

# Codes and Standards Support for Vehicle Electrification

2012 DOE Hydrogen Program and Vehicle Technologies  
Annual Merit Review

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**Project ID #VSS053**

# Overview

## Timeline

- Support of PHEV-Grid related standards started in 2007
- SAE J2907 Motor Rating Standards initiated in 2007
- SAE J2954 Wireless PEV Charging standard initiated in 2010
- SAE J2990 First/Second Responder standard initiated in 2011

## Budget

- FY2010- \$300k
- FY2011- \$400k
- FY2012- \$280k

## Barriers

- **A.** Establishing consensus between competing approaches to intelligently manage vehicle charge and communication
- **C.** Interoperability of vehicle-grid communication and hardware connections is a necessity for effective infrastructure deployment
- **B.** Low cost, secure, validated technology and communication standards are required coincident with PHEV/EV market introductions

## Partners

- Utilities (DTE Energy, Southern Cal. Edison, Commonwealth Edison, Northeast Utilities, TVA, Communications technology vendors)
- EVSE suppliers (Clipper Creek, Coulomb, SPX, Leviton, ECOtality, G.E. Schneider)
- Vehicle OEMS (Ford, GM, Chrysler, BMW)
- National Labs (INL, PNNL, ORNL)



# Relevance

**Provide technical support to establish cohesive vehicle electrification standards via active participation on a focused group of relevant standards committees.**

**Provide transformative developments such as creation of proof of concept systems as well as validation of proposed approaches.**

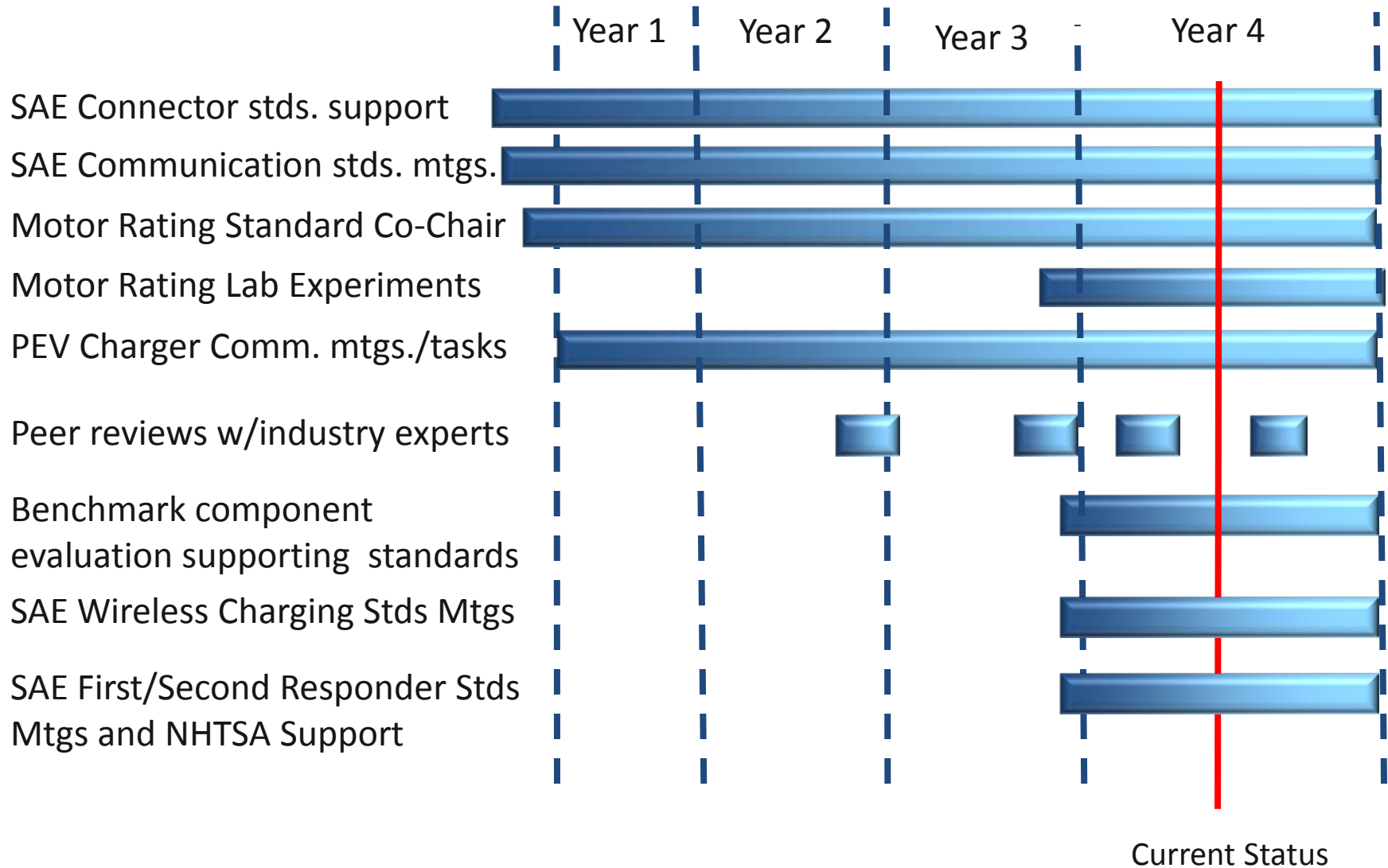
- Encourage harmonized worldwide standards approach
- Improve grid connectivity of electric vehicle charging infrastructure via lower cost, secure, universalized wired and wireless communications technologies
- Validate adopted performance targets in a systems context

