

# 2011 DOE Annual Merit Review Component Standard Research & Development



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Energy Laboratory  
Hydrogen Technologies  
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**May 11th, 2011**

**Project ID # SCS002**

# Overview

## T I M E L I N E

- *Start date: April, 2007*
- *End date: September, 2012*
- Multi year DOE RD&D target date
- *Percent complete: 60%*

## B A R R I E R S

- **Consensus** - Achieving national agenda on codes & standards (A,B,D,L,J)
- **Representation** – Government & Industry support and DOE role (F,G,H,I,K)
- **Technology Readiness** – Jurisdictional issues, available codes and component certification (M,N)

## B U D G E T

- Funding for FY10\*:  
**\$ 400K**
- Funding for FY11:  
**\$ 750K**

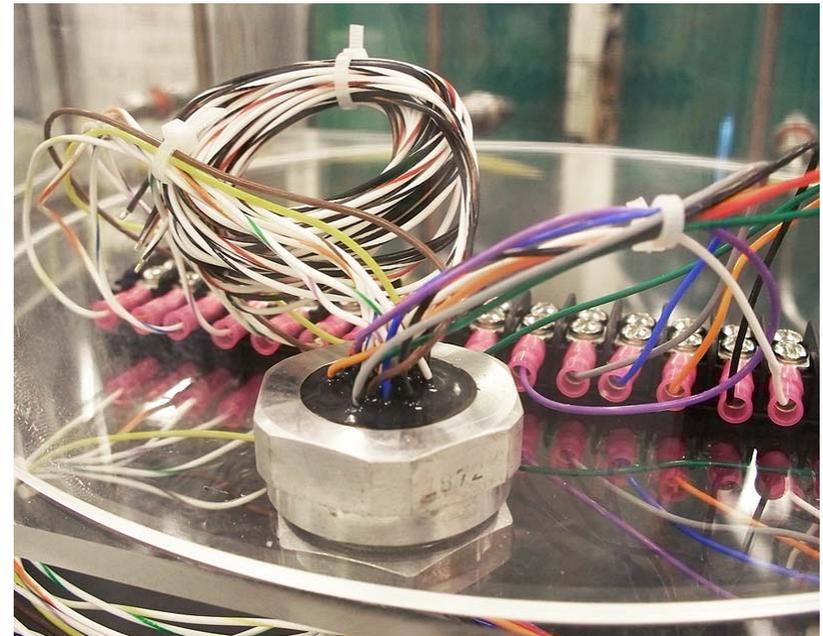
*\* note that FY10 reported funding includes reduced scope compared to FY11 funding so can not be directly compared*

## P A R T N E R S

- Industry (Component Manufacturers, *Automotive OEMs, Gas Suppliers*)
- Laboratories/Universities (JRC, BAM, CSM, NIST, NASA, Battelle, Powertech, JARI, IIT, IEEE)
- Codes & Standards Development Organizations (SAE, CSA, ASME, ISO, UL, NFPA, IEC, GTR, ANSI)

# Relevance

- Acceptance of emerging hydrogen technologies will require:
  - Safe and reliable components with operating capability to end of life conditions
  - Components that are built to approved standards
  - Standards requirements with sound technical basis, representing the latest R&D knowledge



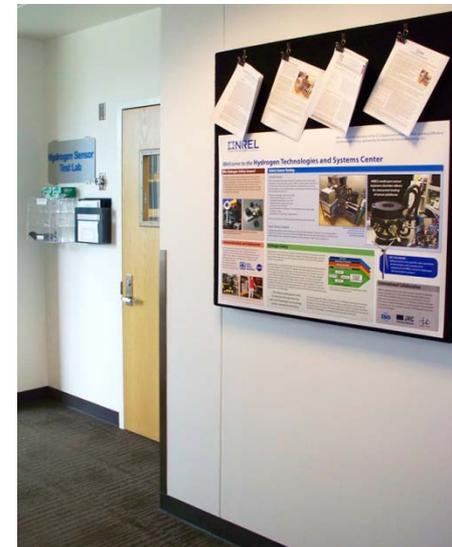
# General Approach

- Work with codes & standards technical committees and stakeholders to identify knowledge gaps
- Define research & development tasks required to close knowledge gaps
- Supply testing and analysis expertise, with DOE support
- Provide results to the technical committee, thereby promulgating standards with a sound technical basis



