

Grid Interaction Technical Team

2011 DOE Hydrogen Program and Vehicle Technologies

Annual Merit Review

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Energy Efficiency and Renewable Energy

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Overview

Timeline

- FreedomCAR Grid Interaction Tech Team (GITT) initiated in summer 2009
- Grid connectivity projects proposed in FY2010 and initiated in March 2010
- Initial results/prototypes in October 2010
- National permitting template project transitioned to Clean Cities in January 2011
- Hardware/software development continues
 - Gen. 2 hardware in January 2011
 - Gen. 3 field testing planned in summer 2011
 - Integration in grid-related projects with OE and international collaborators in FY 2012

Barriers/Key Challenges

- Cost-effective installation of Electric Vehicle Supply Equipment (EVSE) consistent with local building codes & national standards
- Enabling technology for low-cost, revenue-grade *separate* metering and communication of energy used to charge PEVs
- Interoperability of plug-in vehicles, EVSEs, home gateways and the grid; charge couplers and communication
- Global cooperation on enabling technologies (due to the impact on harmonization)

Budget

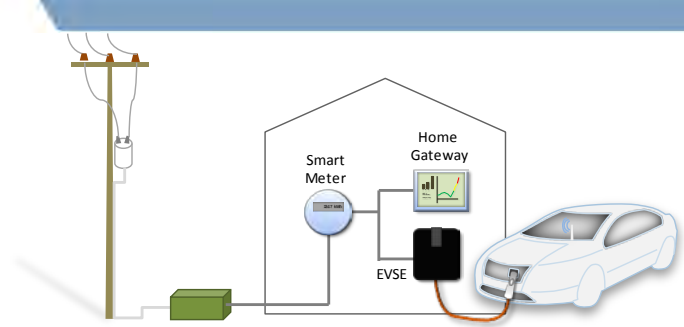
- FY 2010: \$930K(incl. codes & standards)
- FY 2011: \$650K for GITT support
\$200K for Int'l Cooperation

Partners

- Utilities: DTE Energy, Southern Cal. Edison,
- Automotive OEMs: Ford, GM, Chrysler
- USG: DOE (OE, PI), DOC (NIST, US Mission to EU)
- Project Leads: ANL, NREL, PNNL



Objective



Support a transition scenario to large scale grid-connected vehicle charging with transformational technology, proof of concept and information dissemination

The GITT addresses connectivity between light duty plug-in vehicles, the charging infrastructure and the electric power grid, focusing on the following:

- Reduced Cost of Electric Charging Infrastructure
- Harmonization of Global Connectivity Standards
- Enabling Technology Development
- Enhanced Viability of Fast/Consumer-Friendly Charging
- Managed Vehicle Charging Loads Consistent with Smart Grid

GITT Leveraged to Support International Initiatives



The International Cooperation task utilizes GITT resources and the ARRA vehicle/infrastructure learning demonstration program to support policy initiatives, promote harmonization and technical cooperation in support of vehicle electrification:

- Facilitate cooperative technical activities in Europe and China
- Support DOE Policy & International Affairs, EU-US Energy Council, Transatlantic Economic Council, US Mission to the EU and US-China EV initiative
- Provide technical resources for USG-sponsored international events



Approach – Projects Developed

- **National EVSE Installation Permit Template (NREL)**
Streamline the charger permitting and installation process for local jurisdictions
- **SAE J2847 Communication Standard Validation (PNNL)**
Develop and test human-machine interface (HMI) and communication
- **Enabling Technology Development**
 - **Universal Metropolitan Area Network (ANL, UMich-Dearborn)**
Develop and demonstrate Software Defined Radio to facilitate universal communication
 - **Compact Metrology (ANL, 2G Engineering, Viola Enterprises)**
Develop a low-cost, revenue-grade sub-meter with flexible communication capability consistent with the SAE standards (for PEV energy measurement)
 - **Home Gateway (PNNL)**
Integrate SAE J2293 networking and home gateway with HMI
 - **SAE J2953 Test Bench (ANL)**
Fixture to verify interoperability between the elements of the charging infrastructure



National EVSE Installation Permit Template

Issue: Lack of a consistent, timely permitting process for the installation and inspection of charging equipment across the nation

Lead: NREL – C. Rivkin

Objective: Streamline the EVSE permitting, installation and inspection process for local jurisdictions

Approach: Develop a model permit for EVSE installation that can be readily adapted for incorporation in local building codes:

- Draft a template consistent with National Electric Code (NEC) standards,
- Obtain feedback from industry partners and selected, representative local governments;
- Deploy through appropriate organizations



