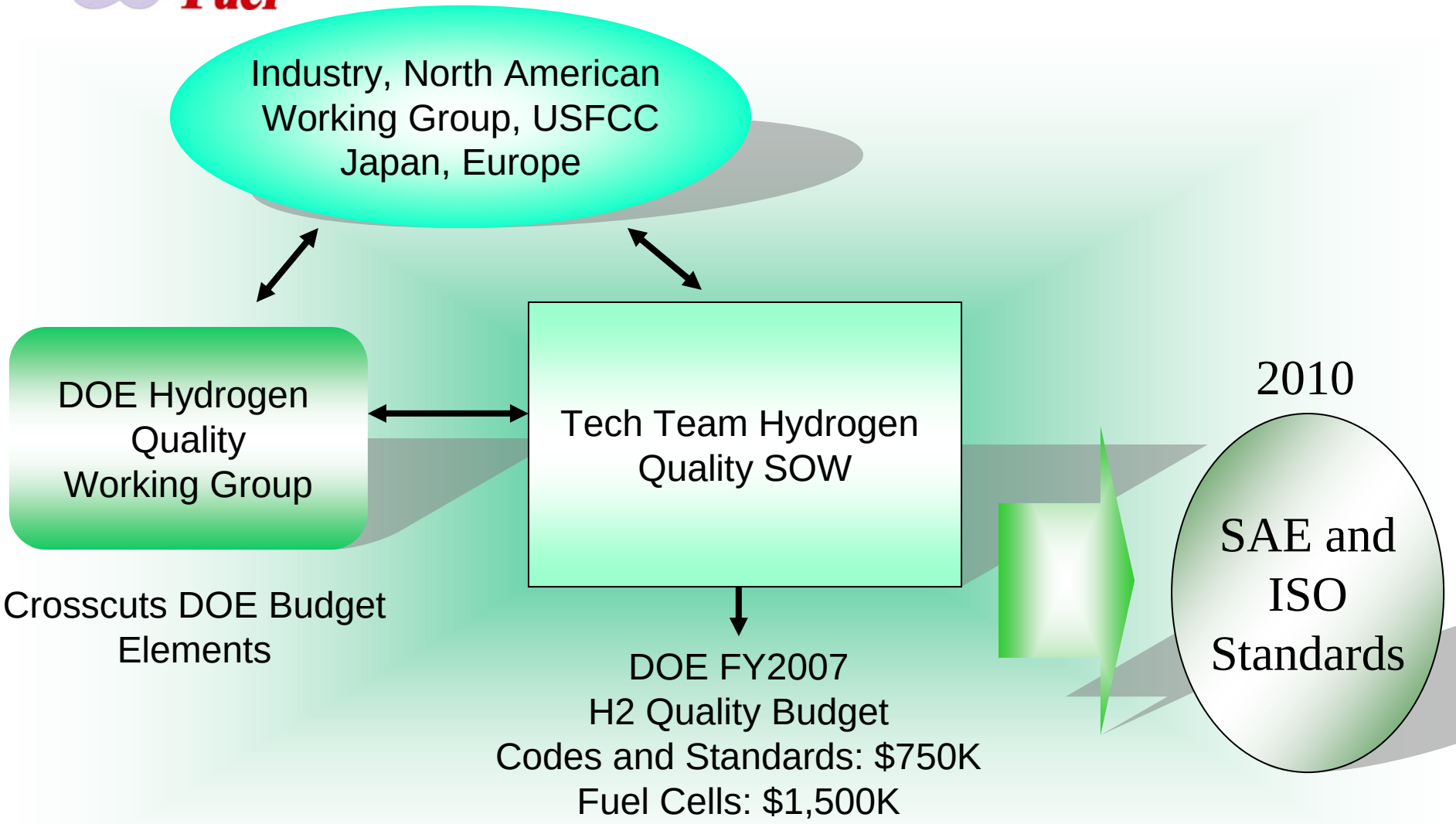


2007 Government/ Industry: "70MPa Multi-Client Study"

- Purpose: Accelerate Progress of Informed Standards for Hydrogen Vehicle Fueling utilizing real vehicle and station hardware
  - Not enough information currently available for standards organizations on fueling protocol and station hardware
- OEMs to bring their onboard storage systems to third party organizations (Powertech & JARI) also as in-kind contribution to the project
  - Participants: **DCX, Ford, GM, Honda, Nissan, Toyota**
- Funding: Energy Companies & Government
  - **Air Liquide, BP, Linde, Nippon Oil, Sandia (DOE), Shell**
- Modeling effort at Sandia for on-board storage and hydrogen station dispensing