Examples include:

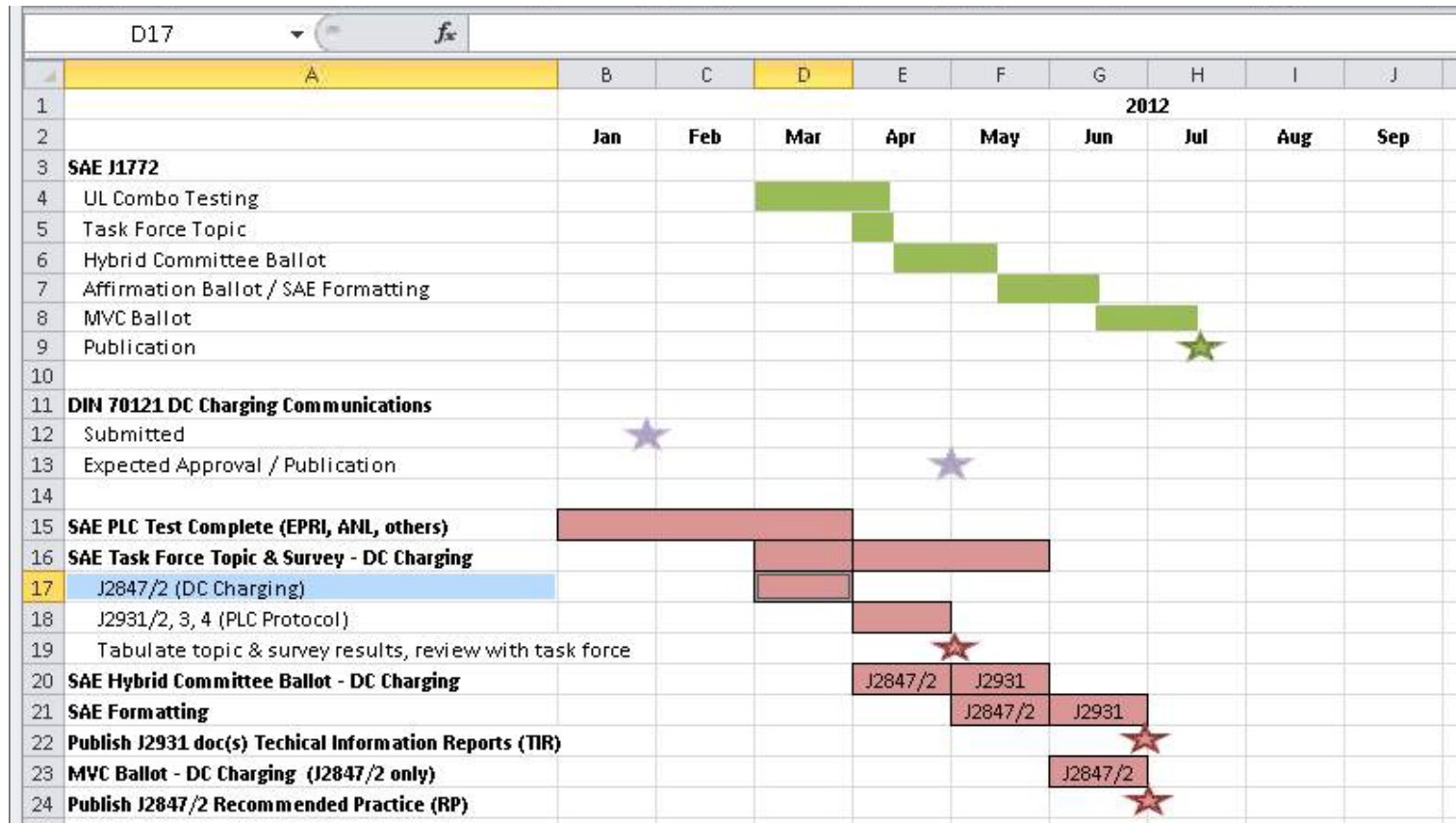
- J2931 Power Line Communication (PLC over Pilot), AutoRem G3 modules, SEP2.0, intensive testing of matrix of coexistence and crosstalk conditions.
- J1772-v5 DC Combination Coupler, supporting UL certification of early prototypes
- J2954 Wireless Power Transfer, Creating a consensus based test protocol/requirements document and scientific research fixture leading to a certification grade test fixture.
- J2990 First/Second Responder Guideline, work with NHTSA on depowering system