# Outline: Component Standards R&D

- NREL's Hydrogen Sensor Testing Lab
  - SINTERCOM international collaboration and round robin testing
  - Manufactured product test support
  - Developmental sensor program
  - Field deployment support
- Support of Hydrogen Component Standards
  - Hydrogen service suitability validation testing in support of HPRD1 draft standard
  - Support of developing hydrogen component standards: SAE, CSA, NFPA, UL, ISO
- Outreach/Publications
  - University Collaborations
  - National and International Conferences and workshops
  - Safety, Codes and Standards committees



# Hydrogen Sensor Laboratory Overview

## *NREL Test Apparatus*

- FY09 - Apparatus fully assembled
- FY10 - test protocol development
- FY11 - Accomplishments

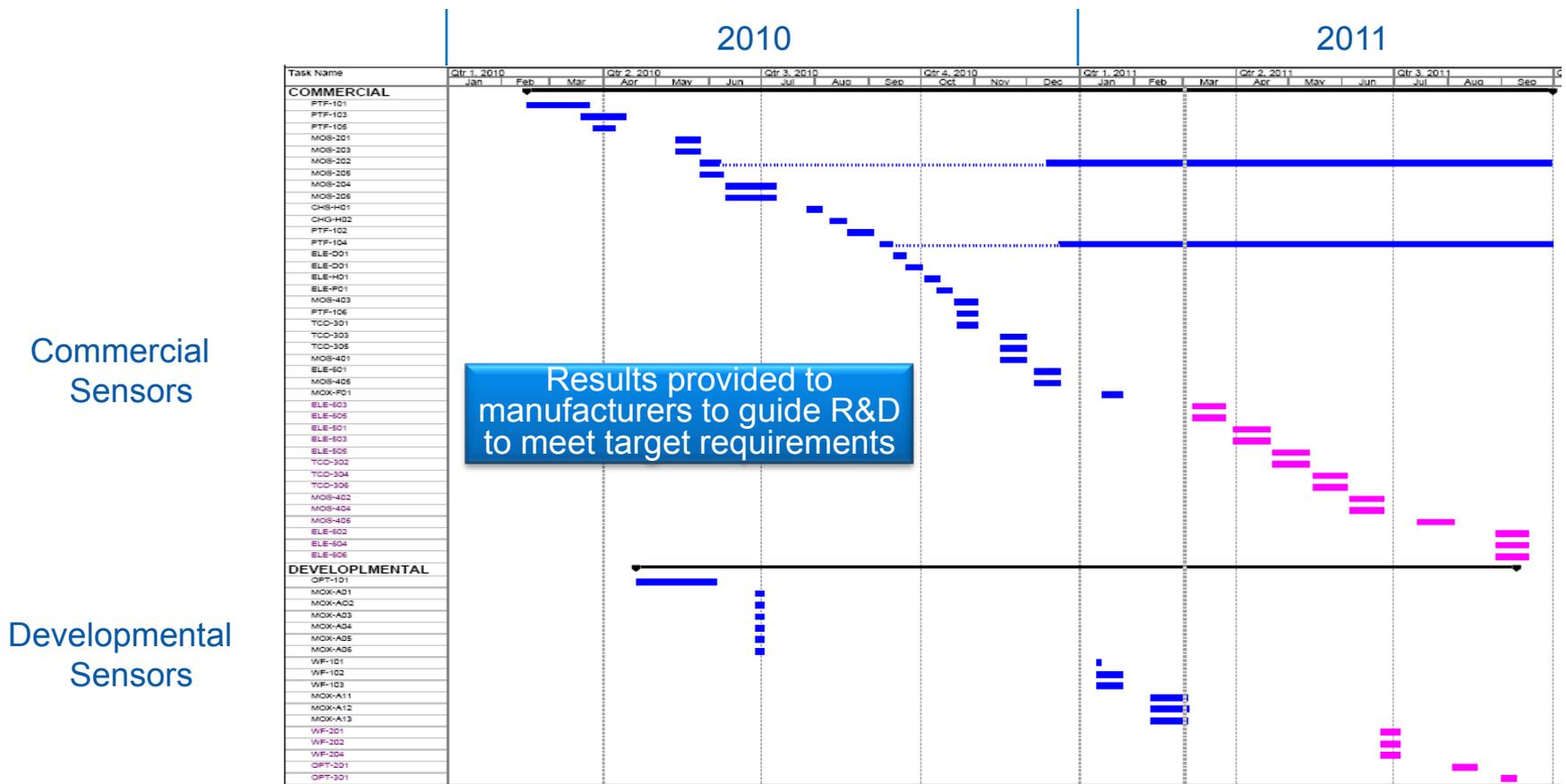
Testing completed for round one and round two of SINTERCOM for two technology types