SAE J2847 Communication Validation



- Issue:** New SAE standards for plug-in vehicle communication require review, refinement and validation prior to adoption and release; current plans to produce vehicles and deploy EVSEs necessitates timely development, validation and adoption of standards
- Lead:** PNNL – K. Gowri
- Objective:** Develop a test capability to evaluate SAE J2847 messages across the vehicle-grid connection between the vehicle, EVSE, home gateway and utility. Develop a representative human-machine interface (HMI) to facilitate the evaluation.
- Approach:** Emulate vehicle and EVSE communication module messages (representative of those proposed by the SAE J2847) and demonstrate bi-directional communication capability; expand to include home gateway and utility when hardware available.

Universal Metropolitan Area Network



Issue: Lack of universal communication capability necessitates different hardware and software solutions for products in different countries

Lead: ANL – T. Bohn (w/UMich-Dearborn)

Objective: Develop single radio solution that supports a variety of global standards, including Zigbee, UMAN, etc. – eliminating the need for different communication modules

Approach: Develop capabilities for single chip ‘software defined radio’ (SDR) in VHDL programming language

Physical layer specs defined by IEEE 802.15.14 (zigbee), IEEE 802.15.14c/d (China and Japan version) and IEEE 802.15.14g (UMAN)

Several modulation modes: FSK, MPSK, Q-QPSK and OFDM in multiple bands including 314-316MHz, 430-434MHz, and 778-787MHz

U-MAN sub-MHz frequency range – listed here for different countries – has better signal penetration through buildings than typical 2.4GHz WiFi or Zigbee wireless



Compact Metrology



- Issue:** A dedicated branch circuit, electric meter and standard charging receptacle will be required to charge a plug-in vehicle in the US; the additional cost could impact plug-in vehicle sales
- Lead:** ANL – T. Bohn (w/Viola Enterprises, Universal Gridworks, 2G Engineering)
- Objective:** Develop a low-cost End Use Measurement Device (EUMD) to replace the additional dedicated electric meter
- Revenue-grade accuracy (0.3% class ANSI C12) over full temp. range,
 - SEP2.0/J2847 communication capabilities,
 - Sized to fit in a standard AC disconnect and
 - Cost less than \$50 in production
- Approach:** Develop flux gate magnetometer-based current sensors; with no core, better than 0.1% accuracy from -40-120°C and ~30¢/pair in volume; integrate communication solutions as they develop

Home Gateway



Open Standards Solutions

greenWAVE



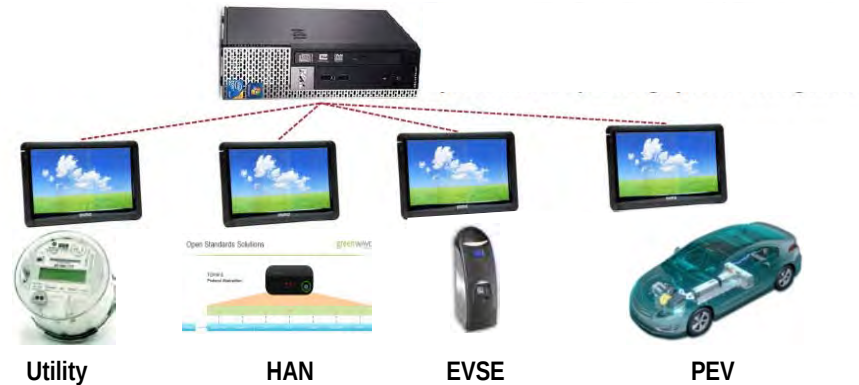
Issue: Home area networks (HANs) will utilize smart meters and appliances with communication and control capability (e.g., Zigbee) to manage/balance loads; PEVs are essentially a large appliance must be compatible with the 'gateway' (i.e., SAE J2847 compliant messaging)

Lead: PNNL – K. Gowri (w/ANL)

Objective: Develop a test fixture to verify compliance with SAE J2847, focusing on vehicle-gateway communication

Approach: Emulate EVSE communication with a production gateway to be provided by a supplier; expand to include the utility, EVSE and vehicle as the balance of the system hardware becomes available.