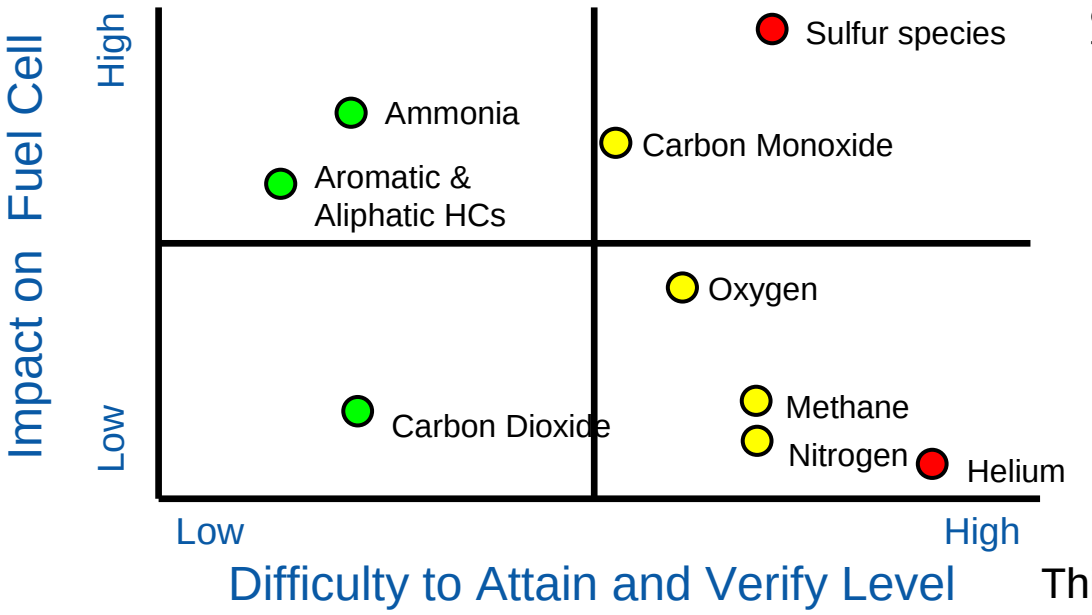
Hydrogen Quality
A Coordinated, Crosscutting Activity



Hydrogen Quality Approach

- Investigates industry consensus critical fuel impurities from both FC and fuel provider perspective
  - Develops/refines fuel cell testing protocols and develops essential, standardized analytical methodologies
  - Conducts R&D and testing to find the balance between requirements of both sides of the vehicle-station interface
  - Addresses fuel cell FCV operational effects and empirical cell modeling
- Parallel effort to evaluate cost implications of meeting specified hydrogen quality level
- Data sharing/report-outs major factor in refining existing fuel quality guidelines

Specification Tradeoffs



Source: Shell Hydrogen

Critical Constituents

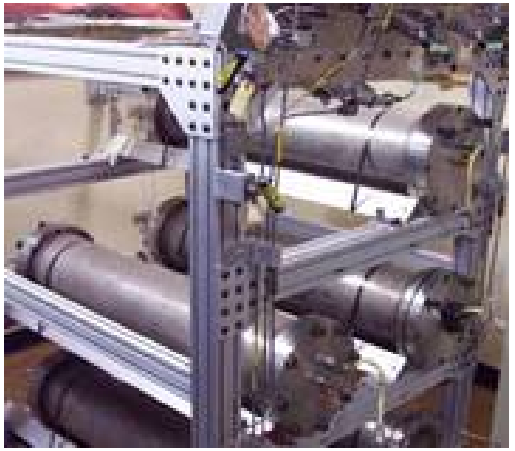
- To date, the North American industry-government team has identified the following as critical constituents around which near-term R&D and testing should be focused:
  - CO
  - S compounds
  - He
  - CH4 and inerts
  - NH3
  - Particulate Matter (<10µ diameter)

This list may change and other critical constituents may be identified as R&D and testing proceed

