

2011 DOE Annual Merit Review Component Standard Research & Development



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**National Renewable
Energy Laboratory
Hydrogen Technologies
& Systems Center**

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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

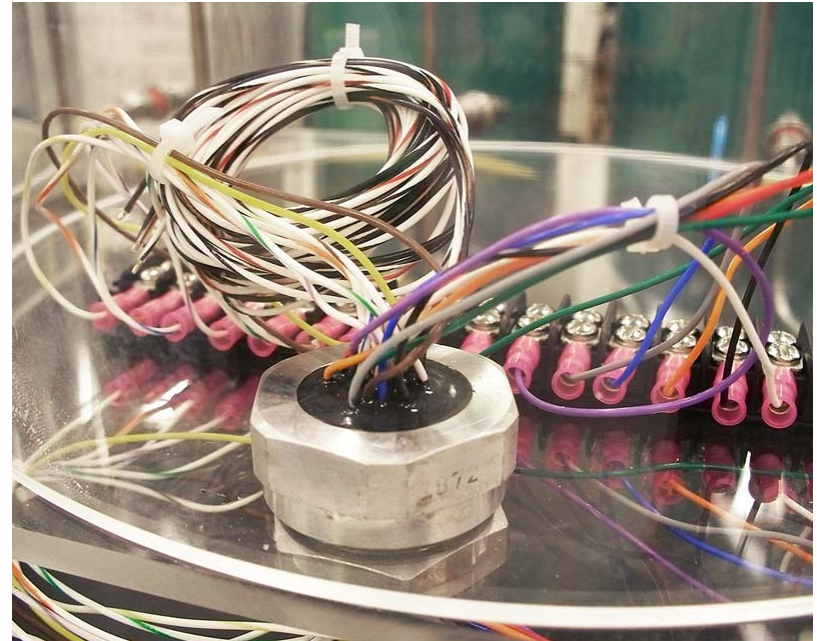
** note that FY10 reported funding includes reduced scope compared to FY11 funding so can not be directly compared*