SAE J2953 Test Bench (Interoperability)



- Issue:** Communication capability between the major elements in the charging infrastructure must be verified/validated as specified in SAE J2953
- Lead:** ANL – T. Bohn (w/industry contributors)
- Objective:** Develop a test fixture to verify connectivity and communication between the vehicle, EVSE, home gateway/HAN and utility messages.
- Approach:** Integrate emulated/physical PEV, production EVSE with EUMD, production home gateway and SEP 1.x AMI development system

Milestones

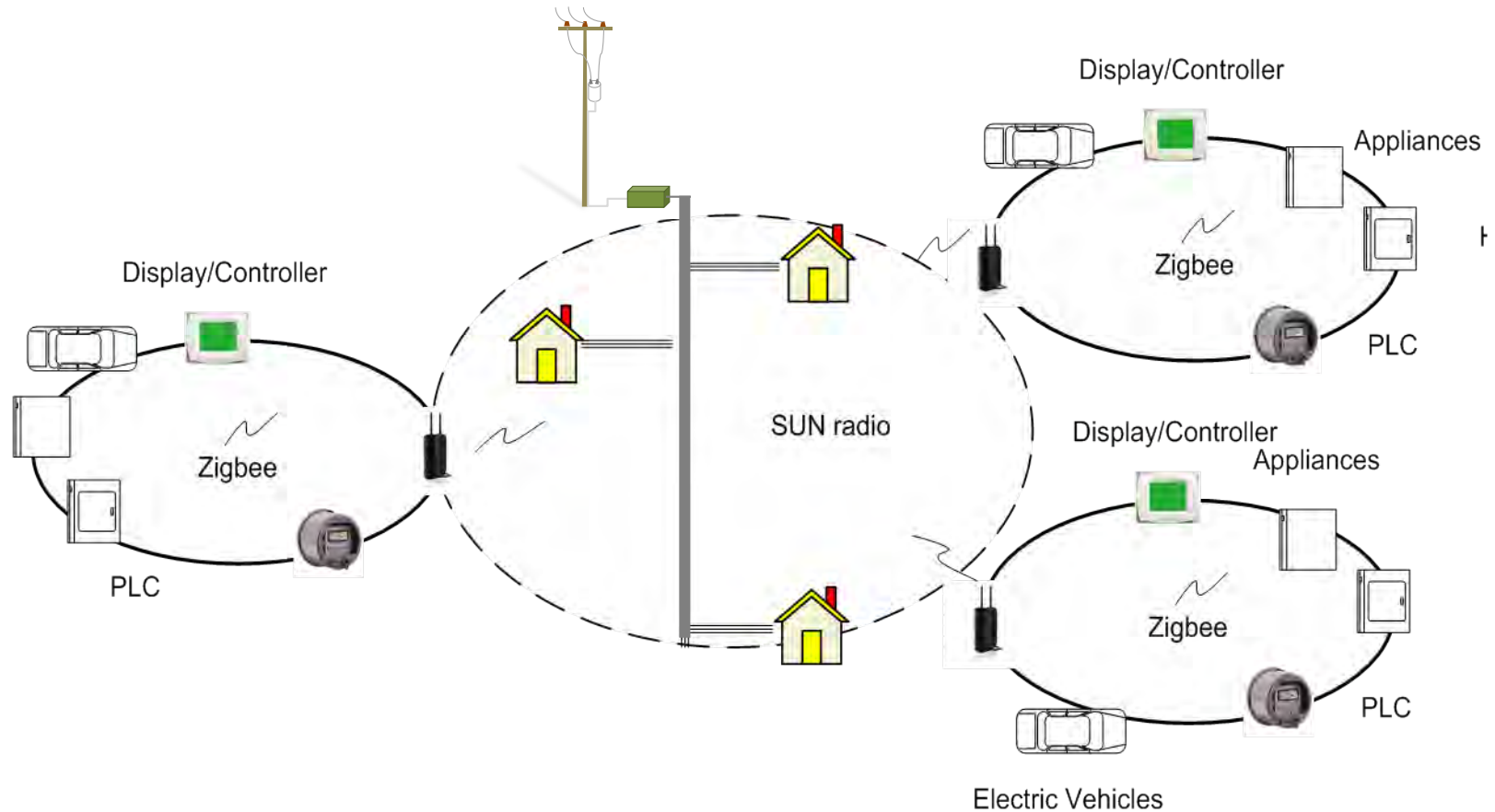
Month/Year	Milestones
Dec '09 – Mar '10	-GITT projects reviewed and initiated
National Permitting Template May '10 Oct '10 Jan '11	-Draft permit complete - Completed external review and DOE deliverable ✓ -Transferred to Clean Cities for deployment
SAE J2847 Communication Validation Oct '10	✓ - Demonstrated emulated Vehicle-EVSE communication and HMI -Integrate in SAE J2953 Interoperability Test Bench project
J2953 Interoperability Test Bench Jun '11	-Demonstration of integrated test bench
Universal Metropolitan Area Network Oct '10 Apr '11? (supplier dependent) Sep '11	✓ - Demonstrated SDR with Zigbee or UMAN capability -Single chip communication integration -Demo advanced communication architecture for smart energy grid -Demo SDR with multiple Vehicles and nodes
Compact Metrology Oct '10 Dec '10 Feb '11 Mar '11 May '11 Jun '11 Sep '11	✓ - Demonstrated flux gate magnetometer current sensors -Evaluated accuracy at DTE Metering Lab -EUMD-REV1 (Custom board with off-the-shelf sensors and Xbee radio) ✓ -EUMD-REV2 (Integrated FGM sensors and Power Line Communication) -EUMD-REV3 (Integrate single chip communication solution) -Field testing begins at ORNL Solar EV EVSE Station -Compact metrology assessment
Home Gateway	-Integrate in SAE J2953 Interoperability Test Bench project