# Milestones



# Milestones- SAE Coupler/Communication Timeline



- Takeaway point:** After several years of due diligence the suite of SAE coupler and communication interrelated standards will be published in 2012, preceded by pre-ballot (affirmed) components submitted into UL certification production components in support of vehicle OEM's production schedule for MY2014 vehicles

## Approach: - SAE Codes and Standards Development

- **Address codes and standards requirements to enable wide-spread adoption of electric-drive transportation with Smart Grid Interoperability**
  - Engage with suppliers, academia, automotive industry, and government officials to continuously assess state-of-the art
  - Provide technically sound guidance to SAE Standards committees
  - Participate with the Institute of Electrical Engineers (IEEE) and the National Fire Protection Agency (NFPA) on electrical wiring standards for charger wiring and installation requirements
  - Participate on the National Institute for Standards and Technology (NIST) in determining Smart Grid standards setting effort for the electrical utility network
  - Evaluate and validate hardware and communication protocol proposals
  - Encourage consistency with international harmonization

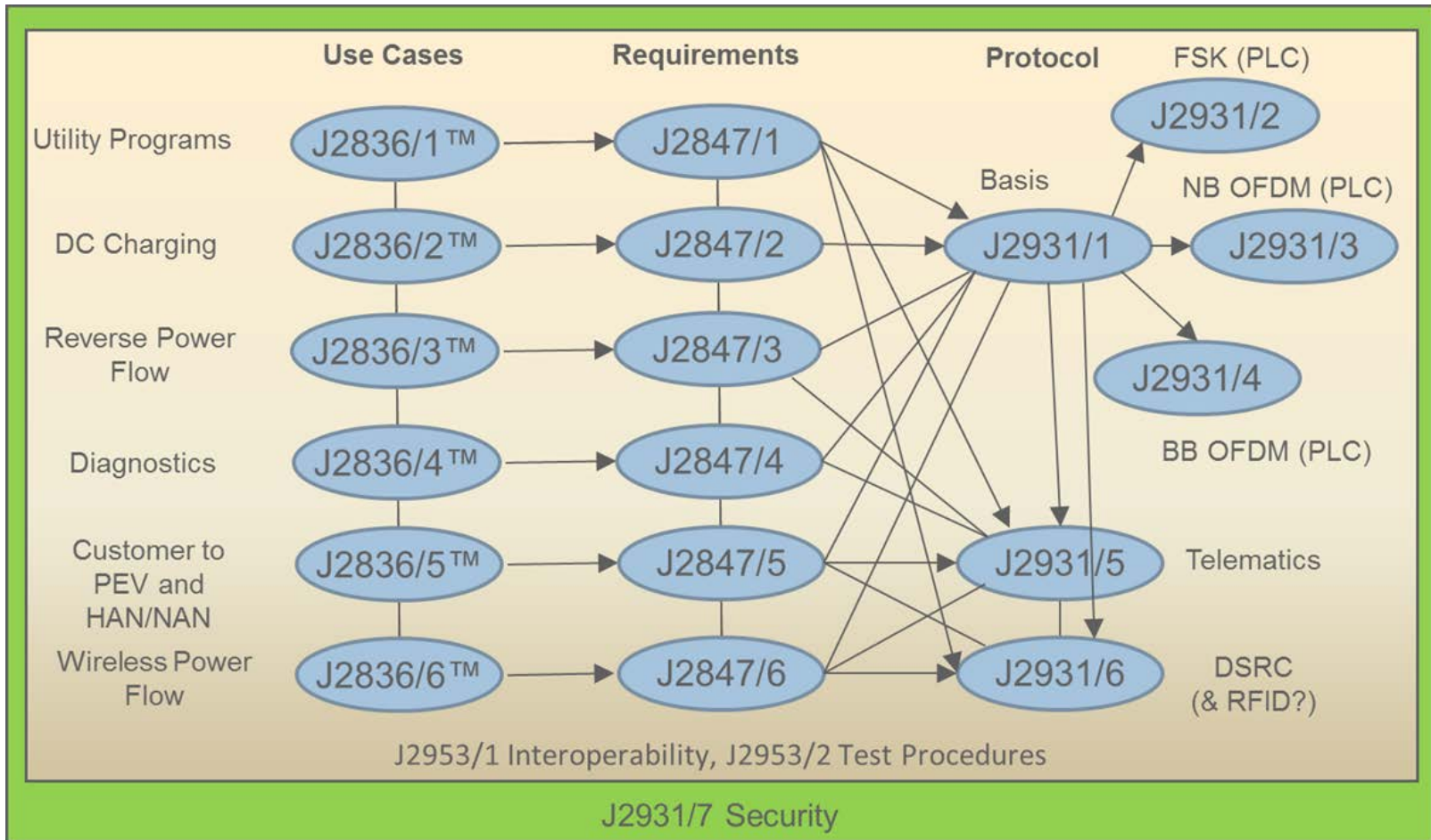


# Approach: - Support SAE PEV/EVSE Related Standards

Document Number	Title – Works in Progress
<a href="#"><u>J1772 (v5)</u></a>	SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler
<a href="#"><u>J2836/3</u></a>	Use Cases for Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow
<a href="#"><u>J2836/4</u></a>	Use Cases for Diagnostic Communication for Plug-in Vehicles
<a href="#"><u>J2836/5</u></a>	Use Cases for Communication between Plug-in Vehicles and their customers.
<a href="#"><u>J2836/6</u></a>	Use Cases for Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid
