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
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
- 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*
### 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

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

End-Use-Measurement Device (EUMD)

- Flux gate magnetometer sensor proof-of-concept
- REV1: Custom board, off-the-shelf sensors, Xbee radio
- REV2: Integrated FGM current sensors and PLC communication

Software-Defined Radio

- SDR in one-chip communication solution using flexible baseband chip (PLC, Zigbee, SUN radio, etc.)

Key Activities:

- Lab/field test at ANL, DTE Energy and SCE
- Field test at ORNL solar EV charge station
- Field test in Europe/Asia
- Expand application to smart energy community

Demonstrate performance and cost potential with the supplier community
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