Further commercial sensors and developmental sensors tested



# Hydrogen Sensor Laboratory Timeline

- Automated, remotely-accessed operation allowing 24-7 testing
- Concurrent sensor installation
- More than 6000 hours of sensor testing in a one year time period



# SINTERCOM (Sensor INTERlaboratory Comparison)

*NREL and JRC have identified a common objective, improving hydrogen safety sensor capability by providing technical support to product manufacturers*

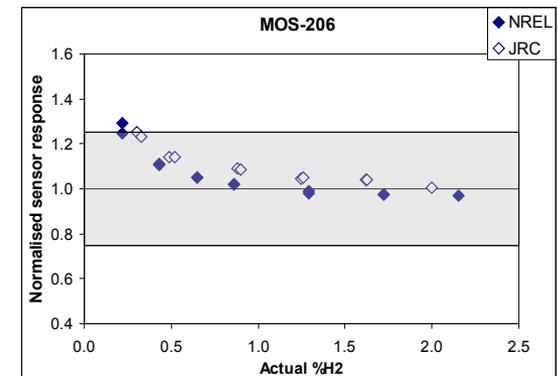
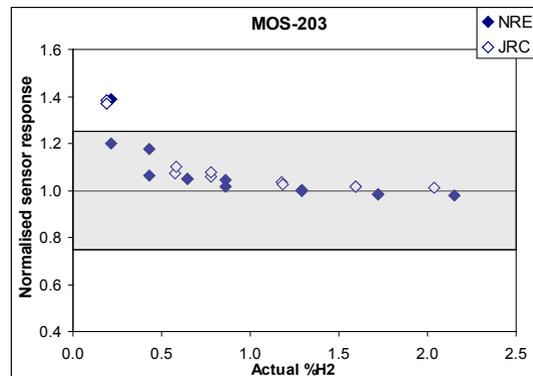
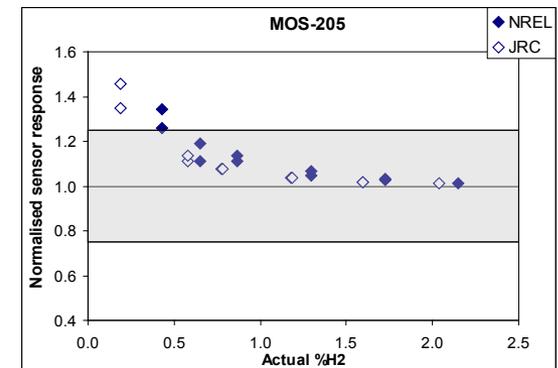
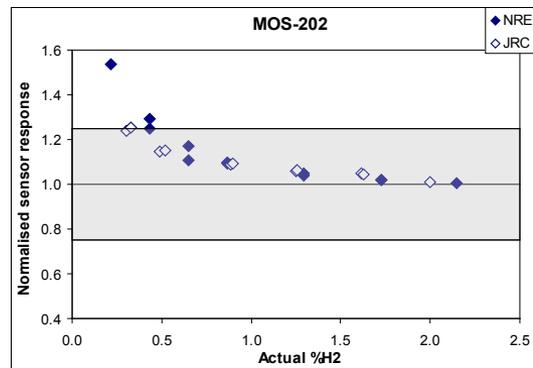
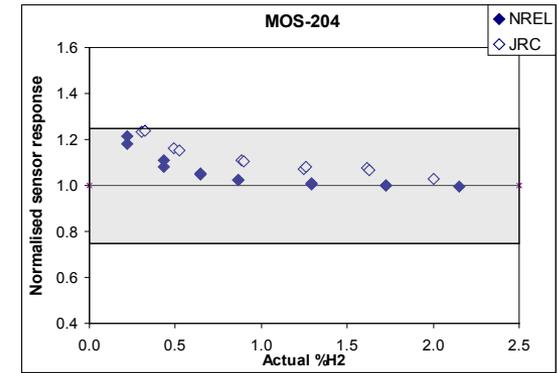
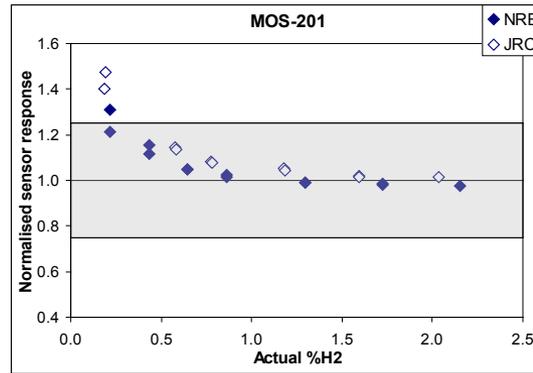
- Formal collaboration agreement signed between NREL and JRC 1st Quarter FY2011 (MOA – Memorandum of Agreement)
- Round robin test program, completion milestone SEP 2011
- Further work underway to understand effects of interfering gases, poisons, oxygen dependency and extended life
- Steering committee meeting to plan future activities scheduled for Sep 2011 at NREL