<a href="#"><u>J2847/1</u></a>	Communication between Plug-in Vehicles and the Utility Grid
<a href="#"><u>J2847/2</u></a>	Communication Between Plug-in Vehicles and Off-Board DC Chargers
<a href="#"><u>J2847/3</u></a>	Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow
<a href="#"><u>J2847/4</u></a>	Diagnostic Communication for Plug-in Vehicles
<a href="#"><u>J2847/5</u></a>	Communication between Plug-in Vehicles and their customers
<a href="#"><u>J2847/6</u></a>	Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid
<a href="#"><u>J2894/2</u></a>	Power Quality Requirements for Plug In Vehicle Chargers - Part 2: Test Methods
<a href="#"><u>J2907</u></a>	Power rating method for automotive electric propulsion motor and power electronics sub-system
<a href="#"><u>J2908</u></a>	Power rating method for hybrid-electric and battery electric vehicle propulsion
<a href="#"><u>J2931/1</u></a>	Digital Communications for Plug-in Electric Vehicles
<a href="#"><u>J2931/2</u></a>	In band Signaling Communication for Plug-in Electric Vehicles
<a href="#"><u>J2931/3</u></a>	PLC Communication for Plug-in Electric Vehicles
<a href="#"><u>J2931/4</u></a>	Broadband PLC Communication for Plug-in Electric Vehicles
<a href="#"><u>J2931/5</u></a>	Telematics Smart Grid Communications between Customers, Plug-In Electric Vehicles (PEV), Energy Service Providers (ESP) and Home Area Networks (HAN)
<a href="#"><u>J2931/6</u></a>	Digital Communication for Wireless Charging Plug-in Electric Vehicles
<a href="#"><u>J2931/7</u></a>	Security for Plug-in Electric Vehicle Communications
<a href="#"><u>J2953</u></a>	Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
<a href="#"><u>J2954</u></a>	Wireless Charging of Electric and Plug-in Hybrid Vehicles
<a href="#"><u>J2990</u></a>	Hybrid and EV First and Second Responder Recommended Practice