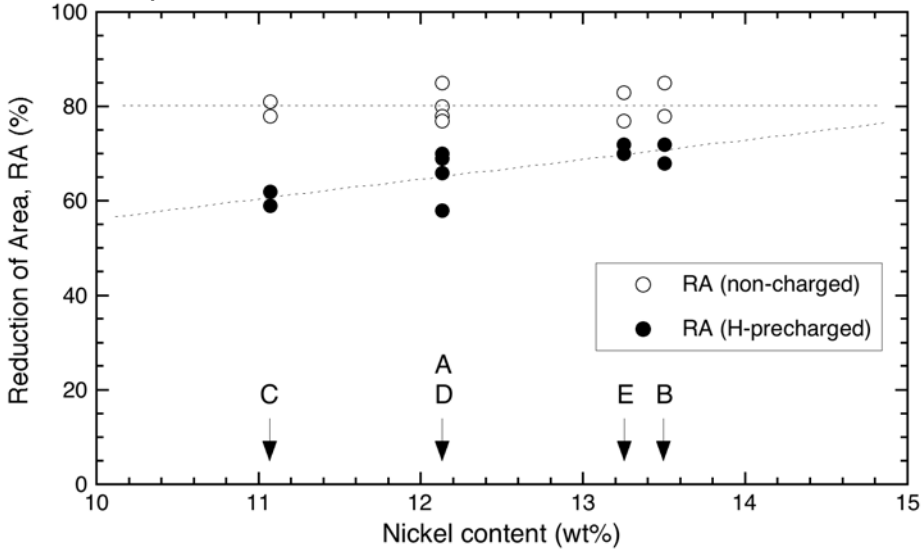
V1.0 of *Technical Reference for H2 Compatibility of Materials* Complete

http://www.ca.sandia.gov/matlsTechRef/

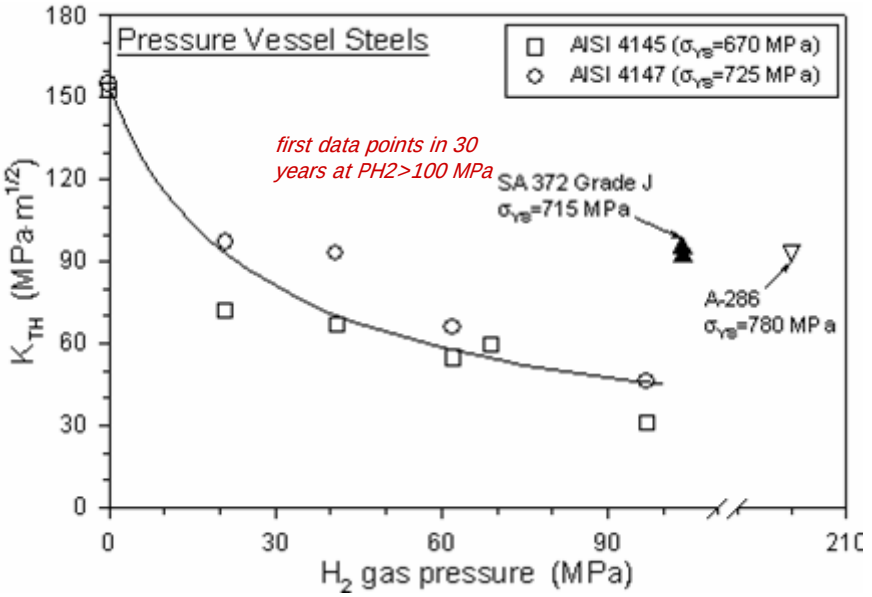
- Increased material strength lowers threshold for H_2-assisted crack growth
- Increased H_2 gas pressure lowers threshold for H_2-assisted crack growth



H_2 compatibility of 316 stainless steel can be optimized by controlling composition, particularly nickel content. Carbon content seems to be less important

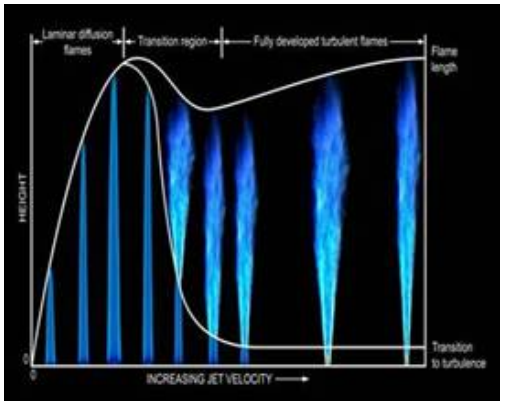


ASME SA-372 Grade J steel is relatively resistant to hydrogen-assisted fracture at high-pressure