NREL/JRC collaboration meeting, Petten, NL  
(JRC - Joint Research Centre, Institute for Energy, Cleaner Energies Unit)

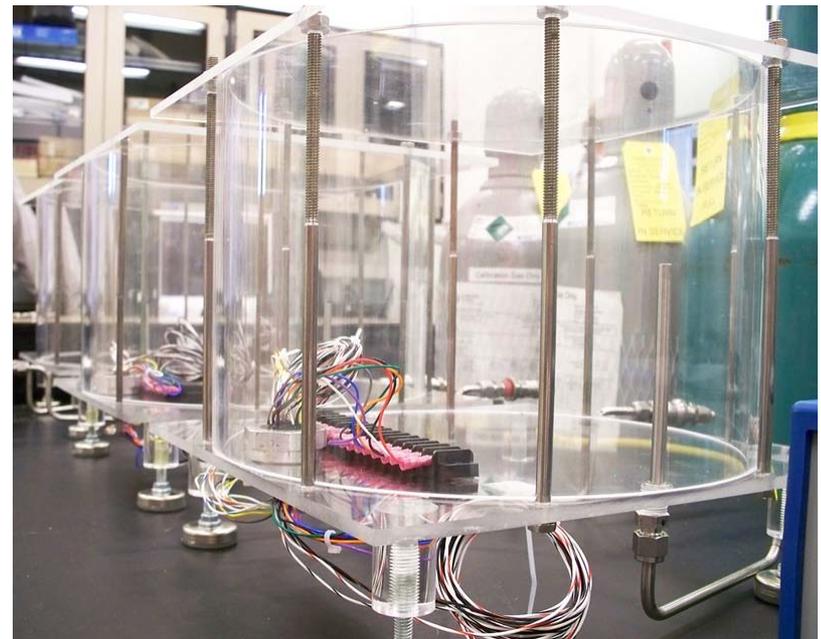
# SINTERCOM Round Robin Data Comparison

- RRT (Round Robin Testing) data shown for six commercial sensors
- NREL/JRC data agreement achieved within accuracy of test measurements
- Sensor characteristics identified include: part to part variability, non-linearity and short term repeatability effects



# Commercial Sensor Product Testing

- Work with manufacturers to provide testing and evaluation of sensor performance
- Sensor platform categories for market characterization (Metal Oxide, Electrochemical, Thermal Conductivity, Combustible Gas, Palladium Thin Film, Optical/Colorimetric)
- Plans for composite data with five technologies from each category, approximately 50% complete
- Application information published



# Developmental Sensor Partnerships

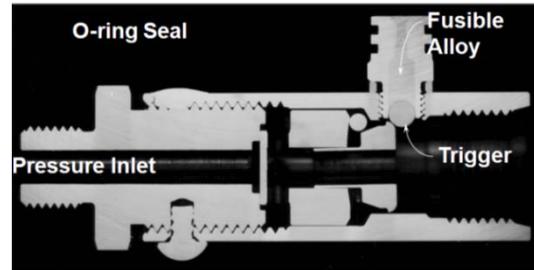
*NREL works closely with organizations that are developing near-term hydrogen sensor technologies*

- LANL/LLNL – First round of testing completed on prototype sensor. Discussion of results included plans for the next phase of testing on sensor with added thermal feedback control and electronics upgrade
- IOS – Testing completed on prototype sensor with plans for electronics package algorithm for sensor output.
- ORNL – Discussion of sensor technology and packaging requirements for ORNL technology to be redesigned into a deployment ready configuration that can be incorporated into NREL's hydrogen sensor testing apparatus
- Element One, MOU (Memorandum of Agreement) is in place to provide NREL shared lab space and to work on deployment and demonstration activities using NREL's wind to hydrogen site

# Field Deployment Collaboration

- GM
  - Working with GM Honeoye Falls and GM/Opel Mainz Kastel balance of plant group on vehicular sensor applications
- NASA TEERM
  - Collaboration on safety sensor deployment for interagency fuel cell back up power demonstration projects at government sites
- NREL/DOE Laboratory deployment
  - Evaluation of sensor system performance for NREL/DOE laboratories including life cycle costs, calibration and operational issues
- End-user data base