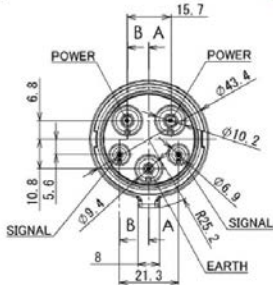


# Approach: Highly Interdependent EVSE and PEV Communication Standards; Covering All of These





# Technical Accomplishment: J1772 DC Coupler Development Continues, Facilitated UL Approval of Sole US Vendor (Rema USA) Product; Available to Vehicle OEMs Now



- SAE J1772 AC Coupler Standard published January 2010
- SAE J1772-v5 DC Coupler standard final publication July 2012
- UL coupler certification process required ~100 plug and inlets, destroyed in the certification process, supplied by ANL/Rema USA.

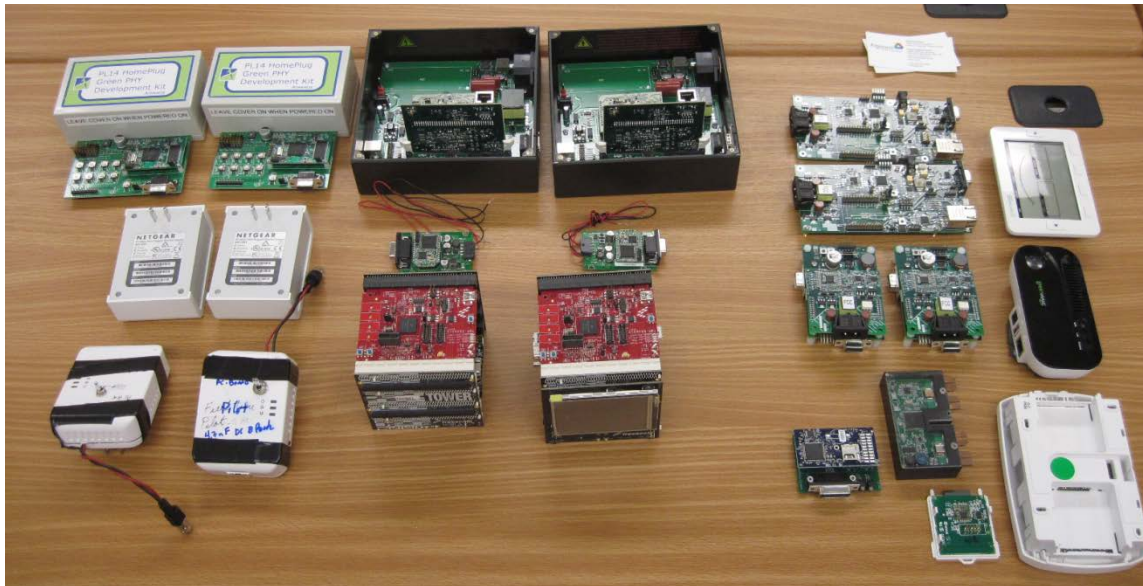
## SAE J1772 AC/DC Level Definitions



Level	Volts	Amps
AC-1	120	20
AC-2	240	<80
DC-1	<450	<80
DC-2	<450	<200
DC-3	<600	<400

# Accomplishment - SAE J2931 Intensive Test Matrix Results- Independent Candidate Comparison

- SAE J2931 Powerline Communication over the 1 kHz pilot wire requires a broad range of coexistence, crosstalk and compatibility rigorous yet vendor independent testing and interpretation of results as compared to the requirements criteria.
- Majority of testing was performed on vendor supplied evaluation hardware, but required extensive software development to be usable in a uniform manner to compare technology A-to-B-to-C in a technology neutral fashion
- Custom built circuit boards/modules designed and constructed by ANL as well (below).