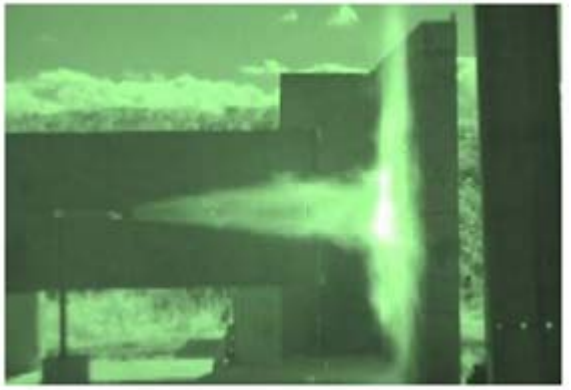


Hydrogen Combustion and Release Scenarios

Flame Characterization

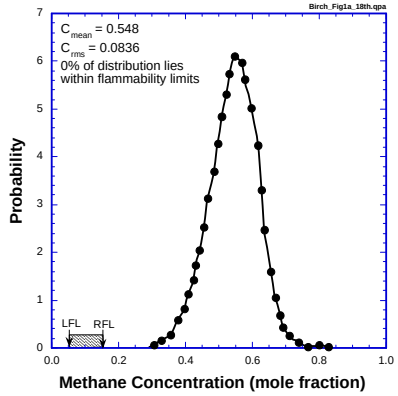


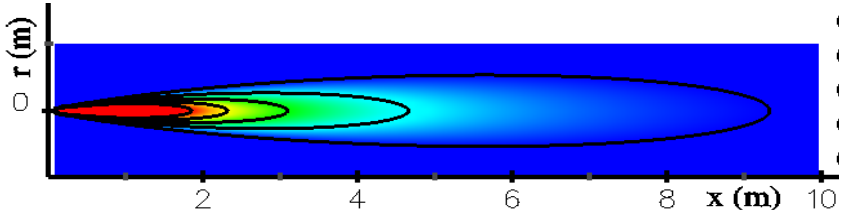
Experimentally Measure Heat Flux



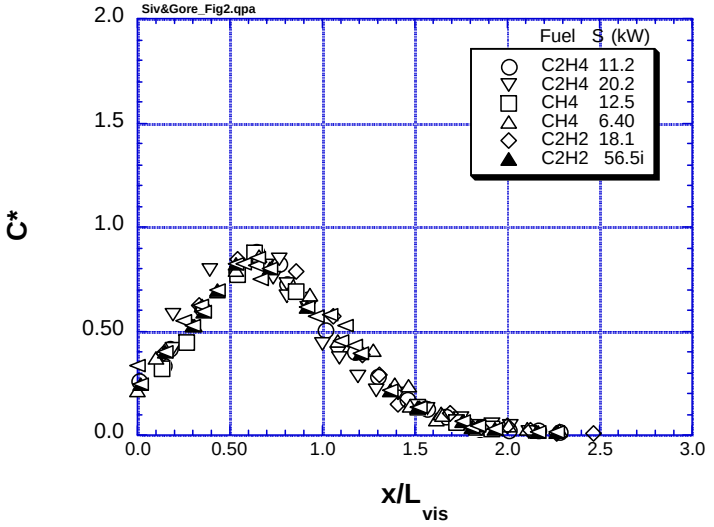
Impinging jet, 10 ft impingement diameter