Accomplishments:

- **National EVSE Installation Permit Template (NREL)**
Completed template and transferred to Clean Cities for deployment; working with industry and trade associations to incorporate in education and training materials
- **SAE J2847 Communication Standard Validation (PNNL)**
Demonstrated emulated vehicle-EVSE communication and HMI; results will be rolled into SAE J2953 interoperability test bench development
- **Universal Metropolitan Area Network (ANL, UMich-Dearborn)** ✓
Demonstrated software defined radio capable of Zigbee and UMAN
- **Compact Metrology (ANL, 2G Engineering, Universal Gridworks, Viola Enterprises)** ✓
Demonstrated the capability of the novel FGM current sensor; designed and developed an integrated revenue-grade sub-meter with accurate sensing, power calculations and flexible communication capability; production cost estimate in volume is \$25-50



Next ... Development of Advanced Communications Architecture for Smart Energy Grid



FY 2011 Goal: Expand Software Defined Radio Demo to Multiple Vehicles and Nodes

Next ... Development of Advanced Communications Architecture for Smart Energy Grid

UMich-Dearborn working toward universal baseband chipset solution with IC manufacturers

Transmission technology

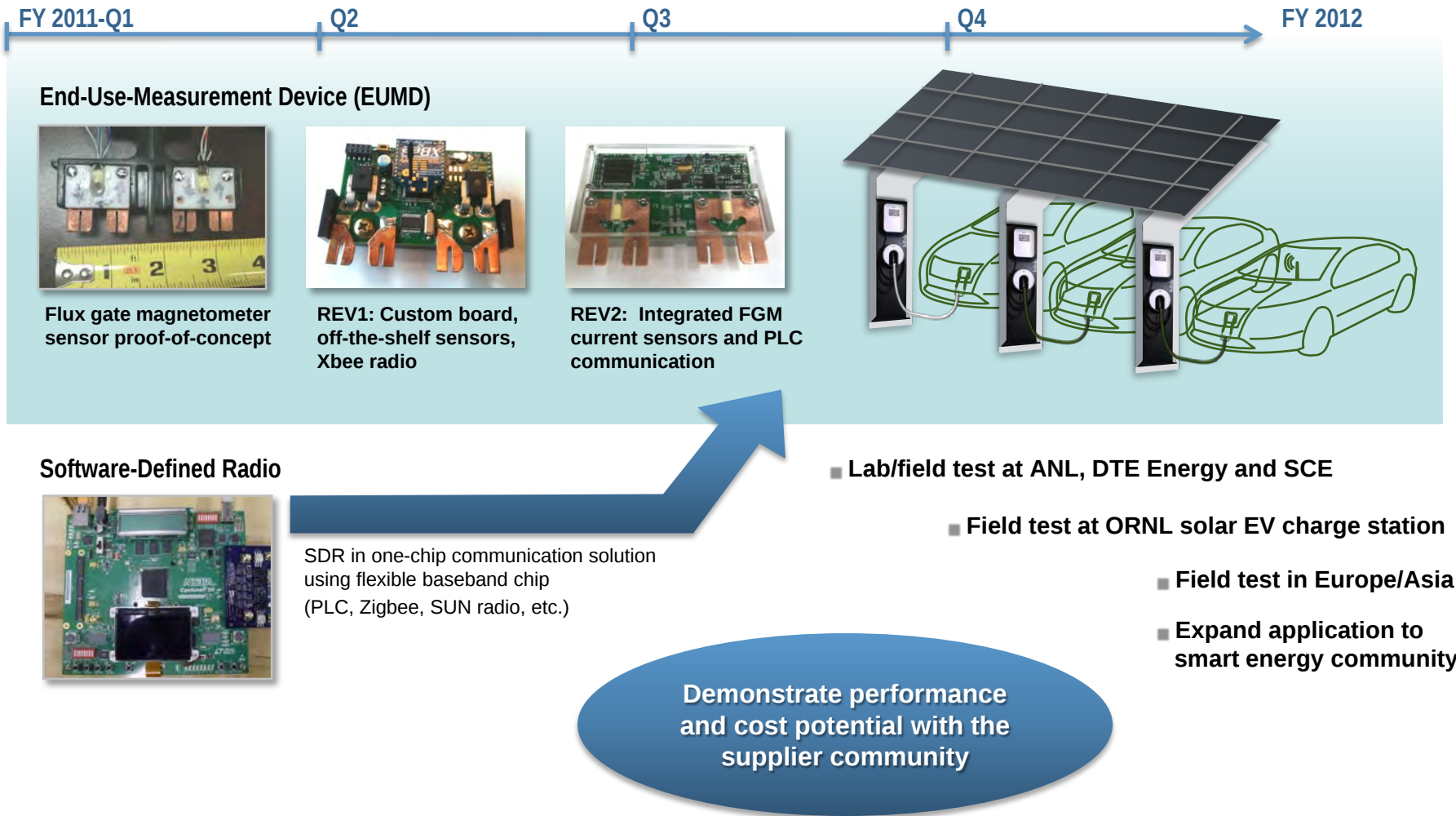
- Power line communications:
Broadband PLC: HomePlug, the IEEE p1901 and ITU-T G.hn
Narrow band PLC: IEEE p1901.2, ITU-T G.hnem and G3-PLC.
- Wireless:
Zigbee (the IEEE 802.15.4) and SUN (the IEEE 802.15.4g, draft)