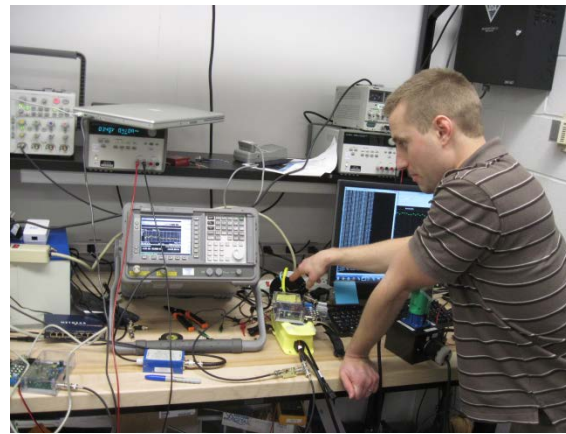


# Technical Accomplishment: SAE J2931 Intensive Test Matrix Results- Independent Candidate Comparison

- In cooperation with EPRI engineers, under an SAE consensus based test matrix, ANL engineers worked closely with PLC candidate technology vendors to ensure that all testing was best case outcome and all opportunity to improve or correct the technology shortcomings was offered to vendors (i.e. no excuses for failed results)
- Candidate technologies each have a separate standards subsection:

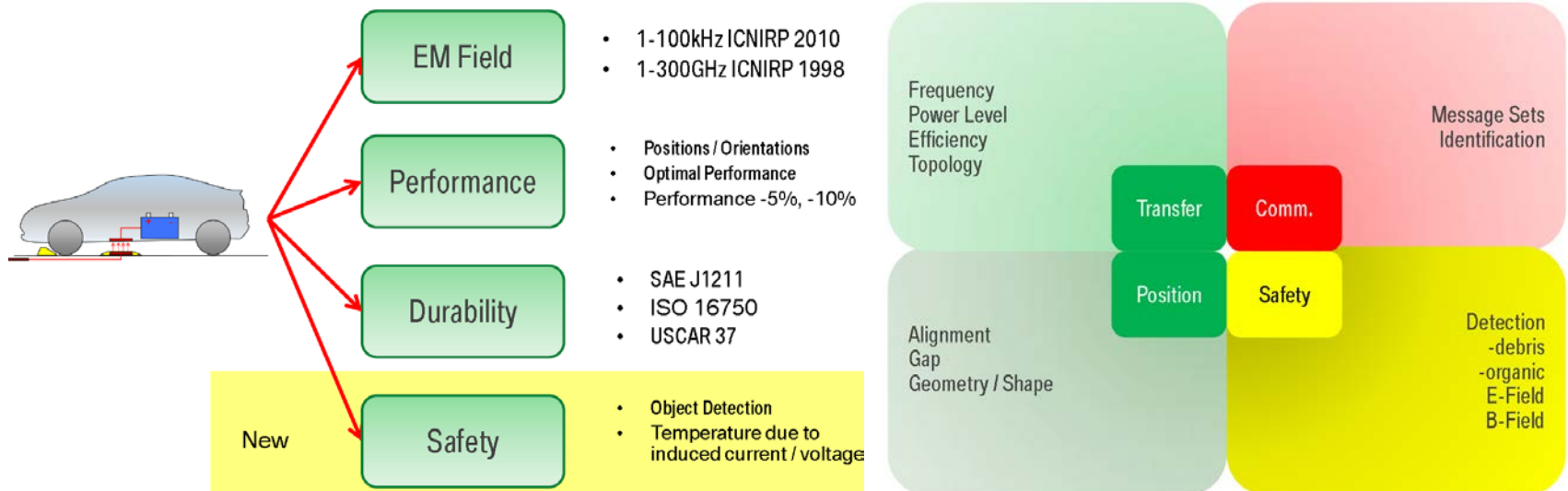
<u>J2931/2 (FSK)</u>	Inband Signaling Communication for Plug-in Electric Vehicles
<u>J2931/3 (G3)</u>	Narrowband PLC Communication for Plug-in Electric Vehicles
<u>J2931/4 (HPGP)</u>	Broadband PLC Communication for Plug-in Electric Vehicles