Flammability Limits & Ignition Probabilities



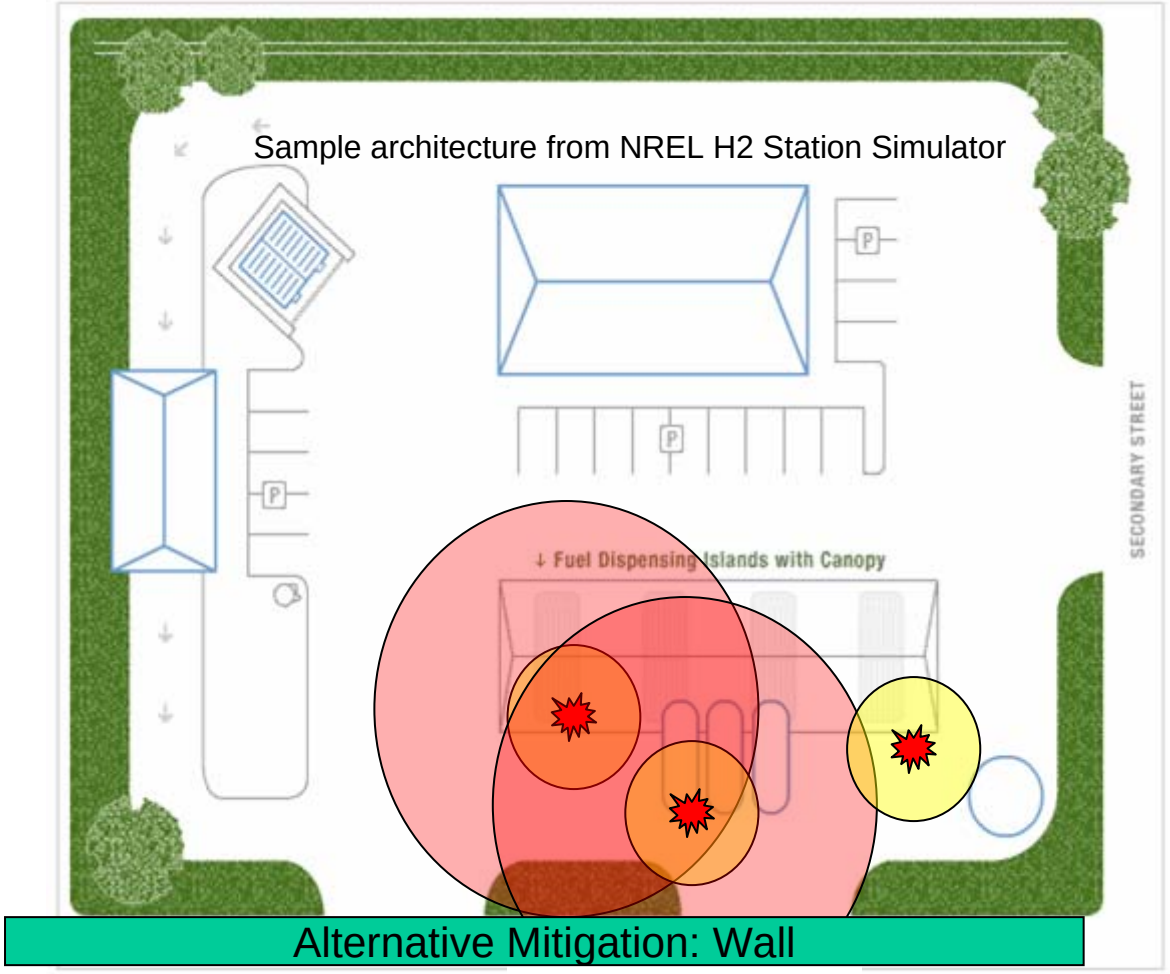


Thermal Radiation Models



Quantitative Risk Assessment Approach for Separation Distances

- Quantitative risk assessment (QRA) provides a framework for making risk-informed decisions. We are applying QRA to help define refueling setbacks.
- Likelihood of events is estimated from component reliability and architecture-based FMEA studies.
- Event consequences are quantified using engineering models from the research program and published data.
- Consequences are integrated and evaluated relative to acceptable risk metrics.
- Site-specific mitigation strategies should be identified where appropriate.



Compendium of Permitting Tools for Hydrogen Fueling Stations

- Information Repository
  - Fact sheet(s)
    - Basic information on hydrogen fueling stations (examples, codes/standards typically used, information sources)
  - Network chart
    - Contact list of code officials whose jurisdictions have issued permits for hydrogen fueling stations
  - Flowchart of permitting requirements
    - Web-based map to navigate requirements
    - Database of key standards and codes
  - Hydrogen fueling station permitting information repository
    - Web-based information and database of code and standards requirements
  - Case studies of hydrogen fueling stations
- Education/outreach
  - Workshops for code officials (nationally and regionally)
  - Web-based training

Compendium – Case Study Activity: A collaboration with NASFM

Goal: To compile case studies of hydrogen fueling stations (HFS) that have been vetted by the building code and fire safety community

Provides a reference for local code officials to consult at their discretion.