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



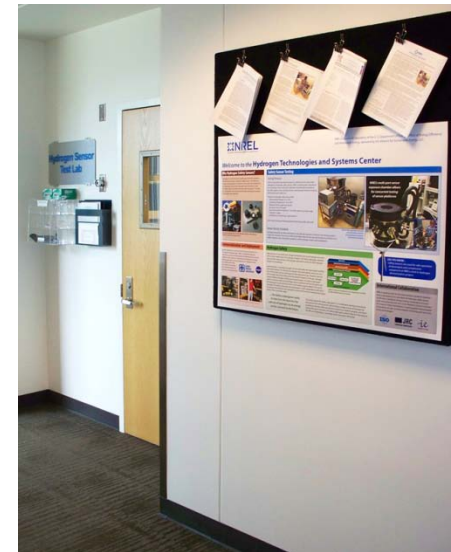
General Approach

- 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

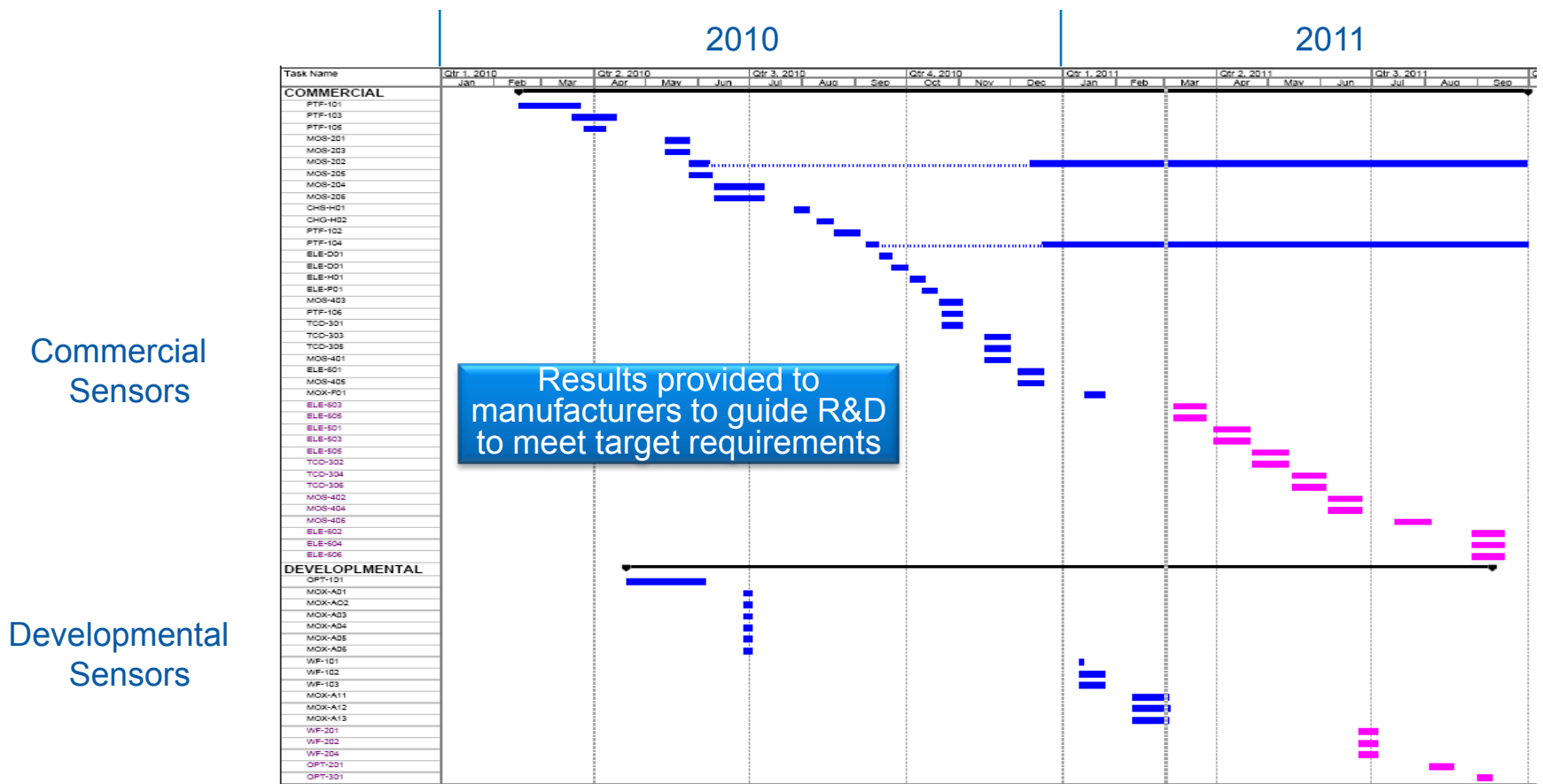
Testing completed for round one and round two of SINTERCOM for two technology types

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

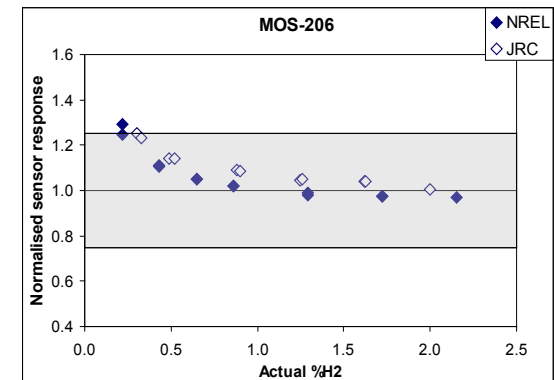
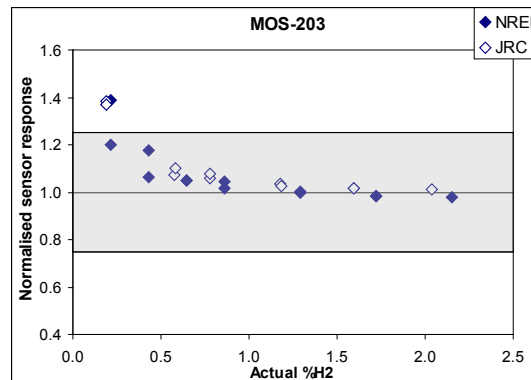
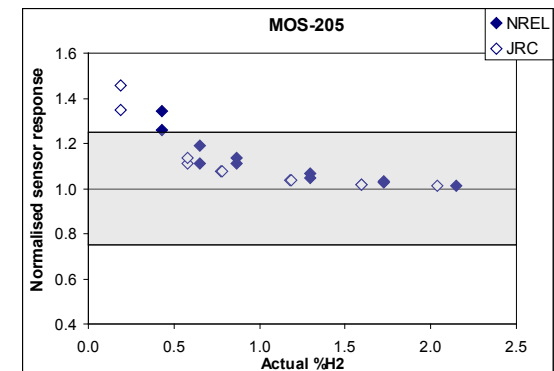
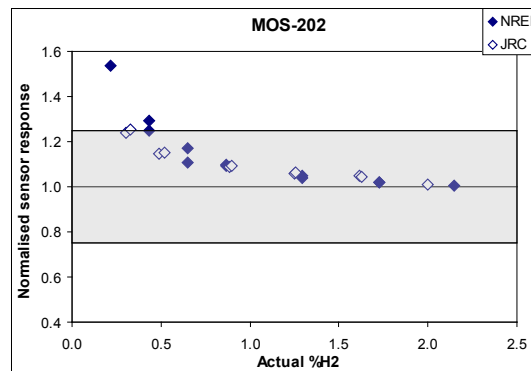
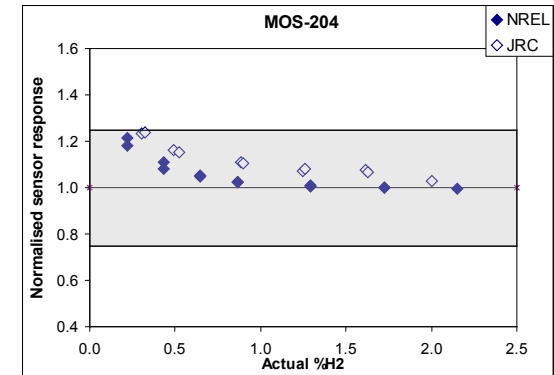
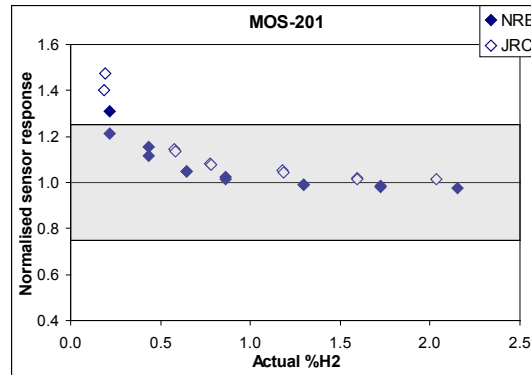
- Formal collaboration agreement signed between NREL and JRC 1st Quarter FY2011 (MOA – Memorandum of Agreement)
- Round robin test program, completion milestone SEP 2011
- Further work underway to understand effects of interfering gases, poisons, oxygen dependency and extended life
- Steering committee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