ANL Engineers working with technology vendors; Leading candidate (right) Homeplug GreenPhy, broadband OFDM powerline communication (PL-16 eval board)



# Technical Accomplishment: SAE J2954 Wireless Charging Evaluation and Testing Protocol/Fixtures

- ANL engineers are working with certification parties (UL/TUV-America), charging system vendors and automotive OEMs on a consensus based testing requirements document and protocol leading to a certification criteria.
- ANL is designing, fabricating and evaluating a scientific investigation based test fixture to clarify the significance of variability in the test criteria (such as mounting surface, ground plane of vehicle, etc) to refine the charging system performance, safety and communication requirements.
- Transportable test fixture will be operated in a certified EMC chamber near ANL.

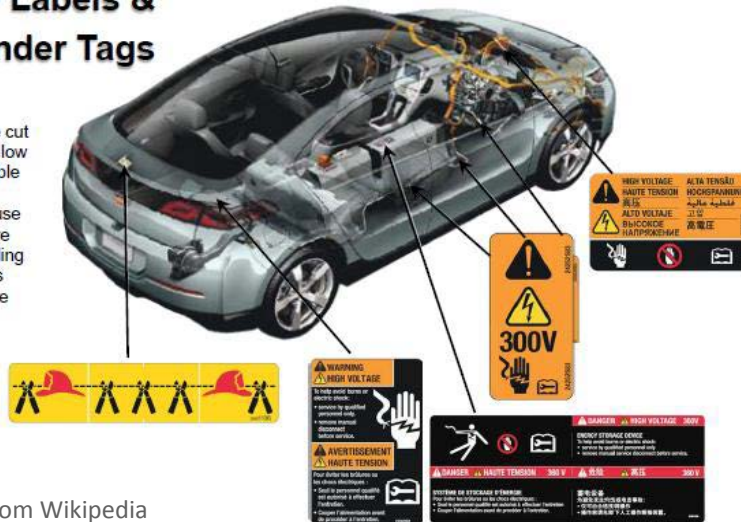


# Accomplishment: SAE J2990 First/Second Responder Guideline, Creation of NHTSA Depowering System



## High Voltage Labels & First Responder Tags

The First Responder cable cut tag is wrapped around the low voltage positive battery cable and is located in the rear compartment behind the fuse panel door. To help ensure that low voltage is not holding the high voltage contactors closed, cut the cable before any extrication work is performed.



Vehicle photo from Wikipedia



Typical Service battery research tools:

- Midtronics scan tool, NHR Electronic load bank
- Basis for ruggedized depowering device used by first/second responders before moving vehicle

## Takeaway Points:

- First/second responders need standard signage and vehicle access procedures to do their jobs safely.
- Post-crash test vehicle storage complications resulted in creation of depowering protocol by OEM(s). ANL is developing hardware/software for this protocol.

# Collaborations

- SAE J2907 Motor Ratings
  - ORNL
  - Vehicle OEMS : GM, Ford, Chrysler, Toyota, Nissan, John Deere, Tesla, Fisker
  - Motor manufacturers: Remy, G.E., Bosch, Azure Dynamics, Magna, etc.
  
- SAE J2894 Charger Efficiency/Quality
  - Charger manufacturers: Delta-Q, Magna E-Car, Azure Dynamics, TDK, Delphi, Delta Products,
  - Utilities: PGE, SCE
  
- SAE J2990 First/Second Responder Guidelines
  - Other Government Agencies (DOT, NHTSA, EPA)
  - SDOs- ANSI, NFPA, SAE
  
- Codes and Standards: IEEE, NFPA, SAE, Industry, Academia, Suppliers, Utilities, National Labs, et.al.