Expected attributes

- Superior anti-multipath and robustness and green design
- Multimode operation: software defined radio and cognitive radio
- Adaptive modulation and adaptive configuration for MIMO config
- Software download and forward compatibility



Next ... Compact Metrology Development & Testing



Additional FY 2011 Activities

- **Joint exercise with OE to set cost targets for electric charging infrastructure**
- **Define cooperative activities with international collaborators**
 - Sharing non-competitive information from vehicle/infrastructure demonstration programs in Europe and Asia
 - Joint testing of enabling connectivity technologies (e.g., connectors, meters, communication modules)
 - Joint validation of connectivity standards



FY 2012 Activities

■ **Electric Charging Infrastructure**

- Joint assessment of charging infrastructure cost reduction technology (with OE) and identification of opportunities for DOE/national lab support
- Support development of fast/consumer-friendly (inductive) charging
- Support EV-Smart Grid load management study (OE)

■ **Harmonization of Standards**

- Support standards development and validation (e.g., J2953)
- Collaborate on field verification of EUMD/universal communication

■ **Enabling Technology Development**

- Implement other internationally compatible communications protocols in Software Defined Radio (SDR) technology.
- Expand EUMD applications to smart energy community environments



Collaborations

- Utilities: DTE Energy, Southern California Edison
- Automotive OEMs: Ford, GM, Chrysler
- National Labs: ANL, NREL, ORNL, PNNL
- USG: DOE OE, DOC NIST
- Grid Connectivity Project Partners
 - University of Michigan-Dearborn
 - Universal Gridworks
 - Viola Enterprises
 - 2G Engineering
- International
 - USG: DOE PI, DOC, DOS, EU-US Energy Council, TEC, TABD
 - European Commission (Green eMotion vehicle/infrastructure demo)
 - National programs (Belgium, Germany and Sweden to date)



Summary

- **The GITT addresses critical needs of the vehicle-grid interface ...** cost reduction, enabling technologies, interoperability and global harmonization/cooperation.
- **Many targets of the grid connectivity projects were met:**
 - The model permit for EVSE installation has transitioned to Clean Cities
 - Point-to-point messaging was demonstrated; integrated communication in Q3
 - Software defined radio was successfully demonstrated and a single chip solution for universal communication will likely be demonstrated in Q4
 - The accuracy of the FGM current sensor apparently supports revenue-grade power calculations; the EUMD with flexible communications will be demonstrated in Q3
- **Joint activities with OE and other collaborators leverage resources to address the major elements of the charging infrastructure as well as smart grid compatibility**