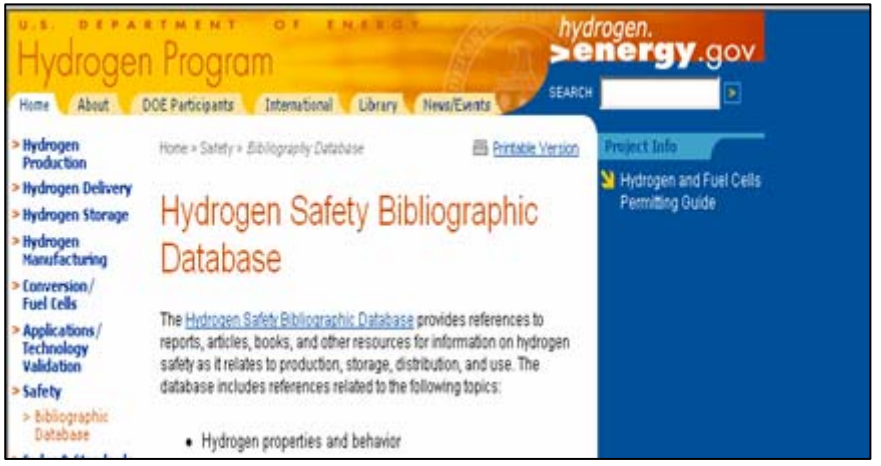
- Collaboration with NASFM, NCBCS, and energy suppliers to identify representative hydrogen fueling station layouts/designs
- Identify all applicable codes and standards for hydrogen fueling stations
- Gain consensus of code officials on identified fueling station designs
- Timeline:

Event	Purpose	Date and Location
DOE workshop at NASFM annual conference	▪ Involve key building and fire code officials ▪ Present and discuss case studies ▪ Demonstrate web-based information repository prototype	Atlanta July 10, 2007
Workshop at NCBCS annual conference	▪ Similar purpose, agenda, format as workshop at NASFM conference	Fall 2007
Publication of case studies	▪ Provide building code and fire safety officials with existing examples of approved hydrogen refueling stations and the codes and standards applied	December 2007

Bibliographic and Incidents Databases

- **H2 Incidents Database**
  - Information on hydrogen incidents and lessons learned
  - 103 incidents documented as of February 2007
  - **www.h2incidents.org**

- **Bibliographic Database**
  - Contains approximately 400 publications related to hydrogen safety
  - **www.hydrogen.energy.gov**



Related Education Activities: First Responders

- **Introduction to Hydrogen Safety for First Responders**
  - 7-module, web-based basics course (includes quiz and video, animations, graphics for visual audience)
  - Print and CD versions available for free from DOE Information Center
  - Development included broad review involving hydrogen industry and emergency response community
  - Averaged 200 unique users/week since course launch in Jan 2007
  - Positive feedback from emergency response community – users include fire fighters, fire department training coordinators, fire marshals, fire plans inspectors/examiners, law enforcement personnel, industry, military, others

www.hydrogen.energy.gov/firstresponders

A "Cliffs Notes" poster is available for fire houses, free from the DOE Information Center

Related Education Activities: First Responders and Code Officials

- **Detailed "Prop Course" for First Responders**
  - Follows intro course, designed for use with hands-on FCV training prop (focus will be vehicles but course will also cover other applications)
  - Prop will be mobile; DOE will loan prop/course to major fire fighter training centers for designated periods
  - Estimated timeline for completion: late spring/early summer 2008
- **Introduction to Hydrogen for Code Officials**
  - Like first responder course – modular, web-based (also print and CD)
  - Will provide more detailed information on technologies and equipment
  - Codes and Standards module will incorporate tools and resources developed by DOE Hydrogen Safety, Codes & Standards Program (fact sheets, network chart, flowchart of permitting requirements, refueling station permitting compendium)
  - Estimated timeline for completion: early 2008

Remaining Challenges Future Direction

- Open Issues/Remaining Barriers
  - Difficult permitting process for retail hydrogen facilities
  - Delayed adoption of approved codes and standards
  - Synchronizing codes and standards development and adoption timeline with technology commercialization needs
- Future Direction
  - Fuel Quality: Follow R&D Timeline/ Launch collaborative international R&D testing effort.
  - 70MPa: Complete expanded cross-industry test program, demonstration project data needed
  - Materials Compatibility: Complete initial materials set and initiate investigation of composite materials
  - Provide technical support/ guidance to local code officials to facilitate permitting of retail hydrogen facilities
  - Publish Best Practices Manual/ Expand Safety Database
  - Work with Education on emergency responder and code official training

- BACKUP SLIDES

H2 Quality Data Generation Timeline for Standardization