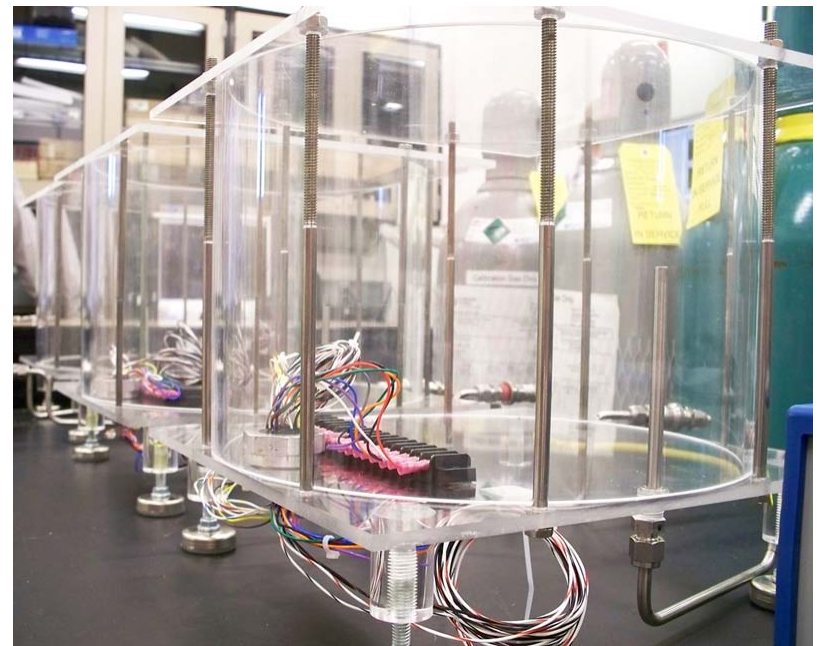
SINTERCOM Round Robin Data Comparison

- 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

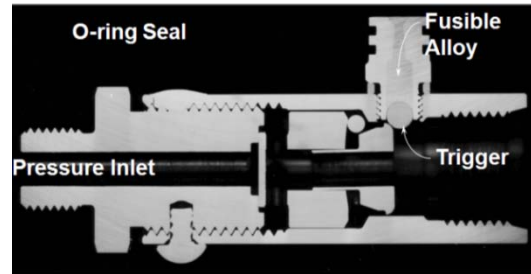
NREL works closely with organizations that are developing near-term hydrogen sensor technologies

- 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 3rd 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