# Future Plans

**Maintain focus on near-term needs with long-term impact, direct support of SAE standards committees.**

## **(Remaining) FY 2012 Activities**

- **SAE standards committee support**
  - Wireless charging test fixture specification and design
  - Wireless charging test fixture fabrication and de-bug at ANL
  - Continue comparison of J2931 PLC over Pilot communication technologies, followed by field testing, compared to lab testing, in a full DC fast charging test condition, and utility message exchange via multi-port router EVSE
- **Sub-metering/communication modules**
  - Refine designs of the EUMD, multi-port router and network gateway to support the build-up of interoperability hardware sets
  - Use case refinement for sub-metering protocols; further support of CPUC and similar protocol investigations
- **Depowering Protocol Investigation/Fixture development**
  - Establish joint DOE/NHTSA project to define and develop depowering standard for post-crash PEVs battery safety, in support of SAE as well



# Activities for Next Fiscal Year

- Continue to investigate limitations and propose solutions for harmonized vehicle-grid communications technologies with emphasis on interoperability between countries as well as regions (utility districts)
  - Specify, fabricate and debug Wireless PEV Charging evaluation fixture, at ANL and at certified EMC/NRTL test lab.
  - Guide standards development for technology neutral sound outcome
- Validate performance targets in a systems context
  - Power electronics and energy storage technology
  - Electric motor ratings standards
  - Expand benchmarking hardware experiments to support validation of methods used to determine electric motor rating standards, with emphasis on cooling methods and their impact.
  - Energy storage system communications technology





# Summary

- Participated in SAE and other standards organizations to provide technical direction
  - Keep informed of technology changes and new stakeholder engagement
  - Disseminate information to DOE and other affected parties
- Provided support and leadership for codes and standards required to enable wide-spread adoption of electric-drive transportation
- Guided grid connectivity technology between electric vehicles while charging
- Evaluated proposals for lower cost, secure utility infrastructure for universalized wired and wireless communications technologies
- Validated electric drivetrain components in a systems context for establishing performance targets



# Technical Back-Up Slides

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# Approach - SAE J2847 Communication Nomenclature

## Focus on Four Communication Nodes

- **Electric Vehicle Supply Equipment (EVSE)** {branch circuit coupled to PEV, off board}
- **End-Use-Measurement-Device (EUMD)** {revenue-grade submeter, PEV energy} *The physical form, location and ownership of the EUMD may be unique for different applications.*
- **PEV/Energy Management System (EMS)** Vehicle and devices to use of smart loads
- **Home Area Network (HAN)/Utility Network** in user's home that connects a person's digital devices, from multiple computers and their peripheral devices to telephones, VCRs, televisions, video games, home security systems, "smart" appliances wired into the network.
- **Human Machine Interface (HMI)** HAN application characteristics that provide local user input and/or output. These are based constrained and based on the data type.

# Accomplishment - Disseminate Information

## Charging Levels - Convenience to Fast Charge

- **SAE J1772 Level 1 AC** (120vac, 20 branch, 15A continuous) Carried in vehicle, uses onboard charger at less than maximum capability (typically 3kW to 7kW onboard)



Nissan Leaf On-board  
Convenience Charger  
(Panasonic 120v/15A input)



120-Volt Portable Vehicle Charge Cord

Chevy Volt On-board  
Convenience Charger  
(Lear 120v/15A input)



BMW-Mini On-board  
Convenience Charger  
(Clipper Creek/Delphi)

# Charging Levels- Convenience to Fast Charge

- **SAE J1772 Level 2 AC** (240vac, up to 100A branch, 80A continuous- 19.2kW, typically 40 branch, 30A continuous) Commercial and residential (onboard charger)



Coulomb Chargepoint  
\$5k (120v/15A,  
240v/30A )



Aerovironment- \$750  
(Nissan Leaf)  
(240v/30A)



Chevy Volt- \$490  
(Lear 240v/30A input)

# Charging Levels- Convenience to Fast Charge

- **SAE J1772 Level 2 DC (draft)** (up to 600vdc/~300A- 50kW+ fed by 480vac 3 phase OFF BOARD CHARGING- smaller units as well in future for level 1 DC- 80A
- Allegedly \$20 minimum fee, 20 minute limit (at 50kW=50/3=12.6kWhr-> \$1.20 of electricity at \$0.10/kWhr; including service fee \$20/12.6kWhr=\$1.59/kWhr)



Blink Fast Charger  
50kW, ~\$125k



Coulomb-  
Acker Wade  
50kW ~\$100k+



Nissan  
50kW, - \$17k



Epyon- Holland,  
50kW, \$30k

All of the above use the JEVS105-1993 (JARI) DC coupler