# HPRD1 Hydrogen Service Suitability



## Mirada PRD schematic

- Validation testing of HPRD (Hydrogen Pressure Relief Device) hydrogen service suitability, subcontract with Powertech Labs
- Low temperature (-40°C) component leaks detected
- Working with CSA HPRD1 committee to complete validation testing with newly defined testing protocol (planned for 3<sup>rd</sup> quarter FY11, interim report presentation at March SAE meetings)
- Modified low temperature test protocols have been added to HPRD1 draft standard
- Identifying root cause for HPRD manufacturer product support focused on improving low temperature performance

# SAE Standards Support

NREL support has included validation testing of onboard storage systems, dispensing components (hoses, fittings, nozzles and breakaways) and fill table modeling, with follow on work including:

- SAE J2579 Onboard Hydrogen Storage Systems
  - Document released as TIR (Technical Information Report), next steps are RP (Recommended Practice), then full standard
  - Current efforts include parking performance, conformity of production, localized fire, defining suitable materials and understanding the tank level stress rupture failure mode
  - Validation testing needs identified for localized fire test and stress rupture testing
- SAE J2601 Dispensing Protocol
  - Document released as TIR, March 2010
  - New RFID fill protocol being added, identified need for validation testing



# Standards Support (continued)

- New SAE standards being developed for hydrogen powered industrial truck on-board storage and dispensing
- CSA HPRD1 component standard identified needs for further testing include evaluation of HPRD repeatability/reliability and long term creep study to determine eutectic material activation time and reliability at different exposure temperatures
- Fork truck standards support includes UL 2267 and CSA HPIT standards
- NFPA 2 Hydrogen code published December 2010. Work is continuing on reserved sections including hydrogen explosion modeling

# Component Certification Workshop

- Collaboration with Sandia Livermore (workshop hosted at Sandia CRF Nov 2010), focus on component certification gaps, led to outreach activities
  - Summary report, Jim Ohi (DOE consultant)
  - GM balance of plant contact led to work on vehicular sensor applications support
  - Further work with FM Global in identifying component certification gaps with applicability to effects on insurability/liability
  - Oil and Gas industry collaboration with UTC Hamilton Sundstrand
    - API Hydrogen compressor case study
    - ASM Hydrogen Damage author, Dr. Bruce Craig consulting

# Outreach/ Publication

- NREL continued support of codes and standards organizing committees to identify needs for future component efforts (tech team, IEA task 31, HPIT)
- University outreach APUP (Alliance Partner University Program) with CSM (Colorado School of Mines) to work with graduate student project to develop sensor response time test program
- NREL technology validation program to analyze fork truck deployment data
- Publication/Presentation IJHE, ICHE, NHA, FCHEA, IEEE, Telcordia, (complete list in supplementary section)



# Proposed Future Work

## *Safety Sensors*

- Host Sensor Workshop, June 2011 at Sensors Expo, Chicago
- NREL/JRC collaboration: complete round robin evaluation Sep 2011 , steering committee meeting Sep 2011, start long term exposure testing
- Publish composite data to be used by manufacturers in market evaluation and end users in sensor applications
- Conduct sensor placement analysis by using CFD model code, previously validated in NREL garage release study
- Continue oxygen dependence and interferent/poison testing
- Complete analytical evaluation of LANL & ORNL sensors, three additional technology assessments and Element One paint samples

# Proposed Future Work (continued)

## ***Components***

- Complete HPRD validation testing and publish final report as NREL peer review document
- NASA/SAE collaboration for tank level stress rupture testing
- Support SAE needs for test validation (COPV's, RFID fill protocol, localized fire)
- Evaluation of HPRD repeatability and reliability
- Long term creep study to determine eutectic material activation time and reliability at different exposure temperatures
- API high pressure hydrogen compressor case study
- Further evaluation of 3rd party certification details with UL

***ESIF Energy Systems Integration Facility Ground breaking on new NREL facility scheduled for 2011, to include sensor lab, components lab and high pressure test lab***



# Conclusions

- NREL component R&D efforts designed to close technology gaps
- NREL subcontracts foster development of infrastructure for component testing, development and certification
- Development of new and improved standards will remove roadblocks to technology commercialization
- NREL support of hydrogen sensors will facilitate safe installation and operation of stationary hydrogen production, storage and dispensing hardware

